A Comparison of Calcium Gluconate and Zephiran® for the Treatment of Dermal Hydrofluoric Acid Exposure

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Abstract

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(Tile)

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Hydrofluoric acid (HF) is an aqueous form of hydrogen fluoride (Lewis, 1993) that typically emits a colorless or fuming irritate gas at room temperature (Hance, Solomon, Salmon, Fall, & Cass, 1997). As one of the more commonly used inorganic compounds in industry today, hydrofluoric acid is highly corrosive and will deteriorate materials such as concrete, glass, natural rubber, and metal alloys that contain silica (EPA Chemical Profile, 1987). From a worker inhalation exposure standpoint, the Occupational Safety and Health Administration (OSHA) has set inhalation limits for hydrofluoric acid at 3 ppm (2.5 mg/m^3)(OSHA, 2001).

Hydrofluoric acid is used in numerous applications in the semiconductor industry in the form of quartz and metal etching; but along with being very beneficial, it also has numerous disadvantages. From a dermal contact standpoint, hydrofluoric acid eventually causes a very corrosive and unique chemical burn. Upon skin contact, hydrofluoric acid causes tissue destruction by two methods. One, the unstable fluoride ions penetrate

tissues and adsorb calcium and magnesium, which can lead to failure of various internal organs. Second, the hydrogen ion causes a deep corrosive burn that is slow-to-heal (American Chemical Society, 1997). Consequently, knowledge of the toxicological effects, as well as treatment methods pertaining to hydrofluoric acid exposure, are vital.

From a dermal exposure standpoint, various studies have been preformed on the treatment methodologies for hydrofluoric acid exposure. Upon exposure, treatment must be administered immediately or the threat of death is substantial (Bracken, Cuppage, McLaury, Kirmin, & Klaassen, 1985). Two possible methods of treatment for skin exposure exist. The more commonly used compound is calcium gluconate, with an alternative but less-utilized organic material known as Zephiran® (Dunn, MacKinnon, Knowlden, Billmaier, Derelanko, Rusch, Naas, & Dahlgen, 1992). One study indicated that the injection of calcium gluconate can be reasonably effective at neutralizing hydrofluoric acid that has penetrated bodily tissues (Dunn, et al., 1992), the chemical composition of calcium gluconate may not lend itself to topical-oriented treatment methodologies to the extent that Zephiran® can.

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Statement of the Problem

Introduction

In the United States there are more than 1,000 cases reported every year for overexposure to hydrofluoric acid (HF) (American Chemical Society, 1997). Hydrofluoric acid (HF) is an aqueous form of hydrogen fluoride (Lewis, 1993) that typically emits a colorless or fuming irritate gas at room temperature (Hance, Solomon, Salmon, Fall, & Cass, 1997). Hydrofluoric acid is one of the more commonly used inorganic compounds in industry today, hydrofluoric acid is highly corrosive and will readily deteriorate materials such as concrete, glass, natural rubber, and metal alloys that contain silica (EPA Chemical Profile, 1987).

In 1997, 247,000 tons of hydrofluoric acid was used for commercial production processes. Hydrofluoric acid is needed for the fabrication of aluminum and stainless steel, etching glass and circuit boards, and producing stain removers, solvents, resins, and pharmaceuticals (Constellation Power Source, 2001). The refrigeration industry is one of the largest users of hydrofluoric acid. This industry uses hydrofluoric acid to produce fluorocarbon, fluoropolymers, and other refrigerant compounds hydrofluoric acid is one of the strongest inorganic acids used by this industry today (Hance, et al., 1997 & Westervelt, 2001 & Siegel & Heard, 1992). Many processes preformed by the semiconductor industry use very hazardous chemicals. Hydrofluoric acid is one such chemical that is very hazardous. Hydrofluoric acid is very important to the semiconductor industry, but it also is very toxic to humans. Dermal exposure to hydrofluoric acid can cause serious and painful burns to the skin. In some cases these burns can be life threatening, specialized first aid and medical treatment is required for any exposure to hydrofluoric acid (Honeywell Inc., 1998).

Treatment methods for exposure to hydrofluoric acid vary depending on what area was exposed, be it dermal or eye contact, inhalation or ingestion (Honeywell Inc., 1998). In regards to treating dermal burns that occur from exposure to hydrofluoric acid, studies have indicated that calcium gluconate is the preferred method for long-term treatment (Bracken, et al., 1985), while other studies have indicated that Zephiran ® is the better choice for treating dermal burns associated with short term exposure to hydrofluoric acid (Dunn, et al., 1992). The focus of this paper is to compare the use of calcium gluconate and Zephiran® for the treatment of dermal based hydrofluoric acid exposures and try to identify which treatment is most desirable by industry today.

Purpose

The purpose of this study was to compare the use of calcium gluconate and Zephiran® for the treatment of dermal based hydrofluoric acid exposure. In order to accomplish this, a review of pertinent literature was conducted. An analysis of policies and procedures for treating dermal exposure to hydrofluoric acid from a number of different universities and industries was conducted during the Fall semester of 2002.

Goals of the Study

The researcher has made three goals. They are:

1. Identify the toxicity and physical properties of hydrofluoric acid.

2. Examine the physical implications associated with dermal-based exposure to hydrofluoric acid**.**

3. Determine topical-based treatment methodologies for dermal hydrofluoric acid exposure as it relates to the use of Zephiran® verses calcium gluconate.

4. Determine the cost comparison between Zephiran® and calcium gluconate in the treatment of dermal exposure to hydrofluoric acid.

5. Determine which topical` based treatment (Zephiran® or calcium gluconate) is most desired by industry and universities today in treating dermal-based exposures to hydrofluoric acid.

Background and Significance

In 1995, an Australia laboratory technician spilled between 100 and 230 ml of hydrofluoric acid onto his lap. The technician rinsed the exposed area with water at 6 liters/minute, but still sustained burns to 9% of his body. The technician did not immediately remove the contaminated clothing and did not receive any first-aid ointment (such as calcium gluconate or Zephiran®) to the exposed area. Several days after the accident occurred, the technician's right leg was amputated. Fifteen days after being exposed to hydrofluoric acid, the technician died from multi-organ failure. After his death, an accident analysis was conducted. The analysis identified that no emergency procedures, safety equipment, or personal protective equipment was available for handling highly concentrated amounts of hydrofluoric acid. The investigation concluded that the death could have been prevented if the appropriate controls would have been in place (University of Washington Environmental Health and Safety, 2000).

Situations like the one discussed in the previous paragraph are not that uncommon. Numerous injuries occur every year from exposure to hydrofluoric acid. The main reasons are: emergency eyewash and safety showers were not available, individuals exposed were not wearing appropriate personal protective equipment, individuals did not immediately remove their contaminated clothing, and did not have the appropriate first aid ointment (such as calcium gluconate or Zephiran®) on hand to apply to the exposed area (Queensland Government, 2002). Figure 1 shows the occupations, costs associated, days off of work due to and activities preformed when exposed to hydrofluoric acid.

Figure 1 - Hydrofluoric acid injuries-Workers' Compensation claims July 1992-June 2000

OCCUPATION	HF EXPOSURE	DAYS OFF	COST $
Chemist	Cleaning fume cupboard	0	$60.00
Boilermaker	Cleaning Weld	22	$12,415.00
Boilermaker	Filling Acid Dip Tank	84	$7,109.00
Boilermaker	Picking Up Drums	22	$2,660.00
Excavator	Siphoning HF	354	$50,987.00
Forklift Driver	Cleaning Aluminum	8	$838.00
Operator	Placing Lid On Drum	10	$1,470.00
Store Person	Packing HF Drums	3	$250.00
Occupational Not Stated	Putting HF Drums Away	28	$3,860.00
Total HF Claims	9	Total HF Days Off 531	Total HF Claims $79,649.00
*Total Acid Claims	412	Total Days OFF 2,185	Total Acid Claims $313,054.00

* Some claims for HF may be in the category for all acid injuries because the type of acid is not always specified.

Note: From Queensland Government. (2002, April).*Hydrofluoric acid poisoning and burns*. Retrieved September 25, 2002 from: http://www.whs.qld.gov.au/alerts/02i04.pdf

Figure 1 shows that hydrofluoric acid burns only makes up 2.2% of the total acid burn cases. The significance of this statement is that hydrofluoric acid burns make up 24% of the lost work time and 25% of the compensation costs for total acid burn cases. This identifies the significance that having the right treatment to treat hydrofluoric acid burns can save thousands of dollars in compensation costs and hundreds of lost workdays. The focus of this paper is to compare the use of calcium gluconate and

Zephiran ® for the treatment of dermal based hydrofluoric acid exposures and try to identify which treatment is most cost effective and predominately used by industry today.

