Emergency Eyewash and Shower Equipment:  
A Comprehensive Literature Review and Comparison

Submitted to American Society of Plumbing Engineers  
Research Foundation (ASPE RF)  
by  
Ashley Bartlein  
Anna Clauss  
Adam Martin  
Mark Walter  
Jae K. Park

Department of Civil and Environmental Engineering  
University of Wisconsin-Madison  

May 4, 2008
EXECUTIVE SUMMARY

Emergency shower and eyewash unit design was investigated using the most advanced search engines and thorough reference collection available at the University of Wisconsin-Madison. Relevant literature dating from as far back as the 1920s up to papers recently published in 2007 was reviewed, and all of the topics related to the design of these units have been weighed and are discussed in detail in this report.

Every year, in the United States alone, thousands of people are hospitalized due to chemical burns, many of which are fatal. Current chemical burn first aid practices have proven to prevent injuries and even save lives, but there are still far too many cases of chemical burns causing significant damage, even when the suggested guidelines are followed. The goal of this review was to discover possible ways to make these pieces of equipment more effective first aid tools in the treatment of chemical burns.

Current flushing fluid temperature standards are vague and must be specified to a greater extent. The Occupational Safety and Health Administration (OSHA) is the agency responsible for regulating emergency shower and eyewash facilities. OSHA generally refers to the American National Standards Institute’s (ANSI) Z358.1 when evaluating facilities. ANSI Z358.1 (2004) only states that flushing fluid should be tepid. In ANSI Appendix B, which is for information only and is not part of the standard, it is stated that medical recommendations suggest that a temperature range of 60 to 100°F (16 to 38°C) is safe for users to be exposed to. However, studies have demonstrated that temperatures on the lower end of this range may cause cold shock, possibly leading to cardiac arrest. Additionally, these colder temperatures may cause users to end chemical flushing before the recommended time has passed, which is generally at least 15 minutes. Therefore, it is recommended that the lower end of the temperature range be increased to 70°F (21°C). Studies have also illustrated that legionellae bacteria, which generally create the greatest bacterial hazards for emergency shower and eyewash users, have an ideal growth rate temperature range of 95 to 115°F (35 to 46°C). Therefore, it is also recommended that the higher end of the temperature range be decreased to 95°F (35°C).

Water has been the standard for flushing fluids since emergency shower and eyewash stations were introduced. Water has generally proven to dilute hazardous chemicals, but studies have also illustrated that specific neutralizing agents are more successful at removing some chemicals. Additional studies suggest that soaps, high molecular weight solvents, alcohols, and oils may be more successful in removing lipophilic chemicals. Some experimental results have even demonstrated that washing the skin with water can increase certain hazardous chemicals’ rate of transfer to the bloodstream. The efficacy of washing with water and alternative solutions must be studied in greater detail. Additionally, it is recommended that emergency shower and eyewash units capable of dispensing multiple flushing fluids be developed.

Flush duration is typically recommended to be 15 to 20 minutes, but alternative durations have been suggested. Studies have demonstrated that severely hazardous chemicals as well as
hydrophobic chemicals will not dilute to relatively safe levels unless a longer flush is administered. A 60-minute flush is often suggested for strong alkalies and a 30-minute flush for all other corrosive chemicals. Others recommend shorter flushing periods, about five minutes, for certain extremely hazardous chemicals in order to focus on advanced treatment more quickly. A shorter flushing duration of about five minutes has also been recommended for mild to non-irritants.

Chemical specific OSHA standards regarding first aid plans, including flush duration, must be developed and nationally accepted to minimize confusion and provide definitive answers on proper early treatment of chemical burns.

The current ANSI standard does not mention American Disabilities Act (ADA) Accessibility Guidelines compliance. However, because the abilities of a potential user are not known at installation, all emergency eyewashes and showers should be ADA compliant. These design aspects include, but are not limited to, slip resistant floors for both eyewash and shower units. Eyewash stations also need to meet the standards for protruding objects and showers need to comply with forward reach standards. Designing for ADA compliance will not only help users with disabilities but will help to better meet the needs of any user that is temporarily disabled from chemical exposure.
# TABLE OF CONTENTS

**EXECUTIVE SUMMARY** ............................................................................................................... i

**TABLE OF CONTENTS** .................................................................................................................. iii

**LIST OF FIGURES** .......................................................................................................................... vi

## 1. BACKGROUND AND DESIGN CRITERIA ................................................................. 1

  1.1. Background.......................................................................................................................... 1
  1.2. History.................................................................................................................................. 1
  1.3. Emergency Eyewash Stations: Purpose and Applicability .................................................. 2
  1.4. Station Location................................................................................................................... 2
  1.5. Additional Considerations ................................................................................................... 3
  1.6. Emergency Shower Design Criteria ..................................................................................... 3
  1.7. Emergency Eyewash Design Criteria .................................................................................. 3
  1.8. Portable Unit Discussion...................................................................................................... 3
  1.9. Designing for Freezing Climates ......................................................................................... 4
  1.10. Water Delivery Design Criteria ......................................................................................... 4
  1.11. Piping and Materials Design Criteria ................................................................................. 4

## 2. DESIGNING FOR THE AMERICANS WITH DISABILITIES ACT ................. 4

  2.1. Considerations for the Disabled........................................................................................... 4
  2.2. General Design Considerations............................................................................................ 5
  2.3. Emergency Eyewash Design Criteria .................................................................................. 5
  2.4. Emergency Shower Design Criteria ..................................................................................... 6
  2.5. Summary .............................................................................................................................. 6

## 3. SIGNAGE, SAFETY, AND TRAINING .......................................................... 6

  3.1. Signage................................................................................................................................. 6
  3.2. Path Clearance ..................................................................................................................... 6
  3.3. Training ............................................................................................................................... 6

## 4. MAINTENANCE ........................................................................................................... 7

  4.1. System Testing ...................................................................................................................... 7
  4.2. Equipment Checks ............................................................................................................... 7
  4.3. Backup Equipment .............................................................................................................. 8
Appendix B: Americans With Disabilities Act Accessibility Guidelines .............................................. 26
Appendix C: Decision Trees for Skin and Eye Exposures ......................................................................... 29
LIST OF FIGURES

Figure 1  Temperature Range for Microbial Growth (Thermoflo Equipment Co. Inc., Pittsburgh, PA, 2008) ........................................................................................................................................ 9
Figure 2  Hot Water Scald Burns, Time-Temperature Relations (Petri, 2005) ........................................ 13
1. BACKGROUND AND DESIGN CRITERIA

1.1. Background

Every year, in the United States, thousands of people are hospitalized due to chemical burns, many of which are fatal. Chemical burns can be very serious injuries and require proper first aid to reduce the damage they cause. The National Institute for Occupational Safety and Health (NIOSH), as well as many first aid organizations, suggest that when flushing the eyes use water and when flushing the skin use water or a soap and water solution for more lipid soluble, generally organic, chemicals (Klinger, 2007). First aid sources usually suggest the length of flushing for skin and eyes to be 15 to 20 minutes (CCOHS, 2005). Additionally, for the standards of the design of the emergency shower and eyewash devices, which provide flushing fluid, the Occupational Safety and Health Administration (OSHA) generally refers to the American National Standards Institute’s (ANSI) Z358.1 (2004). Potable water, suitable for drinking, is generally used as the flushing fluid although the standard states that flushing fluid can be “potable water, preserved water, preserved buffered saline solution, or other medically acceptable solution manufactured and labeled in accordance with acceptable government regulations” (ANSI Z358.1, 2004). This standard also suggests that the flushing fluid temperature should be tepid. This paper reviews information published on design criteria, signage, training, maintenance, microbial growth, flush duration, flushing fluid temperature, and chemical interaction with flushing fluids associated with emergency shower and eyewash units. Through this review, current practices will be supported or questioned, and new studies and standards will be recommended.

1.2. History

Emergency shower and eyewash stations were first introduced in 1928, providing chemical laboratories with emergency aid during experimental accidents. The importance of proper emergency shower and eyewash station design and placement was not completely understood early in their development. However, through research and experience, standards have been continuously updated. The most notable standards developed are those of OSHA and ANSI. The OSHA regulation on emergency showers and eyewash stations can be found under the regulation 29 CFR Section 1910.151(c), which discusses Medical Services and First Aid. It states as follows:

“Where the eyes or body of any person may be exposed to injurious corrosive materials, suitable facilities for quick drenching or flushing of the eyes and body shall be provided within the work area for immediate emergency use.” (OSHA, 2008)

The regulation is fairly vague, but a more precise standard can be found in the American National Standards Institute. Upon questioning, OSHA has directed people to the ANSI standard for direction as is seen here in an excerpt from a letter that OSHA has posted on their website concerning compliance:

“Paragraph (c) of 29 CFR 1910.151 requires that suitable facilities for quick drenching or
Emergency Eyewash and Shower Equipment

flushing be provided within the work area for immediate use if an employee's eyes or body may be exposed to corrosive materials. The OSHA standard does not set specifications for emergency eyewash and shower equipment, but we agree that equipment that complies with ANSI requirements would usually meet the intent of the OSHA standard” (Fairfax, 2008).

According to these OSHA documents, it is clear that OSHA does have a regulation and that they use the ANSI standard as a guideline for compliance.

1.3. Emergency Eyewash Stations: Purpose and Applicability

Industrial safety equipment manufacturers provide a variety of emergency eyewashes and safety showers that meet OSHA regulations. When purchasing a safety fixture, the most important factors are the function and performance. The main purpose of the safety showers is to drench the entire body in a heavy stream of water, whereas the main function of the eyewash station is to bathe the eyes with a substantial amount of water, leaving one’s hands free to hold back the eyelids. OSHA states that facilities that expose workers to corrosive chemicals should install emergency washing equipment. The Stanford Laboratory Standard & Design Guide states the following situations where emergency washing equipment should be installed (2003):

1) Areas where corrosive or injurious chemicals are used, such as:
   i) Solutions of inorganic or organic acids or bases with a pH of 2.0 or less, or 12.5 or more
   ii) Other organic or inorganic materials that are corrosive or irritating to eyes or skin (e.g., methylene chloride) or that are significantly toxic by skin absorption (e.g., phenol)

2) Areas where corrosive chemicals are used in a closed system that can catastrophically fail and cause the chemicals to leak (i.e., liquid lead-acid battery charging areas or areas where pressurized systems with corrosive liquids are used);

3) Storage areas where breakable containers of injurious or corrosive materials (1 gallon or more) are handled outside their original shipping cartons; and

4) Waste accumulation areas that could contain corrosive waste materials.

5) All work areas where formaldehyde solutions in concentrations greater than or equal to 0.1% are handled, and

6) Areas where operations involve the use of air or water reactive liquids or solids.

1.4. Station Location

According to Rettew, Jr. (1977), flushing fluid sources include, “any source of water which is immediately available” thus, if someone is near a sink or shower, they should be directed toward that source. Emergency stations have typically been placed outside of labs, adjacent to the door, to prevent the possibility of a shower or eyewash station being inaccessible in the event of an explosion. ANSI Z358.1 (2004) indicates that the emergency station must be within 10 seconds or 55 ft of a chemical area. The emergency station also has to be on the same floor as the chemical hazard. Stricter standards are in place for extremely acidic or extremely caustic chemicals, which need to be immediately adjacent to emergency washing equipment (Lab Safety Supply-EZ Facts, 2008).
1.5. Additional Considerations

Safety equipment should be tailored to meet the specific needs of the buyer. When considering the design of the emergency equipment that is being purchased, certain factors that one should keep in mind are:

1. The specific hazards to be protected against.
2. The first aid that will be required
3. The location of hazardous operations
4. The number of employees assigned to a hazardous area at a certain time
5. The number of workers performing hazardous operations in the area
6. Water pressure
7. Size of water supply line
8. Compatibility of piping
9. Water quality (including corrosiveness and particulate count)
10. Ambient temperature and the need for heating facilities
11. Vandalism potential
12. Drainage (including the size, the need for frost-proofing, and potential damage if the drain fails) (Wohlen, 1982).

1.6. Emergency Shower Design Criteria

ANSI Z358.1-2004 states very specifically that safety showers must be installed between 82 and 96 inches above the ground. If there is a privacy enclosure, it should be at least 34 inches in diameter. The showerhead must be 60 inches above the floor and have a spray pattern of at least 20 inches in diameter. The center of this spray pattern must be at least 16 inches away from any obstructions. The valve pull handle must not be more than 69 inches above the area where the employee will stand. The plumbed units must have a minimum of 1-inch supply line. The flow rate of the safety shower must be 20 gpm for at least 15 minutes (Cameron, 2001).

1.7. Emergency Eyewash Design Criteria

Emergency eyewash units are divided into two major categories: plumbed units and portable units. Plumbed units must have a 30-psi water supply. The water must flow simultaneously into both eyes at a low velocity to reduce eye injury. Both the plumbed and the portable units must be installed between 33 inches and 45 inches above the ground and 6 inches away from the wall. This allows enough room for the eyelids to be held open with the hands while the water is flowing. An eyewash only station must supply flow of water at 0.4 gpm for 15 minutes while a combination eye and face wash unit must supply a 3 gpm flow for 15 minutes. The difference between the two units is the size of the nozzle and the spray pattern. To functionally operate, the nozzles of these units have to face upward. Therefore, they must be protected from contaminants that may clog the openings or provide a breeding area for microorganisms (Cameron, 2001).

1.8. Portable Unit Discussion

Portable units are also available, but are not recommended for most situations because of the
limited water supply. Their use is only recommended when flowing water is not available. Examples of such conditions would be a construction site or a situation where the job site changes daily (Wohlen, 1982).

1.9. Designing for Freezing Climates

In colder climates, outdoor shower stations could possibly freeze. Designing safety fixtures that will be reliable in winter is a complex task. When emergency fixtures must be installed in cold outdoor climates, frost proof units should be specified (Wohlen, 1982).

There are two principal configurations: The first is a unit that is either buried below the frost line or stored within heated areas and allows the standing water to drain; the second is insulated and electrically heated. When the unit is heated electrically, consideration must also be given to the water supply to ensure that it is also protected from freezing conditions. Additionally, for both systems, in order to prevent scalding or electrical shock, there must be thermal and electrical protection built into any exposed part of the system. Outdoor safety fixtures must also be sheltered from outdoor elements. Minimally, the fixture must have a wind break; however, a complete enclosure is preferred. Lastly, clean, dry clothing should be on hand.