Assumptions

The researcher has made four assumptions. They are:

1. It is assumed that all companies either use Zephiran® or calcium gluconate in treating hydrofluoric acid exposures.

2. It is believed that all written material received from companies will provide accurate data.

3. It is presumed that the semiconductor industry and university organizations are the major users of hydrofluoric acid.

4. It is assumed that all companies that use hydrofluoric acid are aware of the hazards and dangers that this chemical possess.

Limitations

The researcher has made two limitations. They are:

1. No human studies have been preformed to find out toxicology levels of hydrofluoric acid for humans. Only animal studies have been completed in determining lethal dose limits.

2. The research focuses on dermal treatment methodologies for in the semiconductor industry and collects data from only one semiconductor facility.

Definition of Terms

Terms pertinent to the study are defined below:

Calcium gluconate - Calcium gluconate gel is a topical antidote for hydrofluoric acid burns. Calcium gluconate works by combining with hydrofluoric acid to form insoluble calcium fluoride. This helps prevent the extraction of calcium from tissues and bones. Calcium gluconate also helps reduce deep painful burns. Calcium gluconate gel should be present whenever someone is working with hydrofluoric acid (Life Safety Associates, 2002)

Hydrofluoric acid – "Hydrofluoric Acid (HF) is one of the strongest and most corrosive acids known. Therefore, special safety precautions are necessary when using this chemical. HF is used in a variety of applications including glass etching, pickling of stainless steel, removal of sand and scale from foundry castings and as a laboratory reagent. Anyone using HF should implement the following safety measures. Most importantly, do not assume that dilute solutions do not require special precautions (Department of Environmental Health, Safety and Risk Management, 2002 ¶#1)!"

Zephiran ® - "Brand of benzalkonium chloride, NF, a mixture of alkylbenzyldimethylammonium chlorides, is a cationic quaternary ammonium surface-acting agent. It is very soluble in water, alcohol, and acetone. Zephiran® is supplied as a 1:750 aqueous solution; further dilution may be appropriate depending on usage. Aqueous solutions of Zephiran® are neutral to slightly alkaline, generally colorless, and nonstaining. They have a bitter taste, aromatic odor, and foam when shaken (Sanofi-Synthelabo, Inc., 1999, ¶#1)"

CHAPTER 2

Review of Literature

Introduction

The purpose of the literature review was to provide an examination of the toxicological effects of hydrofluoric acid. Another objective of the literature review was to provide an examination of the physical implications associated with dermal-based exposure to hydrofluoric acid**.** The body of the chapter analyzed topical-based treatment methodologies for dermal hydrofluoric acid exposure as it relates to the use of Zephiran® verses calcium gluconate. In addition, a summary of the differences between the treatment methods will be provided. Finally, determining the cost comparison between Zephiran® and calcium gluconate in the treatment of dermal exposure to hydrofluoric acid.

Toxicity of Hydrofluoric Acid

Toxicity is defined as the harmful effects that some substances or some medications have on the human body. The toxic effect of a chemical can be brief, last weeks to a few months, and in some cases result in permanent damage (University of Oxford, 2002). Hydrofluoric acid is an extremely toxic and corrosive substance that exits either as a gas, liquid, or solid (National Safety Council, 1988). Hydrofluoric acid can also be referred to as anhydrous hydrogen fluoride, aqueous hydrogen fluoride or HF-A (National Institute for Occupational Safety and Health, 2000). Hydrofluoric acid is an aqueous form of hydrogen fluoride (Lewis, 1993). Hydrofluoric acid is one of the more commonly used inorganic compounds used in industry today, and is highly corrosive. It will readily attack materials such as concrete, glass, natural rubber, and metal alloys that contain silica (Environmental Protection Agency Chemical Profile, 1987). Some unique proprieties of hydrofluoric acid are shown in Figure 2.

Figure 2 – Proprieties of Hydrofluoric Acid				
Exposure Limits:	NIOSH REL: TWA 3 ppm (2.5 mg/m^3) C 6 ppm (5 mg/m^3) [15-minute]			
	OSHA PEL: TWA 3 ppm			
Boiling Point:	67 °F	19.44 °C	292.4 K	527 R
Flammability:	Nonflammable Gas	**Lower Explosive Limit:**	N/A	
Vapor Pressure:	783 mmHg	**Upper Explosive Limit:**	N/A	
Incompatibilities:	Corrosive to metals. Will attack glass and concrete.			
Target Organs:	Eyes, skin, respiratory system, bones			
Symptoms:	Irritation eyes, skin, nose, throat; pulmonary edema; eye, skin burns; bone changes			
Exposure Routes:	Inhalation, skin absorption (liquid), ingestion (solution), skin and/or eye contact			
Physical Description:	Colorless gas or fuming liquid (below 67°F) with a strong, irritating odor.			

Hydrofluoric acid, in either a gas or liquid form can cause serious respiratory damage. Dermal destruction can occur on contact, with the possibility of causing permanent damage. This substance is often referred to as a cellular poison. A dermal overexposure to hydrofluoric acid can result in the formation of deep ulcers that are slow to heal. From an acute exposure standpoint, it is estimated that exposure to air concentrations ranging from of 50 to 250 ppm of hydrofluoric acid for five minutes can be lethal (Hathaway, Proctor, Hughes, & Fischman, 1991).

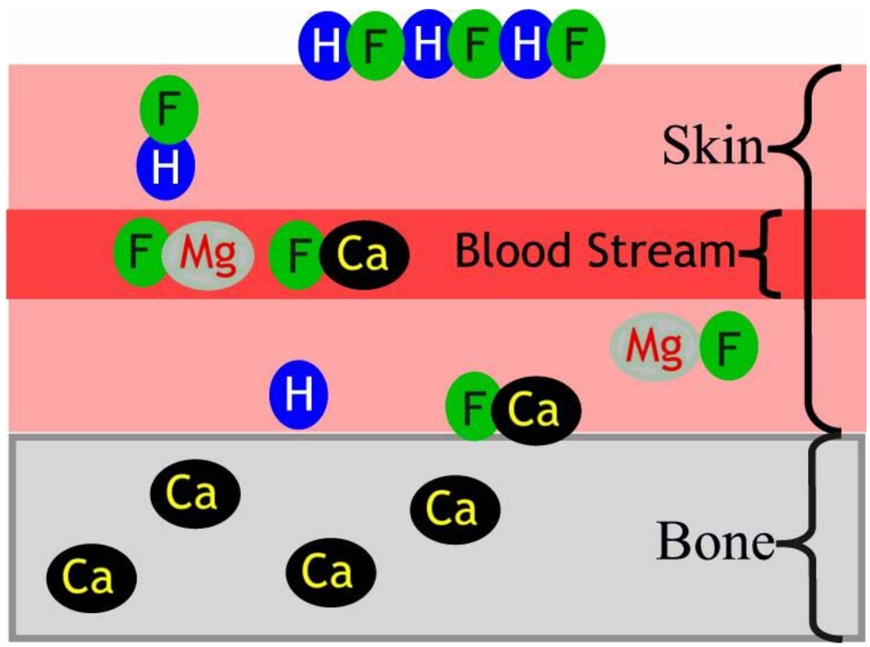
This estimation coincides with these hydrofluoric acid inhalation studies involving rats. Morris & Smith, 1982 showed that an exposure of 166 ppm for a six-hour period results in 100% lethality. In addition, Wohlslagel, Dipasquale, and Vernot (1976) found that 100% lethality also occurred in rats when they were exposed to 1,765 ppm. Since hydrofluoric acid is so toxic, no human studies can ever be performed to determine the lethal dose. However, in 1995, a laboratory technician splashed 100 mL of hydrofluoric acid on his lap and fifteen days later died as a result of the dermal exposure (University of Washington Environmental Health and Safety, 2000). Thus, it could be stated the being dermally exposed to 100 mL of hydrofluoric acid may be the lethal dose.

Physical Implications Associated with Exposure to Hydrofluoric Acid

At least two forms of injury occur when hydrofluoric acid contacts human skin or other body tissues. First, dehydration induced coagulative necrosis occurs immediately upon dermal contact. The second form of injury occurs when hydrofluoric acid penetrates tissues and begins flowing through the bloodstream and depleting the body of needed calcium and magnesium (Bracken, Cuppage, McLaury, Kirmin, & Klaassen, 1985). Once absorbed into the body, hydrofluoric acid forms insoluble fluorine salts. This rapid fluoride salt formation process starts with the fluoride ions binding with calcium and magnesium molecules in the body (American Chemical Society (ACS), 1997). The fluoride ion causes liquefaction necrosis by forming insoluble calcium fluoride salts, which result in the destruction of soft and supportive tissues. This forming process is generally associated with chemicals that have a high alkalinity value; not with chemicals that are highly acidic (ACS, 1997). Hydrofluoric acid tends to act more like a base because of the fluoride ion binding action (Boyd, 2001).

The chemical nature of hydrofluoric acid makes it difficult to neutralize. It readily absorbs into the skin, causing a tissue destruction process that may lasts for days. Flushing the exposed area with water is an effective method for removing surface acid, but does not stop the fluoride ions that have already penetrated the skin. Insufficient amounts of calcium in the body can cause hypocalcemia. Calcium is needed for cell life and cell regeneration. A bond between fluoride ions and calcium inhabits cell existence and reproduction. Hypocalcemia occurs when the heart function is diminished. This results in an abnormal heartbeat, which may ultimately result in cardiac arrhythmia. In addition to cardio related issues involving the heart the liver and kidney may also be damaged through hypocalcemia (ACS, 1997). Figure 3 illustrates how hydrofluoric acid penetrates the skin and binds with calcium and magnesium.

Figure 3 – Destruction Process of Hydrofluoric Acid



Along with its ability to bind to calcium, the fluoride ion can also bind with magnesium to cause hypomagnesemia; low magnesium levels in the blood plasma. This abnormality in the blood plasma can cause neuromuscular hyperirritability, which is the moving of muscles and nerves uncontrollably. Another issue associated with hydrofluoric acid exposure is the formation of various soluble fluorinated salts within the body. These highly toxic salts are direct cellular poisons that interfere with enzyme mechanisms. Then making these toxic salts direct cellular poisons. The recovery process from hydrofluoric acid burns is very long and painful. In some situations death has been the final outcome of being overexposed to hydrofluoric acid (ACS, 1997). Figure 4 illustrates how rapidly and deadly hydrofluoric acid can be when exposure occurs.

Figure 4 - US Fatalities Due To Hydrofluoric Acid (HF) Burns

Exposure	% Body Splashed /Body Location	Time To Death From Exposure
Unclogging pipeline hose, coupling came loose	30% / Arms, Face, and Neck	30 Minutes
Pump hose came loose	40% / Face and Chest	3 ½ Hours
Stepped on bucket containing 70% HF	8% / Right Lower Leg, Foot, and Thigh	15 ½ Hours
Splash from open drain valve	N/A % / Arms, Chest, Face, and Left Leg	4 Hours
Spill from open bucket containing 70% HF	N/A % / Chest, Neck, and Face	30 Minutes
Incorrect lockout, pump sprayed HF	N/A % / No Details	30 Minutes
Incorrect lockout, pump sprayed HF	N/A % / Severe Lung Injury	2 ½ Hours
Incorrect lockout, of HF drain line	15% / Head, Neck, Shoulders, and Arms	4 Hours
Pouring HF from drum to bucket	40% / No Details	4 Hours

Note: From Queensland Government. (2002, April). *Hydrofluoric acid poisoning and burns*. Retrieved September 25, 2002 from: http://www.whs.qld.gov.au/alerts/02i04.pdf

Treatments for Dermal Exposure to Hydrofluoric Acid

If hydrofluoric acid exposures are properly and promptly treated, the results can be successful. However, improper treatment and/or delaying the treatment process can result in permanent cell damage or death. The typical treatments (Zephiran® and calcium gluconate) focus on binding with hydrofluoric acid. The treatments also prevent further tissue destruction from the depletion of calcium and magnesium (ACS, 1997). As previously mentioned, speed is of the utmost importance when treating hydrofluoric acid dermal exposures. Honeywell, Inc. (previously known as AlliedSignal, Inc.), is the world's leading supplier of hydrofluoric acid. They publish a pamphlet titled, "Recommended medical treatment for hydrofluoric acid exposure". This company extensively researched the treatment practices and methods for dermal hydrofluoric acid exposure. Honeywell recommends flushing the affected area thoroughly with large amounts of cool running water no more than five minutes. Once rinsing is completed, apply 0.13% Zephiran® (benzalkonium chloride) solution or 2.5% calcium gluconate gel (Honeywell Inc., 1998). DuPont is another large supplier of hydrofluoric acid. Similar to Honeywell's recommendation from a cleansing standpoint, their material safety data sheet states that exposed skin should be thoroughly rinsed with tap water for five minutes. Any additional flushing is unnecessary and will delay topical treatment time. DuPont recommends applying 2.5% calcium gluconate gel to the exposed area. No duration of time was specified for the application of calcium gluconate (ACS, 1997). Mallinckrodt Baker is the third leading supplier of hydrofluoric acid. Mallinckrodt Baker's material safety data sheet for treating exposure to hydrofluoric acid advises a fifteen to twenty minute water rinse if topical treatments are not available. If treatments are available, rinse the effected area for five minutes. Followed by the application of Hyamine 1622 (tetracaine benzethonium chloride) or 0.13% Zephiran® (benzalkonium chloride) to the exposed area. Contrary to this treatment methodology, the American Chemical Society stated that Mallinckrodt Baker's material safety data sheet also provides a note to the treating physician. This note states "it has been conclusively shown that flushing the affected area with water for one minute and then massaging calcium gluconate gel into the exposed area until pain ceases is the most effective first aid treatment available" (ACS, 1997, ¶.25). This quote cannot be located in the Mallinckrodt Baker material safety data sheet. This raises a question about the validity of this source (ACS, 1997; Mallinckrodt Baker, 2001). Why this discrepancy exists is unknown, but may be answered by research that has been previously done.

In comparing the three major producers of hydrofluoric acid, it can be stated that there are inconsistencies between their treatment methods. Mallinckrodt Baker states that Zephiran® should be used to treat exposures to hydrofluoric acid (Mallinckrodt Baker, 2001). Dupont claims calcium gluconate is more productive and should be used. Honeywell, Inc. states that either calcium gluconate or Zephiran® can be used to treat dermal exposure to hydrofluoric acid. One treatment method must be more effective than that other, thus further research must be preformed to answer this question (ACS, 1997).

Dermal Treatment Studies for Hydrofluoric Acid Burns

Many studies have been performed on treatment methodologies for dermal exposure to hydrofluoric acid. Two of these studies (Bracken, Cuppage, McLaury, Kirmin, & Klaassen, 1985; Dunn, MacKinnon, Knowlden, Billmaier, Derelanko, Rusch, Naas, & Dahlgen, 1992) have used rats and pigs for models in examining which treatment is most effective. Bracken et al., 1985; McCulley, Whiting, Petitt, & Lauber, 1983; researched exposure to hydrofluoric acid and indicated that calcium gluconate was an effective treatment in treating dermal exposure to hydrofluoric acid. Two other studies (Dunn et al., 1992; McCulley, Whiting, Petitt, & Lauder, 1983) suggested that Zephiran® is a more effective method for treating dermal exposure to hydrofluoric acid.

Dermal Exposure of Pigs

Dunn et al. (1992) completed a study to determine what was the most effective treatment for dermal exposure to hydrofluoric acid. Dunn et al. (1992) took Zephiran®, 10 % calcium gluconate injection, 2.5 % calcium gluconate topical treatment, 10 % calcium acetate, and iced Hyamine, and applied them to dermal hydrofluoric acid burns on twenty-four white male adolescent pigs. Hair was removed from the back of each pig twenty-four hours prior to the application of hydrofluoric acid. The pigs were anesthetized just prior to being exposed to hydrofluoric acid at the site of the removed hair. These pigs were dermally exposed to 0.4 mL of 38% hydrofluoric acid. The hydrofluoric acid was allowed to infiltrate the pig's skin for nine, twelve, and fifteen minute time periods. After the application of the hydrofluoric acid, exposed areas were then rinsed with tap water for 1.5 minutes. The effects from dermal exposure to the pigs are shown in Figure 5 and Figure 6. Figure 5 graphically identifies how destructive and caustic hydrofluoric acid can be.