1.10. Water Delivery Design Criteria

The valve must activate within 1 second and must remain on without being held. As a limited option, self-closing valves may be permitted in school laboratories. When combination units (simultaneous shower/eyewash station) are used, they must be supplied with adequate flushing fluid to meet the requirements of each of the components. They shall be positioned so that the components can be used simultaneously (Everleigh, 2001).

1.11. Piping and Materials Design Criteria

Piping of the safety fixtures should also be taken into consideration. Different environments may require different types of piping. Stainless Steel, galvanized iron, and plastic piping are examples of some of the piping options. The drain bowls, eyewash heads, and shower heads are available in plastic, chrome-plated brass, or stainless steel. Self-closing valves and parts made out of stain-less steel and plastic can also be found, but are not recommended (Wohlen, 1982).

2. DESIGNING FOR THE AMERICANS WITH DISABILITIES ACT

2.1. Considerations for the Disabled

Chemicals are used in many different environments; such as labs, factories, and schools. In all of these environments, people of differing abilities can be found working. In any of these environments, accidents can happen and all of the workzones should be prepared to provide adequate first aid for people with different ability levels. If an organization has only provided
emergency solutions for the fully abled people, they are not adequately prepared for all potential users. This lack of foresight could result in liability issues and potentially very damaging lawsuits. It is better to prepare rather than attempt to undo irreparable damage.

In the case of emergency wash stations, ANSI has defined standards. These standards do not specifically address designing for people with disabilities, but rather present standards that should be met for all people. It is currently left to the organization to evaluate how their facility’s emergency washing equipment should be designed. In designing, however, Hayes states that “a reasonable assumption can also be made that designs should probably comply with the requirements of both ADA and ANSI, if there is any possibility of handicapped individuals being in the area.” It is not a requirement in most states but this is slowly changing. In California, for instance, “policy 98-03 now requires a disabled-accessible shower and eyewash in every laboratory classroom, for all school modernization or new construction projects that receive state funding” (Hayes, 2007). It is important to not only design with ANSI’s recommendations in mind, but also to consider the Americans with Disabilities Act (ADA) design guidelines. It is not required in all states, but the future trends may lead to widespread government regulation. In addition, it is cheaper to implement at installation than to retrofit in the future.

The ADA guidelines that are particularly relevant to emergency wash design pertain to wheelchair accessibility and the location of objects protruding from the wall (Appendix B). These guidelines have different applications to the design of eyewash stations and emergency showers. Both of these systems will be addressed in the following section.

2.2. General Design Considerations

Eyewash stations and showers need to follow the standards found in the ADA guidelines that refer to the ground around the accessible station. The ADA guideline Section 4.5 specifies that the ground should be “stable, firm [and] slip-resistant” (ADA, 1994). Similarly, both also need to make sure that there is adequate clearance surrounding the wash station. The ADA mandates that there be at least 32 inches of clearance at a minimum and 36 inches for lengthy confined spaces.

2.3. Emergency Eyewash Design Criteria

Eyewash stations usually protrude from a wall and will need to be approached directly by the injured person who may be walking or in a wheelchair. As such, this station design could benefit by giving consideration to the guideline 4.4 Protruding Objects of the ADA guidelines. This guideline specifies that if the object protrudes from the wall at a height between 27 and 80 inches, the protruding object should stick out no more than 4 inches. If the object is below 27 inches, however, there is no restriction. Since eyewash stations would be above 27 inches they should be set into a wall in order to prevent protruding out more than 4 inches.

Eyewash stations will be approached by wheelchairs from a forward position, meaning that the wheelchair should be able to pull up to the eyewash station. Because of this it is important that the user is able to reach forward and use the station. Therefore, the station must meet the forward reach standards (Appendix B, 4.2.5). The height of the eyewash station is addressed by
Hayes (2007) saying “specifiers should note that ANSI Z358.1, Section 5.4.1 allows for the eyewash spray heads to be as low as 33 inches, even for the non-disabled person. That means that a single shower and eyewash can serve either the able-bodied or the disabled, in installed recognizing both ANSI and ADAAG guidelines”.

2.4. Emergency Shower Design Criteria

While the emergency shower must meet all of the above mentioned standards, it is also important to make sure that the emergency shower has appropriate wheelchair turning area and a pull cord that can be reached. The pull cord must fall within 15 to 48 inches above the ground in order to meet the forward reach guidelines (Appendix B, 4.2.5). Furthermore, the wheelchair turning area must meet the guidelines in Section 4.2.1 (Appendix B) that specify a 60-inch diameter area. These designs can all be combined to meet the needs of a wide group of users.

2.5. Summary

If these guidelines are followed, employees of varying abilities will be positively affected. Not only will these guidelines benefit people who are considered physically disabled, but it will also help others who, previous to a chemical accident, may have been able-bodied but were temporarily disabled by the accident. These guidelines help to make any emergency situation easier to solve by avoiding design pitfalls.

3. SIGNAGE, SAFETY, AND TRAINING

3.1. Signage

Signs have been used to direct people toward the emergency stations. Typically, reflective print behind solid, bold, and flashy colors has been the basic sign design; much like the appearance of road signs. As of now, there are no color standards. The size of a sign is also used to grab the attention of people; however, it is not regulated. Their visibility must stand out under well-lit conditions to provide maximum direction in a state of disorientation.

3.2. Path Clearance

The clearance of obstructive material from the path to emergency stations has also become a major design requirement. Having to navigate around obstacles increases the time it takes a burn victim to reach an emergency station, and possibly causes further injuries in the process. An obstruction free path to the emergency station can make the difference between life and death.

3.3. Training

Training personnel may be the most important safety precaution for chemical burns. Employees and employers need to be aware of possible accidents and understand how to operate
Emergency Eyewash and Shower Equipment

the emergency stations. Conducting mock accident scenarios may reduce the severity of chemical burns. For example, employees may be blindfolded, to simulate being temporarily blinded by a hazardous chemical, and navigate their way to the emergency flushing station. The goal of this experiment is to have the blindfolded workers reach the stations within 10 seconds (Wohlen, 1982). If the safety fixtures are within this range, the victim will likely sustain less trauma and injury. It may also be beneficial to have employees turn the emergency shower and eyewash units on and off as part of a training program. Every employee should be included in training programs because people around the affected person also need to react efficiently, as a team, to help this person receive proper first aid.

4. MAINTENANCE

4.1. System Testing

Once the emergency fixtures are installed, proper maintenance of the unit is crucial. “No matter how painstakingly installed and placarded, an emergency eye flush or shower station will be useless or unreliable unless properly maintained and tested” (National Safety News, 1977). It is recommended by Wholen that emergency showers are tested each working day, ideally once a shift. Eyewashes should be tested for proper flow, aeration, and temperature once a day as well, ideally once a shift (Wohlen, 1982). Some companies require daily drills for employees that are working with hazardous chemicals. These drills require the employees to get under the shower just before quitting time (National Safety News, 1977). During these regular checks, personnel should be looking for leaks, valve adjustments, and loose connections. On outdoor safety showers, especially ones that are located some distance from the plant or are in isolated areas, it is very important to look for damage caused by vandalism.

4.2. Equipment Checks

Emergency stations that have faulty parts can have dramatic, life threatening effects because of the importance of flushing with large volumes of water immediately after chemical contact.