Figure 5 - Tissue samples of pig skin dermally exposed to hydrofluoric acid

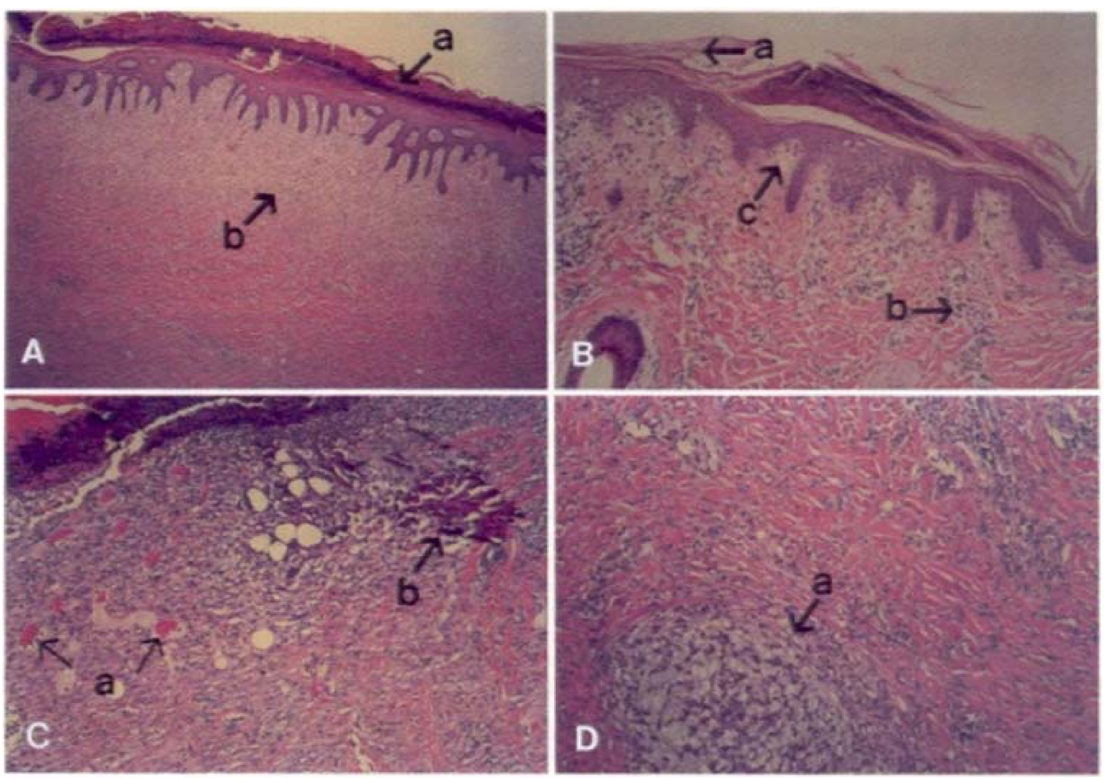


Figure 6 - Details for Figure 5

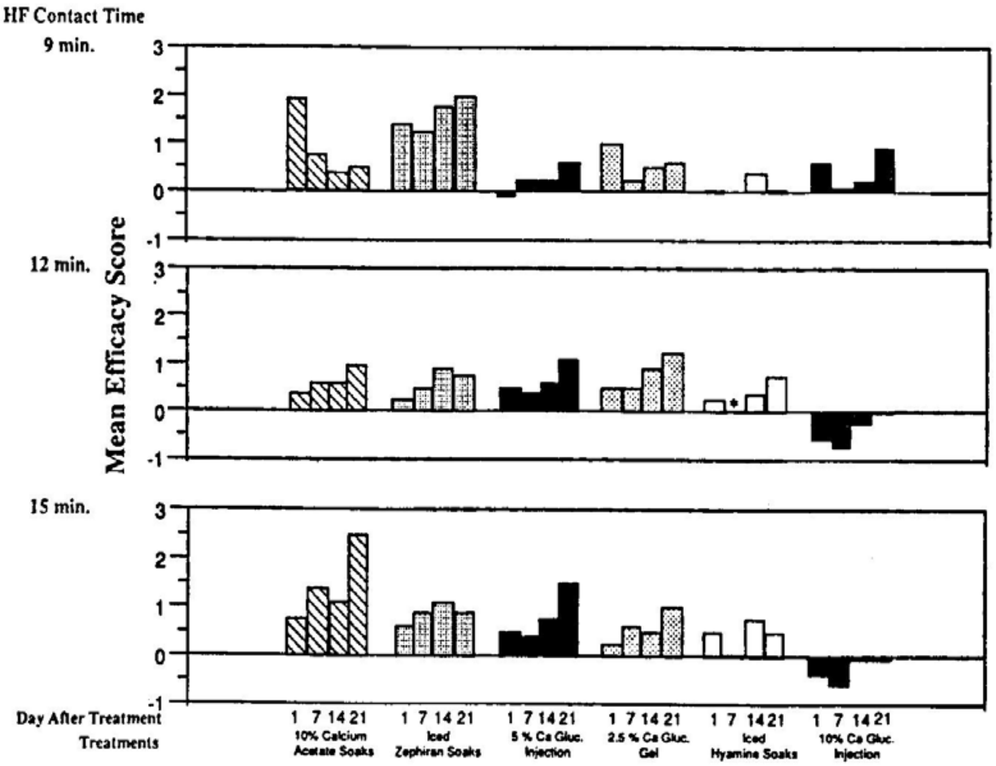
Section	Sub Section	Explanation of Detail
A	a	Epidermal inflammation-is the swelling of the first layer of skin.
	b	Dermal connective tissue necrosis-is death of cells in the second layer of skin that bind tissues together
B	a	Epidermal hyperkeratosis-is the decomposing of the first layer of skin.
	b	Sub dermal chronic inflammation-is swelling in the second layer of skin
	c	Dermal connective tissue necrosis-is death of cells in the second layer of skin that bind tissues together
C	a	Sub dermal acute hemorrhage-is bleeding in the deepest layer of skin
	b	Sub dermal mineralization-is the build up of bile salts in the deepest layer of skin
D	a	Sub dermal adipose tissue necrosis-is the death of fat in the form of triglycerides in the layer of skin that comes in contact with the bone

Note: From Dunn, B.J., MacKinnon, M.A., Knowlden, N.F., Billmaier, D. J., Derelanko, M.J., Rusch, G.M., Naas, D.J. Dahlgen, R.R. (1992). Hydrofluoric acid dermal burns. *Journal of Occupational Medicine*. *34*, (9) 907. Permission Given.

Figure 6 defines all the medical terminology stated in figure 5. Figure 5 and 6 identify the significance on how important it is to understand and recognize how toxic and corrosive hydrofluoric acid can be. (Dunn et al., 1992)

The study was completed to determine what the most effective treatment for dermal exposure to hydrofluoric acid. Pigskin was used for a model; the findings of this study are graphically represented in Figure 7. Figure 7 shows the mean efficacy scores of the different treatments that were used in the experiment. The pig study indicated that Zephiran® is the most effective treatment for short-term exposure to hydrofluoric acid. 2.5 % calcium gluconate is the most effective treatment for long-term exposure to hydrofluoric acid. It should be noted that 10 % calcium acetate soaks were presented as being the most effective treatment method for a hydrofluoric acid exposure period of fifteen minutes. The pig study also indicated that topical treatments were more effective than injection treatments (Dunn et al., 1992).

Figure 7 Mean efficacy scores for HF exposed skin receiving various treatments



Note: From Dunn, B.J., MacKinnon, M.A., Knowlden, N.F., Billmaier, D. J., Derelanko, M.J., Rusch, G.M., Naas, D.J. Dahlgen, R.R. (1992). Hydrofluoric acid dermal burns. *Journal of Occupational Medicine*. *34*, (9) 905. Permission Given.

Dermal Exposure of Rats

An experimental study by Bracken, Cuppage, McLaury, Kirmin, and Klaassen (1985) was performed to determine what treatment was most effective for dermal exposure to hydrofluoric acid. White male Sprage Dawley rats weighing between 200 to 300 grams were used for this study. Forty-eight hours prior to this experiment, the hair on the hind legs of rats was removed. The rats were sedated orally and given similar amounts of hydrofluoric acid. Two eye drops of 70% hydrofluoric acid were put on the hind legs of each rat. After the placement of hydrofluoric acid, the exposed areas were then rinsed with tap water for five minutes. In this study Zephiran®, calcium gluconate, A+D ointment, aloe gel, and magnesium ointment were applied to the areas that were exposed to hydrofluoric acid (Bracken et al., 1985).