A randomized survey of 200 facilities was conducted by Fendall Company of Smithfield, RI (Hurley, 2000) for various components of emergency stations. The most common flaws included: nozzle covers uninstalled, clogging, broken or missing nozzles, inoperable activating valves, improper water pressure, low fluid levels in self-contained eyewash units, and foreign particles in bowls.

This survey, as well as many others, indicates the importance of proper training and maintenance. Maintenance of the plumbing units and system components is essential for emergency shower and eyewash systems to perform as intended. Some sources recommend daily flushing of the emergency stations; however, others suggest weekly flushing to verify operation and fluid clarity. Valves have previously posed a safety threat by prematurely shutting off the flow of water. New standards require the flow of water to be shut off manually (ANSI Z358.1 5.5.2). Emergency shower and eyewash units also require instructional labels with expiration dates with
portable units, to prevent faulty operation. Additionally, alarms have been used to indicate an accident allowing other personnel to be aware of the situation and move away from the emergency washing units.

4.3. Backup Equipment

Specifications and maintenance records should be filed and accessible to maintenance personnel to facilitate rapid repair (Wohlen, 1982). In order to prevent the in-operation of a safety shower and eyewash, a variety of spare parts should be kept in stock. At a minimum, companies should have a replacement valve, a set of seals for every valve in use, an extra shower head, one set of eyewash heads, one drain bowl, handles, and all hardware needed to connect handles. Personnel should then record, who repaired the unit, when it was repaired, and when the safety fixture was put back into operation.

4.4. Importance of Communication

If malfunctions cannot be repaired, obvious warning signs should be placed near the unit indicating that it is not operating. In addition, employees should then be informed of the location of the nearest operating safety shower and eyewash station. If possible, a portable unit should temporarily replace the malfunctioning unit.

5. MICROBIAL GROWTH

5.1. Background

A major concern in emergency eyewash and shower station safety is microbial growth. Regular flushing is a mandated part of the ANSI standard (ANSI Z358.1-2004). Experiments on flushing eyewash and shower systems strongly indicate that flushing a plumbed system helps lower microbial growth (Bowman et al., 1996). At the time an eye is contaminated by a hazardous chemical, the defense system of the eye is greatly reduced. In fact, “an injured eye has less resistance to infection than the bloodstream” (Hurley, 2000). For this reason it is even more imperative that emergency stations be properly maintained to prevent unnecessary microbial growth.

5.2. Bacterial Risks

In 1999, Fendall Company conducted a survey of 200 manufacturing facilities. The results showed that 58% of the eyewash stations contained the pseudomonas bacteria (Hurley, 2000). The first few seconds following hazardous chemical contact is a disastrous time to expose the eye to unwanted pathogens. The opportunity for the bacterial growth develops “if devices are not properly maintained [and] the flushing fluid (water in plumbed devices) remains stagnant for an extended period, significantly increasing the risk of contamination” (Hurley, 2000). Furthermore, if left with little maintenance, “a biofilm may form, attach to the inside surface of the water line or the self-contained device and continue to grow, providing a source of bacterial
contamination that resist removal by periodic flushing” (Hurley, 2000). When bacteria and microbes are present at dangerous levels, it is questionable whether the eyewash is helping users or causing more damage. Certain types of microbes are health hazards. Additionally, the body has a lowered resistance when already under attack because of chemical exposure, therefore increasing the risk of infection. If, for instance, an eye infection is caused by acanthamoeba, the resultant infection is “generally...severe and resistant to antibiotic therapy,” a condition made worse when coupled with chemical burns (Hurley, 2000).

Temperature affects bacterial growth, specifically the growth of the legionellae bacteria. As can be seen in Figure 1, the ideal growth temperature for legionellae at the low end is 95°F (35°C) which overlaps with the tepid water range, which is generally defined as 60°F-100°F (16°C-38°C) (See Section 6.5 Extreme Temperatures).

![Figure 1: Temperature Range for Microbial Growth (Thermoflo Equipment Co. Inc., Pittsburgh, PA, 2008)](image-url)
5.3. Station Models

With a clear understanding of the hazards of microbial growth in eyewash stations, it is important to look at the various types of stations available and the preventative measures that can be taken for each. Different eyewash station designs require varying degrees of maintenance. The first type of eyewash station is one that is connected to the plumbing in the building. These stations are referred to as plumbed eyewash stations and “are permanently connected to a source of tap water. Their greatest attribute is the ability to deliver plentiful amounts of flushing fluid. [However,] they are expensive to install, impractical to move and require weekly flushing maintenance [to limit bacterial growth]” (Osley and Mello, 2006). A second type of eyewash system is the portable station. “Portable stations…must be cleaned and refilled in accordance with the manufacturer’s instructions; however, this only needs to be done every six months” (Osley and Mello, 2006). Another type of portable eyewash station is the “sealed-fluid cartridge device…[which] feature[s] factory-sealed cartridges containing a purified, buffered saline solution that remains free of bacteria or contamination for 24 months” (Osley and Mello, 2006). The optimal system choice varies by situation and should be evaluated on a case-by-case basis.

5.4. Bacterial Growth Preventative Measures

With each different station, there are different up-keep measures to prevent or limit microbial growth. The portable sealed-fluid cartridge devices and the portable stations merely need to be replaced at 24-month and 6-month intervals, respectively. This is an expense that will continue to be incurred, but, more importantly, a maintenance item that has to be remembered. The plumbed water systems do not require replacement cartridges, but instead need weekly maintenance to ensure that the system is flushed to remove bacteria and amoebae growth. It has been found that amoebic and bacterial concentrations temporarily decreased when at least a three minute flush was used weekly (Bowman, 1996). Therefore, it is important to maintain the weekly flushing to help decrease the bacterial concentrations found in eyewash systems.

5.5. Washing Fluid Comparison

Another aspect of eyewash stations that should be considered when choosing a design or model is the effectiveness of the chosen system at maintaining a lower microbial population and the consequent interaction of solution with the eye. Beaudoin (2003) claimed that flushing with tap water was found to damage three or more layers of the protective corneal epithelial cells. Eyes flushed with a buffered, saline solution incurred less damage to the epithelial cells, resulting in a quicker healing and recovery time. Furthermore, in contrast to water, saline solutions containing an anti-microbial preservative were proven to reduce the likelihood of causing additional damage to an injured eye. These anti-microbial saline solutions generally contain a combination of bactericide, fungicide, and algaeicide additives, to prevent bacterial growth. This aspect of sealed saline solutions can be very beneficial to eyewash station users. However, the cost of maintaining these systems, which have to be replaced every 6-24 months, can be quite high.

5.6. Summary

With all the decisions that go into eyewash stations, the microbial growth and maintenance
Emergency Eyewash and Shower Equipment

systems should be thought through very carefully. The eyewash system is intended to bring relief to an injured party. If their maintenance is neglected, the system could instead do more harm than good. An upper tepid temperature of 95°F (35°C) would avoid the ideal growth range of the legionellae bacteria. However, the tepid temperature still remains an environment conducive to microbial growth. Therefore, weekly flushing of at least three minutes is an essential preventative measure to minimize risk.