The results of the Bracken et al. (1985) study indicated that dermal injury from the hydrofluoric acid exposure occurred instantaneously in rats. Figure 8 shows the efficiency of each treatment that was used in this experiment. It illustrates the treatment method verses the size of the surface area during a six, twenty-four, and forty-eight hour period. The 2.5% calcium gluconate (CaG) had a 4% decrease in surface area between hour 6 and hour 24. What is remarkable is that there was a 40% decrease in surface areas between the 24-hour period and the 48-hour period when using calcium gluconate. This study indicated that calcium gluconate is the most effective treatment in decreasing and delaying hydrofluoric acid burn development. The study also indicated that Zephiran® is not effective in treating dermal exposure to hydrofluoric acid (Bracken et al., 1985).

Figure 8: Efficiency of topical burn treatments at various periods after HF application

Effectiveness of Topical Burn Treatments at Various Times After HF Application

Treatment*	Surface Area, mm²†		
	6 hr	24 hr	48 hr
HF + H_2O	267 ± 9.6 (25)	254 ± 18.4 (12)	170 ± 11.8 (12)
HF + CaG	161 ± 8.0 (20)‡	154 ± 12.7 (10)‡	94 ± 6.8 (10)‡
HF + Zeph	337 ± 15.0 (15)‡	295 ± 40.8 (5)	210 ± 25.9 (5)
HF + aloe	247 ± 9.8 (15)	226 ± 16.9 (5)	128 ± 5.5 (4)
HF + A+D	322 ± 19.7 (10)§	266 ± 5.4 (3)	178 ± 20.5 (3)

Note: From Bracken, W. M., Cuppage, F., McLaury, R.L., Kirmin, C., & Klaassen, C. (1985). Comparative effectiveness of topical treatments for hydrofluoric acid burns. *Journal of Occupational Medicine. 27* (10) 736. Permission Given.

Comparing Dermal Treatment Studies for Hydrofluoric Acid Burns

The treatment of hydrofluoric acid burns in the workplace is necessary to minimize the extent of tissue damage. Bracken et al. (1985) and Dunn et al. (1992) experimented with different treatment methods for skin that was exposed to hydrofluoric acid. The study by Dunn et al. (1992) stated that Zephiran® was the most effective treatment for short-term exposure to hydrofluoric acid but was not as effective for long-term exposure. Bracken et al. (1985) concluded that calcium gluconate is the most effective for treating skin that had been exposed to hydrofluoric acid. Bracken et al. (1985) also indicated that Zephiran® is not an effective treatment for dermal exposure to hydrofluoric acid. The results obtained from the Bracken et al. (1985) and Dunn et al. (1992) studies suggested that calcium gluconate was overall the most effective treatment in decreasing and delaying hydrofluoric acid burns. These two studies (Bracken et al., 1985 & Dunn et al., 1992) were conducted on laboratory animals, not on any human subjects.

A characteristic that appears to be overlooked by both the Bracken et al. (1985) and Dunn et al. (1992) studies was the comparison of rat and pig skin to that of human skin. A dermal study tried to use integrins to obtain a better understanding of wound healing and vesication (Zhang & Monteiro-Riviere, 1997). The study performed by Zhang and Monteiro-Riviere (1997) revealed that pigskin has similar characteristics to human skin. Thus indicating that pigskin is an accurate model to use when evaluating the potential toxic effects on human skin (Zhang & Monteiro-Riviere, 1997). Another dermal study tried to identify penetration and permeation of griseofulvin across rat and human skin (Ritschel & Hussain, 1988). Ritschel and Hussain (1988) identified that dimethylacetamide and diethylene glycol monoethylether ointment is absorbed faster through rat skin than human skin. The study determined that human skin is much less permeable than rat skin (Ritschel & Hussain 1988). An analysis of the previously mentioned hydrofluoric acid dermal exposure studies (Dunn et al., 1992 & Bracken et al., 1985), as well as two skin compassion studies (Zhang & Monteiro-Riviere, 1997 & Ritschel & Hussain, 1988), concludes that the results of the pig study performed by Dunn et al. (1992) was more accurate because pig skin is similar to that of human skin. This gives more validity to the statement that calcium gluconate is more efficient at treating dermal exposure to hydrofluoric acid (Dunn et al., 1992).

Cost Comparison Between Calcium Gluconate and Zephiran®

A cost comparison analysis is the breaking down of costs between two or more items using some form of common criteria. These criteria could constitute market cost, availability, shipping costs, storage costs, or even labor costs. A cost comparison model can be derived from the criteria collected. The cost comparison model identifies the criteria for each item analyzed and reports the costs separately using a form of visual illustration (Dictionary.com, 1997). The cost comparison model used in this review of literature will be cost versus accessibility. One reason for selecting this model was because cost plays an important roll when budgeting for the future. Another reason is that exposure to hydrofluoric acid can usually happen in any number of locations in a facility, thus it is important that the treatment can be available in different places. In the case of medical treatments, a cost comparison analysis should only be the determining factor when different treatment methods demonstrate the same results during and after treatment methodologies. When two separate compounds are used to treat the same chemical exposure it is vital the more efficient treatment method is used.

Benzalkonium chloride, more commonly know as Zephiran®, is a quaternary ammonium compound and is mainly used as a medical disinfecting agent (University of Oxford, 2002). In addition to treating burns associated with exposure to hydrofluoric acid, Zephiran® is generally used an antiseptic. It treats mouth ulcers, gum disease, and other infections that occur in the mouth and throat (Xrefer, 2002). Zephiran® also is an ingredient that is put into creams, paints, deodorants, mouthwashes, aftershaves and lotions for treating a variety of dermal skin disorders (Xrefer, 2002 & Total Skin Care, 2002).

Another cost benefit of using Zephiran® than any other ammonium compounds is that Zephiran® is a non-prescription drug, and is recommended for use in the United States (Honeywell Inc., 1998). On average one 8oz (236 mL) container of aqueous benzalkonium chloride costs about $24.19 (Westbury Pharmacy, 2002). With all the beneficial applications that Zephiran® provides it would indicate that benzalkonium chloride is a very cost effective chemical in treating skin disorders, oral infections, and chemical burns. Using iced benzalkonium chloride has some very beneficial advantages. It reduces local pain and slowing the rate of tissue destruction. In addition Zephiran® slows down the penetration of the fluoride ion into the skin tissues and blood stream from dermal exposure to hydrofluoric acid. Unfortunately there has been evidence indicating even low concentrations of Zephiran® can cause severe allergic reactions in humans (The American Academy of Optometry, 2002).

It is hard to associate a cost to pain. The process used for treating hydrofluoric acid burns is a painful process, despite the method of treatment. It is known that prolonged immersion in iced benzalkonium chloride has lead to frost bite and cold discomfort due to the chilling of benzalkonium chloride prior to treatment. It should be noted that Zephiran® should not be used on the faces, ears, eyes, or other areas that contain sensitive tissues due to its irritating nature. Another negative cost associated with using Zephiran® is the amount that is needed during in the treatment process (Honeywell Inc., 1998). No data or information could be found on the total amount used during any treatment method process. It should be noted that two studies (Dunn et al., 1992 & Bracken et al., 1985) indicated that the iced Zephiran® soaked bandages were changed every two to four minute. This would indicate that excessive amounts could be needed when treating larger burns.

Calcium gluconate gel is a water-soluble lubricant that is mainly used for treating hydrofluoric burns. This treatment is convenient to carry and can be used to initially treat small burns and can relieve dermal pain. Calcium gluconate is useful for treating hydrofluoric acid burns on the face, ears, mouth, and eyes, because it is not an irritating agent (Honeywell Inc., 1998). Some of the general benefits with using calcium gluconate are identified. They are:

- How easy it can be used
- Can be self administered if needed
- Can be applied immediately to a burn from hydrofluoric acid
- It is painless when applied to the burned area
- Calcium gluconate produces no risk of increasing mussel tension or tissue stress
- The methods of administering include topical, opthalmical, and injection able

- It reduces the possibility of acquiring hypocalcemia
- No specialized equipment is needed

Another major cost benefit associated with calcium gluconate is the mixing your own solution. Almost every local pharmacy can make up calcium gluconate solution without a doctors prescription, and is considerably cheaper than purchasing the treatment (Segal, 1997).