6. TEPI D FLUSHING FLUID TEMPERATURE

6.1. History

Temperature standards are essential for emergency shower and eyewash systems to ensure that users can safely withstand flushing hazardous chemicals for an adequate period of time. Excessively high temperatures can cause scalding and increased chemical reaction rates. Excessively low temperatures can cause hypothermia. Excessive temperatures can also create discomfort for users, resulting in treatment being cut short of the recommended flushing duration. Early in the development of safety shower and eyewash units, water temperatures were generally 112°F (44°C) upper threshold and a lower threshold undetermined (Rettew Jr., 1971). Historically there was misinformation pertaining to water temperature safety, in fact, it was stated in the National Safety News, “Eyes” #111.17-2, “even ice water causes no harm and is not uncomfortable enough to discourage irrigation” (Rettew Jr., 1971).

6.2. ANSI Standards 1981 and 1990

In 1981, ANSI Z358.1, the first consensus standard for emergency shower and eyewash equipment in the United States, was developed. In 1990, ANSI revised Z358.1. This standard only mentioned fluid temperature in the appendix, which, “is not part of American National Standard Z358.1-1990, but is included for information only” (ANSI Z358.1-1990). The appendix states that these units will be installed in various locations and because it would be difficult to predict atmospheric conditions for all units, that it is the responsibility of the specifying authority to determine a safe water temperature. The appendix does, however, suggest that 60 to 95°F (16 to 35°C) is a comfortable range and that medical advisors should be consulted for temperature optimization in cases where water temperature may increase the rate of chemical reaction. No references are provided in this document.

6.3. ANSI Standards 1998

In ANSI Z358.1-1998, the next revision of the emergency shower and eyewash standard, temperature recommendations appear in the main text, rather than the appendix, for the first time. This standard states that installers are responsible for ensuring that all safety shower and eyewash units “deliver tepid flushing fluid” (ANSI Z358.1-1998). ANSI defines tepid as moderately warm or lukewarm. No temperature range is specified in this document, but the appendix again suggests that 60 to 95°F (16 to 35°C) is a comfortable range. The reason tepid temperatures are suggested is because tepid water cools chemical burns, prevents chemical
absorption, encourages safety equipment use, encourages the full 15-minute drench time, and encourages the removal of contaminated clothing (George, 2008).

6.4. ANSI Standards 2004

ANSI Z358.1-2004, the most recent revision to the standard, includes additional information in its appendix about tepid flushing temperatures. It states that medical recommendations suggest that a flushing fluid at temperatures higher than 100°F (38°C) “have proven to be harmful to the eyes and can enhance chemical interaction with the eyes and skin” (ANSI Z358.1-2004). Furthermore, low temperature flushing fluids may cause users to abort flushing prior to the recommended duration, and that “recent information indicates that a temperature of 60°F (16°C) is suitable for the lower parameter for tepid flushing fluid without causing hypothermia to the equipment user” (ANSI Z358.1-2004). These temperature statements, however, are not directly cited with supporting information, decreasing their credibility and suggesting the need for further studies.

6.5. Extreme Temperatures

As discussed above, a concern with emergency eyewash and shower stations is the temperature of their flushing fluids. The standards call for tepid temperatures, but it is important to look at the effects of extreme temperatures in order to define the range of tepid water. In the following sections, the danger of extreme temperatures will be analyzed.

6.6. Cold Shock

A common cold water related concern is cold shock. Cold shock is the reaction the body has immediately after being exposed to cold water where cold water is generally considered to be less than 60°F (16°C). The body may experience two reactions to the cold water that can be fatal. The first is the reaction to gasp for air. This results in water being inhaled into the lungs and drowning. While this is less of a risk in safety showers than it is in a body of water, it can still be dangerous if one’s head is facing up towards the showerhead. The second reaction is for the body to experience an increased heart rate or blood pressure possibly leading to cardiac arrest (Seidel, 2008).

6.7. Scalding

On the other extreme, it is important to prevent exposure to scalding water temperatures. This requirement is two-fold: prevention of burning and protection against speeding up chemical reactions with the skin. The relationship between water temperature and burn risk can be seen in Figure 2. This graph shows the logarithmic relationship between these two variables and demonstrates that above 120°F (49°C) the time of exposure before very damaging burns occur decreases drastically. An upper bound of 100°F (38°C), as recommended by Appendix B of ANSI Z358.1-2004, appears to successfully prevent scalding injuries.
7. CHEMICAL FLUSHING

7.1. Background

Various first aid resources suggest that the general consensus on chemical burn first aid is to immediately flush the affected area with 60 to 100°F (16 to 38°C) water, for 15 to 20 minutes, and follow with advanced medical attention. Although this method of care for chemical burns has been in place for many years, it is important to evaluate its effectiveness and explore other options that may be more successful at treating these types of injuries.

7.2. Benefits of Water

The use of immediate flushing of the skin and eyes with water as a first aid measure for chemical burns has proven to be effective when compared to leaving the burn untreated. Basic chemistry demonstrates that water serves to dilute, rinse off, and decrease the reaction rate of hazardous chemicals. Water also decreases tissue metabolism to prevent inflammatory reactions, minimizes hygroscopic effects, and helps the skin return to its normal pH (Hall and Maibach, 2006). The benefits of flushing with water are also illustrated in multiple studies. Leonard et al. (1982) compared chemical burn cases that most commonly involved acids. The study focused on two groups, those receiving proper first aid, which primarily includes flushing with
Emergency Eyewash and Shower Equipment

water, and those not receiving proper first aid, having groups of 20 and 16 people, respectively (Langerman and Sussman, 2007). Results indicated that proper first aid led to 12.5% full-thickness burns and 7.7 days of hospitalization, on average, whereas 63% of those not receiving necessary first aid developed full-thickness burns, and required an average hospitalization time of 20.5 days. Additionally, Sykes et al. (1986) analyzed 16 chemical burn cases, most commonly involving alkalis, in which victims received proper first aid, which primarily includes flushing with water, versus 19 cases in which victims did not receive proper first aid. The results showed that group receiving proper care had a 9.5% mortality rate and 19% required skin grafting, compared to 21% mortality and 36% skin grafting required in the group not receiving proper care. Latenser and Lucktong (2000) analyzed a case where two men were similarly exposed to anhydrous ammonia. One victim showered and changed clothes immediately, eventually resulting in overnight hospitalization for corneal abrasions and face and neck redness. The other victim did not shower or change clothing. The latter victim, who arrived at a hospital 90 minutes after his exposure, was hospitalized for 13 days and required incubation, a ventilator, debridement, and skin grafts (Langerman and Sussman, 2007).

7.3. Disadvantages of Neutralization

The use of water has historically been promoted over specific neutralization because finding the proper neutralizing agent generally takes more time than flushing with water, allowing the chemicals to penetrate and disperse deeper into the skin (Seth et al., 2007). Yano et al. (1995) conducted an experiment in which rats were subjected to 2N-NaOH and washed with water 1, 10 and 30 minutes after the exposure resulting in maximum skin pH values of 7.97, 10.57, and 12.17, respectively. This study also illustrated that washing was not at all effective in lowering the pH levels of the skin when the delay in washing was 10 and 30 minutes. Another study conducted on rats by Bromberg et al. (1965), using HCl, illustrated that washing with water immediately after contamination resulted in no tissue damage, whereas washing after 30 minutes, and longer, produced significant tissue damage. Although these studies focus on flushing with water only, they do demonstrate the importance of immediate flushing rather than allowing chemicals to penetrate further into the skin while attempting to find specific neutralizing agents. Neutralization has also been discouraged because it may cause further tissue damage due to the heat of reaction, the neutralizing agent itself may burn the skin, and this strategy provides greater opportunity for the victim to accidentally use an incompatible neutralizing agent (Seth et al., 2007). The discouragement of using specific neutralizing agents on chemical burns dates as far back to 1927 when Davidson (1927) subjected rats to various acids and alkalis and tested the efficacy of various neutralizing agents versus washing with water. Davidson (1927), based on tissue damage and mortality rates, concluded that burn treatment was “decidedly better when the caustic agent was removed by dilution with water than when rendered inert by neutralization.”