The cost of calcium gluconate varies from supplier to supplier as seen in figure 9:

Figure 9 – Cost Comparison of Calcium Gluconate Suppliers

Suppliers Name	Container Amount	Cost for Container	Shelf Life	Storage	References
Life Safety Associates	25 grams	$31.95	2 year	Refrigeration	Life Safety Associates, 2002
Attard's Minerals	60 grams	$40.00	2 year	Room Temperature	Attard's Minerals, 2002
Pharmascie nce Inc.	25 grams	$27.55	N/A	N/A	ORS Emergency Response, 2001
Cameron Medical	25 grams	$32.82	N/A	N/A	ORS Emergency Response, 2001

The average cost of a 25-gram tube of calcium gluconate is $27.25 this does not take into consideration shipping and handling costs. There are some different of options, as it relates to the storage of calcium gluconate. Some producers state that room temperature is sufficient and other manufactures stress that calcium gluconate must be stored in a refrigerated unit (Life Safety Associates, 2002 & Attard's Minerals, 2002).

A cost comparison should not just analyze how much a treatment or medicine costs. The analysis should consider availability, side effects, and other pertinent information that may be important. The cost difference between calcium gluconate and Zephiran®, is extremely large. Zephiran® costs on average $4.84 per 25 grams

(Westbury Pharmacy, 2002) and calcium gluconate costs about $27.25 per 25 grams (Life Safety Associates, 2002 & Attard's Minerals, 2002 & ORS Emergency Response, 2001). It should be noted that calcium gluconate could be made by the local pharmacy for a lower cost. Besides feasibility, treatment effectiveness and attainability are two very important consideration factors. One negative aspect in using Zephiran® is it cannot be applied to the face, ears or other sensitive tissues. Calcium gluconate can be applied to the face, ears and other sensitive tissues without the occurrence of any negative effects. Another benefit is that calcium gluconate can be stored at room temperature and transported without any special considerations. Zephiran® must be kept in a frozen or refrigerated storage compartment because of the treatment method. After identifying all the cost comparison factors between Zephiran® and calcium gluconate, it can be stated that calcium gluconate may cost more but its benefits do pay for themselves (Honeywell Inc., 1998). One benefit is that calcium gluconate can be stored at room temperature another benefit is that calcium gluconate can be made at the local pharmacy, which reduces the cost significantly. The treatment that is most effective and beneficial in treating hydrofluoric acid burns should be used despite the cost of the medicine or treatment methodologies.

Summary

Hydrofluoric acid is a very unique and complex chemical that needs to be used with extreme caution. Overexposure to hydrofluoric acid can lead to serious injury and even death. There are many ways that an overexposure to this chemical can happen. The need for proper training, as well as other protective measures is essential in preventing injuries and illnesses from exposure to hydrofluoric acid.

Knowing what method of treatment to use for an exposure to hydrofluoric acid may mean the difference between life and death. Studies performed by Bracken et al. (1985) and Dunn et al. (1992) indicated that calcium gluconate was by far was the most effective treatment for long-term dermal exposure to hydrofluoric acid. In addition, Dunn et al. (1992) indicated that Zephiran® was the most effective treatment for short-term dermal exposure to hydrofluoric acid. Since Bracken et al. (1985) did not take into consideration the skin differences between rats and humans, the Bracken et al. (1985) study may not truly indicate the best dermal treatment for humans who are exposed to hydrofluoric acid. When considering the available research based information, Zephiran® appeared to be the best method for short-term dermal exposure to hydrofluoric acid and calcium gluconate showed evidence as being the most effective treatment for long-term dermal exposure. When applied to the operational aspect of an organization that utilizes hydrofluoric acid in its processes, this finding would not only determine the different forms of dermal treatment to be stocked, but also influence the training that associated employees would receive.

CHAPTER 3

Methodology

Introduction

The goal of this study was to evaluate Zephiran® and calcium gluconate in the treatment process for dermal exposure to hydrofluoric acid. The purpose of this chapter was to identify how the researcher accomplished this activity. The main objective of this study was to conduct an evaluation of policies that relate to treatment methodologies for dermal exposure to hydrofluoric acid. More specifically, to determine whether Zephiran® or calcium gluconate was most desired by industry and universities today in treating dermal-based exposures to hydrofluoric acid. The researcher used the following methodology to complete this study.

Method of Study

The researcher preformed a literature review on the toxicological effects of hydrofluoric acid. This information was used to understand how the human body reacts when exposed to hydrofluoric acid. The researcher examined the physical implications associated with dermal-based exposure to hydrofluoric acid through a literature review. This information was used to obtain an understanding of how the human body reacts when exposed to hydrofluoric acid. Next the researcher analyzed topical-based treatment methodologies for dermal hydrofluoric acid exposure. The researcher used Zephiran® and calcium gluconate as the two topical-based treatments. Zephiran® and calcium gluconate were used in this study because they have been used in previous studies. Through a literature review, the researcher determined the cost comparison between Zephiran® and calcium gluconate. This allowed users of Zephiran® or calcium gluconate to acquire a better understanding of costs associated with using one treatment over the other. The last goal was to determine which topical based treatment, Zephiran® or calcium gluconate was most desired by industry and universities today in treating dermal-based exposures to hydrofluoric acid.

To accomplish this the researcher identified companies and universities that use hydrofluoric acid in their manufacturing process and laboratory studies. The researcher obtained policies and procedures from ten companies and ten universities. The policies and procedures were obtained through the Internet. The Internet was used because it was the most easiest duplicated for locating treatment policies and procedures. Next the researcher analyzed each set of policies and procedures to determine what treatment methodologies were most preferred for treating exposure to hydrofluoric acid.

During the analysis process, three items were identified to determine which treatment methods were most preferred by companies and universities. The first criteria identified the length of time that the exposed area should be rinsed with water. This information was important because in most cases people exposed to hydrofluoric acid delay topical treatment by rinsing under a safety shower for to long. The second criteria was to determine if the policies or procedures discussed removing all contaminated clothing immediately after being exposed to hydrofluoric acid. This helps clarity if the companies and/or universities understand the importance of removing clothing once it has been contaminated. This question was important because the clothing acts as a barrier between the hydrofluoric acid and the skin. The third and final criteria identified whether Zephiran® or calcium gluconate was the preferred method of treatment. The policies and procedures indicated whether to use Zephiran® or calcium gluconate in treatment method. The data and information that was collected in the literature review was compared to the information gathered from these policies. The results and data collected from the answered criteria are detailed in the next chapter.

CHAPTER 4

Results of Study

Introduction & Discussion

The purpose of this chapter was to report the results of study. Toxicological effects and physical implications associated with dermal-based exposure to hydrofluoric acid were investigated. Topical-based treatment methodologies for dermal hydrofluoric acid exposure as it relates to the use of Zephiran® verses calcium gluconate was identified. In addition, results from a cost comparison between Zephiran® and calcium gluconate in the treatment of dermal exposure to hydrofluoric acid was delineated in this chapter. Information on which topical based treatment (Zephiran® or calcium gluconate) is most desired by industry and universities today in treating dermal-based exposures to hydrofluoric acid is delineated in this chapter as well. This was accomplished by identifying companies and universities that used hydrofluoric acid in their manufacturing process and laboratory studies. Once identified the criteria from each treatment policy was noted and organized per company and university.

Using the methodology that was delineated in Chapter 3, an assessment of treatment policies was conducted.

Goal #1

Identify the toxicity and physical properties of hydrofluoric acid.

- Hydrofluoric acid can also be referred to as anhydrous hydrogen fluoride, aqueous hydrogen fluoride or HF-A (National Institute for Occupational Safety and Health, 2000).

- Hydrofluoric acid is an extremely toxic and corrosive substance that can exit either as a gas, liquid, or solid form (National Safety Council, 1988).
- Hydrofluoric acid will deteriorate materials such as concrete, glass, natural rubber, and metal alloys that contain silica (EPA Chemical Profile 1987).
- Hydrofluoric acid is a corrosive substance that exits either as a gas, liquid, or solid that causes visible destruction or permanent changes in human skin tissue at the site of contact (National Safety Council, 1988).
- From an acute exposure standpoint, it is estimated that exposure to air concentrations ranging from of 50 to 250 ppm of hydrofluoric acid for five minutes can be lethal (Hathaway, Proctor, Hughes, & Fischman, 1991).
- A dermal overexposure to hydrofluoric acid can result in the formation of deep ulcers that are slow to heal.
- In some cases these burns can be life threatening, specialized first aid and medical treatment is required for any exposure to hydrofluoric acid (Honeywell Inc., 1998).