7.4. Common Exceptions to Traditional Water Flushing

Although it is usually recommended to flush chemical burns with water, there are certain chemicals that are advised not to wash with water. For hydrofluoric acid (HF) contact with skin, washing should be limited to five minutes, followed by more specific treatment (Segal, 2007). Honeywell International Inc. (Morristown, NJ), the world’s largest HF producer, suggests using a 0.13% iced benzalkonium chloride solution or a 2.5% calcium gluconate gel after the five
Emergency Eyewash and Shower Equipment

minute flush (Honeywell International Inc., 2000). Suggested first aid for HF exposure to eyes remains a water or saline wash (Honeywell International Inc., 2000). Specific treatment for HF is required because its F-ion penetrates deeply into skin tissues, making it difficult to remove with water, and it is extremely toxic (Segal, 2007). Another chemical with special provisions is phenol. Phenol is not water-soluble and irrigation can increase skin absorption (Segal, 2007). Emergency procedures for phenol burns consist of wiping the affected skin with a 50% water polyethylene glycol (PEG 300 or 400) solution (Segal, 2007).

The NIOSH Pocket Guide to Chemical Hazards lists a number of chemicals that may cause frostbite (NIOSH, 2005). If frostbite has not occurred, it is recommended to flush the eyes with water and the skin with soap and water. If frostbite has occurred on the eye, it is suggested to seek immediate medical attention, rather than attempting to flush. If frostbite has occurred on the skin, it is recommended to seek immediate medical attention, and not to rub or flush the skin, or remove frozen clothing (NIOSH, 2005).

Certain elemental metals, such as sodium, potassium, lithium, and magnesium, can ignite spontaneously with moisture, thus requiring a first aid method alternative to water flushing (Segal, 2007; Cox, 2005). Forceps should be used to remove the fragments of these metals (Segal, 2007). Extracted metal fragments should then be submerged in mineral oil (Segal, 2007). If all fragments are removed, the skin should be flushed for 30 minutes (Segal, 2007). If fragments cannot be removed, they should be covered with mineral or cooking oil (Segal, 2007). Also, for lithium hydride, the NIOSH Pocket Guide to Chemical Hazards recommends brushing and states not to wash (NIOSH, 2005). Specific cases have also been documented as in Clare’s analysis (1988) demonstrating a fast recovery from elemental metal exposure in one patient following emergency guidelines versus 16 days of hospitalization for second and third degree burns resulting from using a school shower while clothed to treat potassium burns rather than removing fragments and clothing prior to washing (Langerman and Sussman, 2007). Additionally, white phosphorous is easily oxidized to form P$_2$O$_5$, which reacts violently with water, thus requiring the victim to immerse the affected area in water while manually removing particles (Segal, 2007). Skin and eyes should be flushed with a 0.5% hypochlorite solution to remove vesicants, such as mustard gas (Fitzgerald, 2006). Special treatment for these substances is required due to their ability to irreversibly bind to the skin within minutes (Fitzgerald, 2006). Additionally useful resources on determining adequate chemical burn treatment are the decision trees from the Canadian Centre for Occupational Health and Safety’s (CCOHS) “The MSDS – A Practical Guide to First Aid”, found in Appendix C.

7.5. Disadvantages of Washing with Water

Less widely accepted studies have proposed additional situations in which water may do more harm than good. These studies suggest that hydrating the skin may allow chemicals that are not normally soluble in water to dissolve to a certain degree, allowing them a path into the bloodstream (Klinger, 2007). It has been proposed that the lower the degree of solubility of the chemical, the greater the advance in systemic uptake to the bloodstream will be when washing with water (Klinger, 2007). Evidence of this effect was demonstrated in a study by Moody et al. (1995), which revealed that the amount of DDT (Dichloro-Diphenyl-Trichloroethane) and DEET (N,N-diethyl-meta-toluamide) entering the bloodstream was about five times greater when
Emergency Eyewash and Shower Equipment

washed with aqueous solution 24 hours after exposure compared to not washing at all (Klinger, 2007). This study, however, did not demonstrate the effects on washing immediately after exposure, rendering it somewhat irrelevant to the discussion of emergency wash solutions. A study by Loke (1999) demonstrated that more diethylmalonate was absorbed into the skin when washing with water one hour after exposure compared to no treatment (Klinger, 2007; Loke et al., 1999). However, decreased absorption, compared to no treatment, was demonstrated when washing with water 15 minutes after exposure (Klinger, 2007; Loke et al., 1999). These studies suggest that if the exposed chemical is allowed to remain on the skin for a prolonged period of time, leaving the affected area untreated may be more effective, but that if immediate flushing is possible, it is a more desirable procedure.

7.6. Alternative Solutions

Water flushing has proven to be effective when compared to providing no first aid, but many studies illustrate that other solutions may be more effective in providing first aid to hazardous chemical exposures. Skin acts as a barrier to keep water inside of the body, as well as prevent outside water from penetrating (Klinger, 2007). This suggests that water flushing is a good first aid measure when the spilled chemicals are water soluble, but that alternative solutions may be more effective in treating chemical burns resulting from substances that have a low degree of solubility in water (Klinger, 2007). United States Environmental Protection Agency (USEPA) (1992) accepted the following model relating the octanol/water partition coefficient (K_{ow}) and molecular weight (MW) of chemicals in aqueous solution to their permeability of skin in centimeters per hour (K_p) as follows (Klinger, 2007):

\[
\log K_p = -2.72 + 0.71 \log K_{ow} - 0.0061 MW
\]  

(1)

This equation illustrates that chemicals with low molecular weights pose greater risks and further demonstrates that alternative solutions may be required for chemicals with high K_{ow} (low solubility) values (Klinger, 2007). It has been suggested that chemicals with mid-range water solubility and low molecular weights pose the greatest risks as they cannot be completely flushed away with water or alternative solutions and have the ability to penetrate the skin as well as the bloodstream, leaving the victim susceptible to systemic uptake (Klinger, 2007).

Additionally, a stepwise regression was performed with the K_p, log K_{ow}, and MW data published by the USEPA (1992). Molecular diffusion coefficient values, found in the Pennsylvania Department of Environmental Protection’s Chemical and Physical Properties Database (2008) were also included in the regression analysis. It was found that the permeability was affected or most closely correlated with log K_{ow} and molecular weight as a variable was rejected at p value < 0.05, although the prediction was improved slightly. Thus, it can be said that the permeability may be judged only by log K_{ow}. Further study is needed to determine the washing time for various organic compounds covering the wide range of log K_{ow} values. Further research should be conducted to determine if washing time should be increased or alcohol should be used as a washing fluid, when log K_{ow} values are greater than two.

Many studies are critical of first aid resources, which almost exclusively call for flushing chemically exposed areas with water (Klinger, 2007). Part of this criticism is due to the fact that NIOSH (1997) and other first aid resources do not cite data to support their suggested
Emergency Eyewash and Shower Equipment

decontamination procedures (Klinger, 2007). Additionally, the recommended treatment does not differ much for high and low-solubility chemicals (Klinger, 2007). NIOSH does recommend a soap wash of the skin for a number of lower solubility, generally organic, chemicals, such as benzene, but a basic soap and water wash may not be enough to successfully remove these dangerous compounds (NIOSH, 2005). Conversely, it has been demonstrated that common soap ingredients, such as citrus oils, especially limonene, significantly enhance chemical absorption through the skin and into the bloodstream (Klinger, 2007).

In many cases, water, or soap and water, may not be the best flushing fluid, but there is little quality data to support the use of other substances. The pharmaceutical industry has published data illustrating that high MW solvents, such as polyethylene and polyethylene glycols, help prevent the absorption of lipophilic chemicals into the skin (Klinger, 2007). These effects were studied on rats and illustrated that the dose required for toxicity was much higher in the subjects that had a protective barrier prior to exposure (Klinger, 2007). However, this does not demonstrate the effects of applying a high molecular weight solvent after exposure. Another study looked at the decontamination of methylene diphenyl di-isocyanate (MDI), which revealed that corn oil and polyglycol removed 95% MDI after five minutes and after 8 hours, whereas soap and water removed 85% after five minutes and only 60% after 8 hours (Klinger, 2007). Again, this study appears to illustrate that other substances may be more effective than water long after initial exposure, but if applied immediately after exposure, have little difference. Another example is demonstrated in the study of Green Tobacco Illness. NIOSH (1999) found that when tobacco harvesters washed their hands with soap and water, it had little effect on illness rates (Klinger, 2007). However, studies have illustrated that nicotine becomes water soluble when introduced to organic acids (Klinger, 2007). Additionally, it has been observed that tobacco harvesters who crush tomatoes, containing organic acids, in their hands, while picking tobacco plants are relatively unaffected by Green Tobacco Illness (Klinger, 2007). These findings suggest that there are most likely better alternatives to water flushing for minimizing the effects of hazardous chemical exposure. Without controlled scientific experiments, however, little can be concluded from observations alone, such as the effectiveness of the tomato crushing remedy.

7.7. Benefits of Neutralization

Neutralization has often been discouraged, but certain studies promote specific neutralization agents over water. In another study, two groups of rats were exposed to 2N sodium hydroxide, an alkaline substance, and after one minute, one group was treated with water and the other was treated with 5% acetic acid (Andrews et al., 2003). The results revealed that, “animals treated with acetic acid demonstrated a shorter treatment period, returning to physiologic pH (14.69±4.06 minutes versus 31.62±2.83 minutes) more rapidly than animals treated with water,” as well as less tissue damage and faster healing of wounds (Andrews et al., 2003).

7.8. Provisions to Typically Accepted Flushing Duration

Exceptions to the length of flush typically recommended, 15 to 20 minutes, have been suggested. The duration of washing chemicals from the skin is important because more hazardous chemicals often require a longer flush duration to dilute their concentrations to relatively safe levels. Additionally, hydrophobic chemicals can stick to the skin and resist a quick rinse. CCOHS has
reviewed multiple case studies and data and suggested flushing times of 60 minutes for strong alkalis; 30 minutes for other corrosives, including acids; 15 to 20 minutes for moderate to severe irritants; and five minutes for mild to non-irritants (CCOHS, 2005).

7.9. Summary

Through years of observations and studies conducted, it has been demonstrated that flushing areas exposed to hazardous chemicals, with tepid water, generally has a positive effect and decreases burn severity for a great deal of chemicals. However, the use of water is heavily based on simplicity and availability. Although these are logical reasons, it should be noted that many studies have outlined alternative treatment methods with more successful results. These studies are often very specific, performed on animals, and do not reflect real-world situations, but they do serve to illustrate that there are alternatives that must be investigated in detail and discussed throughout the medical, regulatory, and first aid communities. Comprehensive chemical exposure first aid procedures must be continually developed, with cited studies, to avoid confusion and ensure people are receiving the most effective treatment. Due to a lack of clear evidence that alternative solutions provide better treatment than water, the standard tepid water flush should continue to be used while researching and developing possible substitutes. Currently, the consequences of incorrectly using chemical specific treatments outweigh their benefits. However, instead of accepting the current standard as the best option, it should be thought of as a temporary remedy while the necessary efforts are put into ongoing research to discover new strategies that will further prevent injuries and save lives.

8. CONCLUSIONS, RECOMMENDATIONS, AND AREAS FOR FURTHER RESEARCH

8.1. Conclusions

An extensive literature review has been conducted, examining the various aspects of chemical burn first aid. The general consensus is to flush the affected areas with large quantities of water for 15 to 20 minutes. Most serious chemical burns occur on jobsites, leading to OSHA’s regulation of emergency shower and eyewash units. The OSHA requirements are quite vague, but OSHA generally refers to ANSI Z358.1 when evaluating facilities. Currently, neither the OSHA or ANSI standards have been adopted as laws, causing a great deal of confusion. Even if the components of ANSI Z358.1 were to be made into laws, many important chemical burn first aid questions would still be left unanswered.

It has been clearly demonstrated that emergency shower and eyewash facilities have helped to prevent numerous injuries and save many lives. The current practices are effective, to a certain degree, but people are still being severely injured and killed by chemical burns. The most important questions of chemical burn first aid that are lacking sufficient answers are:

What flushing fluid or removal method should be used?
What should be the temperature of the flushing fluid?

What should be the duration of flushing?

Proposed answers to the above questions often vary for a specific chemical and provoke widely differing opinions when considering the best universal first aid procedures for all chemicals in general. These questions are quite complex, considering the many different factors that affect them. It is, however, necessary to work towards discovering the most effective, scientific evidence based decontamination procedures for every potentially hazardous chemical.

Water has been the standard for flushing fluids since emergency shower and eyewash stations were introduced. Water has generally proven to dilute hazardous chemicals, but studies have also illustrated that specific neutralizing agents are more successful at removing these chemicals. Additional studies suggest that soaps, high molecular weight solvents, alcohols, and oils may be more successful in removing lipophilic, generally organic, chemicals. Some experimental results have even demonstrated that washing the skin with water can increase certain hazardous chemicals’ permeability into the bloodstream.

In reference to flushing fluid temperature, ANSI Z358.1 (2004) only states that it should be tepid. In ANSI Appendix B, which is for information only and is not part of the standard, it is stated that medical recommendations suggest that a temperature range of 60 to 100°F (16 TO 38°C) is safe for users to be exposed to. Safely withstanding exposure to emergency shower and eyewash flushing fluid temperature is important because a flush duration of at least 15 minutes is generally called for. Studies have illustrated that certain chemicals may require a much greater flush duration, illustrating that raising the lower limit of the temperature range may be required, as users often stop flushing prematurely, due to uncomfortably low flushing fluid temperatures. Conversely, certain chemical reactions may speed up when introduced to higher temperatures and skin porosity may increase when temperature increases.

Bacterial growth within emergency shower and eyewash units can also pose serious health risks to users. This must be considered when deciding at what temperature flushing fluid should be set because hazardous bacteria have ideal growth temperature ranges which can overlap current ranges for "tepid" water. For example, legionellae bacteria, which generally create the greatest bacterial hazards for emergency shower and eyewash users, have an ideal growth rate temperature range of 95 to 115°F (35 to 46°C).