- Some unique properties of hydrofluoric acid are shown in Figure 10

Figure 10 – Proprieties of Hydrofluoric Acid

Boiling Point:	67 °F	19.44 °C	292.4 K	527 R
Flammability:	Nonflammable Gas	**Lower Explosive Limit:**	N/A	
Vapor Pressure:	783 mmHg	**Upper Explosive Limit:**	N/A	
Incompatibilities:	Corrosive to metals. Will attack glass and concrete.			
Target Organs:	Eyes, skin, respiratory system, bones			
Symptoms:	Irritation eyes, skin, nose, throat; pulmonary edema; eye, skin burns; bone changes			
Exposure Routes:	Inhalation, skin absorption (liquid), ingestion (solution), skin and/or eye contact			
Physical Description:	Colorless gas or fuming liquid (below 67°F) with a strong, irritating odor.			

Goal #2

Examine the physical implications associated with dermal-based exposure to hydrofluoric acid**.**

- Hydrofluoric acid reacts with the body in two ways: (Bracken, Cuppage, McLaury, Kirmin, & Klaassen, 1985)
    - First, dehydration induced coagulative necrosis occurs immediately upon dermal contact.
    - The second injury occurs when hydrofluoric acid penetrates tissues and starts to bind with calcium and magnesium, causing internal organ failure.

Goals #3

Determine topical-based treatment methodologies for dermal hydrofluoric acid exposure as it relates to the use of Zephiran® verses calcium gluconate.

- Dunn et al. (1992) stated that Zephiran® was the most effective treatment for short-term exposure to hydrofluoric acid.

- Dunn et al. (1992) concluded that Zephiran® was not as effective for long-term exposure.
- Bracken et al. (1985) concluded that calcium gluconate is the most effective for treating skin that had been exposed to hydrofluoric acid.
- Bracken et al. (1985) also indicated that Zephiran® is not an effective treatment for dermal exposure to hydrofluoric acid.
- The results obtained from the Bracken et al. (1985) and Dunn et al. (1992) studies suggested that calcium gluconate was overall the most effective treatment in decreasing and delaying hydrofluoric acid burns.

Goal #4

Determining the cost comparison between Zephiran® and calcium gluconate in the treatment of dermal exposure to hydrofluoric acid.

- Figure 11 identifies a cost comparison between Zephiran® and calcium gluconate.

Figure 11 - Cost Comparison Model Between Zephiran® & Calcium gluconate

Treatments	**Cost per 25 Grams**	**Storage**	**Side Effects**
Zephiran®	$4.84	Must Be Refrigerated	Can Not Use On Sensitive Tissue/Known Allergen
Calcium gluconate	$27.25	Room Temperature is Adequate	Can Be Used On Sensitive Tissue/Not An Allergen

Goal #5

Determine which topical based treatment, Zephiran® or calcium gluconate, is most desired by industry and universities today in treating dermal-based exposures to hydrofluoric acid.

- The following tables summarize the information that was collected from company and university treatment policies for exposure to hydrofluoric acid. This information will be delineated and tabulated on the following pages:

Figure 12 - Washing Times for Universities

Source of Polices:	**Policies Rinsing Time Description:**	**References:**
Boston	Wash area for at least 5 minutes	University of Boston, 2002
California-Berkeley	Wash area for 5 minutes	University of California-Berkeley, 1997
California-Davis	Wash area for 5 minutes	University of California-Davis, 2000
California-Los Angels	Wash area for 15 minutes	University of California-Los Angels, 1997
Delaware State	Wash area for at least 1 minute	University of Delaware, 2002
Louisiana State	Wash area for a minimum of 15 to 20 minutes	University of Louisiana State, 2001
Northwestern	Wash area for a maximum of 5 minutes	University of Northwestern, 2001
South Carolina State	Wash area for a minimum of 5 minutes	University of South Carolina, 2000
Washington State	Wash area for a maximum of 5 minutes	University of Washington, 2000
Western Australia	Wash area for a minimum of 10 minutes	University of Western Australia, 1999

Figure 13 - Clothing Statement in University Policies

Source of Polices:	**Remove clothing was stated in policy:**	**References:**
Boston	Not Mentioned in Policy	University of Boston, 2002
California-Berkeley	Yes, Stated in Policy	University of California-Berkeley, 1997
California-Davis	Yes, Stated in Policy	University of California-Davis, 2000
California-Los Angels	Yes, Stated in Policy	University of California-Los Angels, 1997

Delaware State	Yes, Stated in Policy	University of Delaware, 2002
Louisiana State	Yes, Stated in Policy	University of Louisiana State, 2001
South Carolina State	Yes, Stated in Policy	University of South Carolina, 2000
Northwestern	Yes, Stated in Policy	University of Northwestern, 2001
Washington State	Yes, Stated in Policy	University of Washington, 2000
Western Australia	Yes, Stated in Policy	University of Western Australia, 1999

Figure 14 - Treatment Methods Stated in University Policies

Source of Polices:	Treatment Method		References:
	% Concentration	Suggested Treatment	
Boston	0.13 % & 2.5 %	Zephiran® & Calcium gluconate	University of Boston, 2002
California-Berkeley	N/A	Calcium gluconate	University of California-Berkeley, 1997
California-Davis	2.5 %	Calcium gluconate	University of California-Davis, 2000
California-Los Angels	N/A	Calcium gluconate	University of California-Los Angels, 1997
Delaware State	2.5 %	Calcium gluconate	University of Delaware, 2002
Louisiana State	0.13 %	Zephiran®	University of Louisiana State, 2001
Northwestern	N/A	Calcium gluconate	University of Northwestern, 2001
South Carolina State	N/A	Calcium gluconate	University of South Carolina, 2000
Washington State	N/A	Calcium gluconate	University of Washington, 2000
Western Australia	N/A	Calcium gluconate	University of Western Australia, 1999

Figure 15 - Washing Times for Companies

Source of Polices:	Policies Rinsing Time Description:	References:
AGA Gas, Incorporated	No time specified	AGA Gas, Incorporated, 2000
Air Products	Wash area for at least 5 minutes	Air Products, 1999
DuPont	Wash area for 5 minutes	DuPont, 2001
EM Industries Incorporated	Wash area for at least 15 minutes	EM Industries Incorporated, 2001

Honeywell Inc.	Wash area for a minimum of 5 minutes	Honeywell Inc., 2002
Kendon Chemical & MNFG Corporation	Wash area for at least 20 minutes	Kendon Chemical & MNFG Corporation, 2000
Mallinckrodt Baker, Inc.	Wash area for a minimum of 15 minutes	Mallinckrodt Baker, Inc., 2001
Omega Chemistries, Incorporated	Wash area for a minimum of 5 minutes	Omega Chemistries, Incorporated, 1999
Regions Hospital Emergency Medical Services	Wash area for 5 minutes	Regions Hospital Emergency Medical Services, 2000
WorkCover Corporation	No time specified	WorkCover Corporation, 2002

Figure 16 -Clothing Statement in Company Policies

Source of Polices:	**Remove clothing was stated in policy:**	**References:**
AGA Gas, Incorporated	Yes, Stated in Policy	AGA Gas, Incorporated, 2000
Air Products	Yes, Stated in Policy	Air Products, 1999
DuPont	Yes, Stated in Policy	DuPont, 2001
EM Industries Incorporated	Yes, Stated in Policy	EM Industries Incorporated, 2001
Honeywell Inc.	Yes, Stated in Policy	Honeywell Inc., 2002
Kendon Chemical & MNFG Corporation	Yes, Stated in Policy	Kendon Chemical & MNFG Corporation, 2000
Mallinckrodt Baker, Inc.	Yes, Stated in Policy	Mallinckrodt Baker, Inc., 2001
Omega Chemistries, Incorporated	Yes, Stated in Policy	Omega Chemistries, Incorporated, 1999
Regions Hospital Emergency Medical Services	Yes, Stated in Policy	Regions Hospital Emergency Medical Services, 2000
WorkCover Corporation	Yes, Stated in Policy	WorkCover Corporation, 2002

Figure 17 - Treatment Methods Stated in Company Policies

Source of Polices:	**Treatment Method**		**References:**
	% Concentration	**Suggested Treatment**	
AGA Gas, Incorporated	N/A	Calcium gluconate	AGA Gas, Incorporated, 2000
Air Products	0.13 %& 2.5 %	Zephiran® & Calcium gluconate	Air Products, 1999
DuPont	2.5 %	Calcium gluconate	DuPont, 2001