Flush duration is typically recommended to be 15 to 20 minutes, but alternative durations have been suggested. Studies have demonstrated that severely hazardous chemicals as well as hydrophobic chemicals will not dilute to relatively safe levels unless a longer flush is administered. A 60-minute flush is often suggested for strong alkalis and a 30-minute flush for all other corrosive chemicals. Others recommend shorter flushing periods, about five minutes, for certain extremely hazardous chemicals in order to focus on advanced treatment more quickly. A shorter flushing duration of about five minutes has also been recommended for mild to non-irritants.
8.2. Recommendations

Based on extensive literature review and analysis of published scientific data regarding emergency shower and eyewash units, the following recommendations have been made:

1) Change tepid temperature range and OSHA regulation.
   a) Increase the minimum flushing fluid temperature recommendation to 70°F (21°C) to further protect from cold shock and encourage users to flush affected areas of skin and eyes for the full time
   b) Decrease the maximum flushing fluid temperature to 95°F (35°C) to avoid the Legionellae bacteria ideal growth temperature
   c) Include the above temperature recommendations and make ANSI Z358.1 integral to OSHA regulation rather than simply referenced

2) Design systems able to dispense multiple solutions so they are ready to use if alternative solutions are found to be more effective than water at treating certain chemical burns

3) Design all systems to be ADA compliant in order to better serve users with disabilities and users temporarily disabled due to chemical exposure

8.3. Areas for Further Research

In addition to the recommendations above, the literature review and analysis of published scientific data regarding emergency shower and eyewash units also provided questions and suggestions, which demonstrate the need for the following topics to be researched in greater detail:

1) Develop a more specific OSHA standard, including a nationally mandated temperature range for tepid water
2) Develop and evaluate flushing fluid alternatives to water
3) Use lipid solutions (rather than water) for lipophilic chemicals
4) Comprehensively evaluate the effectiveness of neutralizing agents
5) Determine chemical specific OSHA standards regarding first aid plans, including flush duration, to be nationally mandated
6) Determine the washing time for various organic compounds covering the wide range of log $K_{ow}$ values
7) Determine if washing time should be increased or alcohol should be used as a washing fluid, when log $K_{ow}$ values are greater than two
REFERENCES


Emergency Eyewash and Shower Equipment


Emergency Eyewash and Shower Equipment


Appendix A: List of Acronyms and Abbreviations

°C Degrees Celsius
°F Degrees Fahrenheit
ADA Americans with Disabilities Act
ANSI American National Standards Institute
CCOHS Canadian Centre for Occupational Health and Safety
DDT Dichloro-diphenyl-trichloroethane
DEET N, N-diethyl-m-toluamide
GPM Gallons per minute
HCl Hydrochloric Acid
HF Hydrofluoric Acid
$K_{ow}$ Octanol water partition coefficient
$K_p$ Skin permeability (in centimeters per hour)
MDI Methylene diphenyl di-isocyanate
MW Molecular Weight (in grams per mole)
N Normality (gram equivalent weight of a solute per liter of solution)
NIOSH National Institute for Occupational Safety and Health
OSHA Occupational Safety and Health Administration
PEG Polyethylene glycol
PSI Pounds per square inch
USEPA United States Environmental Protection Agency
Appendix B: Americans with Disabilities Act Accessibility Guidelines

4.2.1 Wheelchair Passage Width. The minimum clear width for single wheelchair passage shall be 32 in (815 mm) at a point and 36 in (915 mm) continuously.

4.2.3 Wheelchair Turning Space. The space required for a wheelchair to make a 180-degree turn is a clear space of 60 in (1525 mm) diameter (see Fig. 3(a)) or a T-shaped space (see Fig. 3(b)).

4.2.4* Clear Floor or Ground Space for Wheelchairs.

4.2.4.1 Size and Approach. The minimum clear floor or ground space required to accommodate a single, stationary wheelchair and occupant is 30 in by 48 in (760 mm by 1220 mm) (see Fig. 4(a)). The minimum clear floor or ground space for wheelchairs may be positioned for forward or parallel approach to an object (see Fig. 4(b) and (c)). Clear floor or ground space for wheelchairs may be part of the knee space required under some objects.
4.2.5* Forward Reach. If the clear floor space only allows forward approach to an object, the maximum high forward reach allowed shall be 48 in (1220 mm) (see Fig. 5(a)). The minimum low forward reach is 15 in (380 mm). If the high forward reach is over an obstruction, reach and clearances shall be as shown in Fig. 5(b).

4.4 Protruding Objects.

4.4.1* General. Objects projecting from walls (for example, telephones) with their leading edges between 27 in and 80 in (685 mm and 2030 mm) above the finished floor shall protrude no more than 4 in (100 mm) into walks, halls, corridors, passageways, or aisles (see Fig. 8(a)). Objects mounted with their leading edges at or below 27 in (685 mm) above the finished floor may protrude any amount (see Fig. 8(a) and (b)). Free-standing objects mounted on posts or pylons may overhang 12 in (305 mm) maximum from 27 in to 80 in (685 mm to 2030 mm) above the ground or finished floor (see Fig. 8(c) and (d)). Protruding objects shall not reduce the clear width of an accessible route or maneuvering space (see Fig. 8(e)).

4.5.1* General. Ground and floor surfaces along accessible routes and in accessible rooms and spaces including floors, walks, ramps, stairs, and curb ramps, shall be stable, firm, slip-resistant, and shall comply with 4.5.
Emergency Eyewash and Shower Equipment

Fig. 8 (a) Walking Perpendicular to a Wall

Fig. 8 Peeling Objects
Appendix C: Decision Trees for Skin and Eye Exposures (CCOHS, 2005)
Emergency Eyewash and Shower Equipment
Emergency Eyewash and Shower Equipment

DECISION TREE FOR EYE EXPOSURES

from page 1 of eye decision tree

CORROSIVE (NOT A STRONG ALKALI)?

CORROSIVE (STRONG ALKALI)?

CAUSES FROSTBITE OR FREEZES TISSUE?

SOLID OR REACTS WITH WATER TO PRODUCE HEAT OR A MORE TOXIC CHEMICAL?

Quickly and gently, blot or brush chemical off the face.

Quickly and gently, blot or brush chemical off the face.

Quickly remove victim from source of contamination. Immediately and briefly, flush with lukewarm, gently flowing water. DO NOT attempt to rewarm. Cover both eyes with a sterile dressing. DO NOT allow victim to drink alcohol or smoke. Quickly transport victim to an emergency care facility.

Immediately flush the contaminated eye(s) with lukewarm, gently flowing water for at least 30 minutes, while holding the eyelid(s) open. If a contact lens is present, DO NOT delay irrigation or attempt to remove the lens. Neutral saline solution may be used as soon as it is available. DO NOT INTERRUPT FLUSHING. If necessary, continue flushing during transport to emergency care facility. Take care not to rinse contaminated water into the unaffected eye or onto face. Quickly transport victim to an emergency care facility.

Immediately flush the contaminated eye(s) with lukewarm, gently flowing water for at least 60 minutes, while holding the eyelid(s) open. If a contact lens is present, DO NOT delay irrigation or attempt to remove the lens. Neutral saline solution may be used as soon as it is available. DO NOT INTERRUPT FLUSHING. If necessary, continue flushing during transport to emergency care facility. Take care not to rinse contaminated water into the unaffected eye or onto face. Quickly transport victim to an emergency care facility.