EM Industries Incorporated	N/A	Zephiran® & Calcium gluconate	EM Industries Incorporated, 2001
Honeywell Inc.	0.13 %& 2.5 %	Zephiran® & Calcium gluconate	Honeywell Inc., 2002
Kendon Chemical & MNFG Corporation	2.5 %	Calcium gluconate	Kendon Chemical & MNFG Corporation, 2000
Mallinckrodt Baker, Inc.	0.13 %& 2.5 %	Zephiran® & Calcium gluconate	Mallinckrodt Baker, Inc., 2001
Omega Chemistries, Incorporated	0.13 %& 2.5 %	Zephiran® & Calcium gluconate	Omega Chemistries, Incorporated, 1999
Regions Hospital Emergency Medical Services	Iced & N/A	Zephiran® & Calcium gluconate	Regions Hospital Emergency Medical Services, 2000
WorkCover Corporation	N/A	Calcium gluconate	WorkCover Corporation, 2002

Discussion

Collecting all the data from the different treatment policies indicated that calcium gluconate is the most noted treatment for dermal exposure to hydrofluoric acid. It can also be stated that calcium gluconate is most cost effective than Zephiran® because it can be made cheaper by a farm iciest. Calcium gluconate is more cost effective because of its shelf life and storage conditions are longer and less stringent than Zephiran®.

In analyzing the rinsing time periods, the periods had a range between 1 minute and 20 minutes. This range of time conflicts with the issue on how long treatment should be applies. The longer treatment methods are delayed the more time is given for hydrofluoric acid to cause dermal destruction. A large majority of the treatment policies indicated that clothing contaminated with hydrofluoric acid should be removed immediately. All treatment policies were identified and studied to determine which topical` based treatment, Zephiran® or calcium gluconate is most desired by industry and universities today in treating dermal-based exposures to hydrofluoric acid. Out of the 20 samples taken 95% stated that calcium gluconate may be used fro treating dermal exposure to hydrofluoric acid. Calcium gluconate by far was the more desired treatment method than Zephiran® as it relates to treating dermal exposure to hydrofluoric acid.

CHAPTER 5

Conclusion & Recommandations

Introduction

The purpose of this study was to compare the use of calcium gluconate and Zephiran® for the treatment of dermal based hydrofluoric acid exposure. In order to accomplish this, pertinent literature was reviewed in addition to analyzing policies and procedures for treating dermal exposure to hydrofluoric acid. Discussion, conclusions and recommendations are delineated in this chapter.

Discussion

In order for the reader to follow the researcher thought pattern the previous chapters are summarized. To summarize this study a restatement of the problem, methods used, and major findings are provided.

Restatement of the Problem

The purpose of this study was to compare two treatment methodologies that were used for treating dermal exposure to hydrofluoric acid. Calcium gluconate and Zephiran® were the two treatments used for comparison. In order to accomplish this a review of pertinent literature was conducted. An analysis of policies and procedures for treating dermal exposure to hydrofluoric acid was conducted. The policies and procedures were obtained from a number of different universities and industries that use hydrofluoric acid in their experiments and manufacturing processes.

Methods and Procedures

The study investigated the toxicological effects and physical implications that were associated with dermal exposure to hydrofluoric acid. This was conducted by reviewing pertinent literature in addition to analyzing topical-based treatment methodologies for dermal exposure to hydrofluoric acid. Zephiran® and calcium gluconate were the two treatment methodologies studied. A cost comparison between Zephiran® and calcium gluconate was preformed. The cost of Zephiran® and calcium gluconate was determined by identifying suppliers of the two treatments. The last objective was to determine which topical based treatment, Zephiran® or calcium gluconate, was most desired in universities and industry today. This was conducted by identifying which universities and business used hydrofluoric acid in their production and experimental processes. Finally, the policies and procedures were obtained for analysis. All the policies and procedures were acquired from Internet sites.

Major Findings

In regards to the toxicological effects and physical implications associated with exposure to hydrofluoric acid, it can be stated that hydrofluoric acid is very toxic to humans (EPA Chemical Profile, 1987). This is important to know because it identifies that hydrofluoric acid is dangerous and should be handled with care. By knowing the dangers of hydrofluoric acid management can properly set up engineering and administrative controls for hydrofluoric acid. From the analysis of Zephiran® verses calcium gluconate in the treatment of dermal exposure to hydrofluoric acid, calcium gluconate was more effective than Zephiran® (Dunn et al., 1992). This is important to know because the most effective hydrofluoric acid dermal burn treatment needs to be used. When determining which treatment is more cost effective benefits like storage, easy of application, and transportation issues need to be taken into consideration. Thus calcium gluconate may have a larger direct cost than Zephiran®, but benefits such as storage, easy application, and ease of transportation make calcium gluconate more cost effective than Zephiran®. In determining which topical based treatment, Zephiran® or calcium gluconate, is most desired in industry and university settings an analysis of pertinent policies and procedures was conducted. The results of the analysis indicated that 80% of universities suggested calcium gluconate for the treatment. Ten out of ten industries indicated calcium gluconate for the treatment of dermal exposure to hydrofluoric acid. Out of the ten industry policies analyzed 60% indicated that Zephiran® could be used for treating dermal exposure to hydrofluoric exposure if calcium gluconate is not available for treatment.

Conclusion

In conclusion, this study compared the use of calcium gluconate and Zephiran® for the treatment of dermal based hydrofluoric acid exposure. Throughout this study pertinent literature was reviewed in addition to analyzing policies and procedures for treating dermal exposure to hydrofluoric acid. The researcher identified the toxicological effects and physical implications associated with dermal-based exposure to hydrofluoric acid. Information ascertained form pertinent literature indicated that hydrofluoric acid is an extremely toxic and corrosive substance that can exit either as a gas, liquid, or solid form (National Safety Council, 1988). The researcher can conclude that hydrofluoric acid should be handled with extreme causation.

The information delineated in the studies (Bracken et al., 1985 & Dunn et al., 1992) showed that calcium gluconate is a better treatment than Zephiran® when treating skin that has been exposed to hydrofluoric acid. Topical-based treatment methodologies for dermal hydrofluoric acid exposures were analyzed. For this analysis it can be concluded that calcium gluconate may be more effective than Zephiran® in treating dermal exposures to hydrofluoric acid. A cost comparison between the two treatments indicated that calcium gluconate is a more cost effective than Zephiran®. Thus, it can be concluded that calcium gluconate may be less expensive than Zephiran® depending upon were the treatment is purchased. A random sampling method was used in determining which topical based treatment was most desired by industry and universities today.

Calcium gluconate was identified as the main treatment that industries and universities use for treating exposure to hydrofluoric acid. From the random sample taken 95% of the samples suggested calcium gluconate for the treatment of exposure to hydrofluoric acid. From this information it can be concluded that calcium gluconate maybe used more than Zephiran® for the treatment of dermal exposure to hydrofluoric acid.

In summary, a review of pertinent literature it can be stated that calcium gluconate may be more effective at treating dermal burns that occur from exposure to hydrofluoric acid. Based on the previous stated information it can be conclude that calcium gluconate is more cost effective than Zephiran®. Calcium gluconate is more effective in treating dermal exposure to hydrofluoric acid than Zephiran®. From previously stated data it can be stated that universities and industries use calcium gluconate more than Zephiran® when treating dermal exposure to hydrofluoric acid.

Recommendations Related to this Study

The researcher recommends that proper emergency policies need to be in place prior to using hydrofluoric acid in any amount. Hydrofluoric acid has been identified as a corrosive substance, thus personal protective equipment must be worn when handling hydrofluoric acid. Emergency eyewash and safety showers should be located in area where hydrofluoric acid is used. Gloves, goggles, face shield, chemical resistant apron, and rubber boots should be worn when handling hydrofluoric acid.

After reviewing pertinent literature on treatment methodologies for dermal exposure to hydrofluoric acid and reviewing policies and procedures from companies that use hydrofluoric acid the researcher can state that calcium gluconate should be used over Zephiran® for treating dermal exposure to hydrofluoric acid. The researcher recommends that either calcium gluconate or Zephiran® should be available for treatment depending on the policies or procedures of the facility. The researcher notes that engineering controls should be used whenever possible, personal protective equipment and administrative controls should be the last option.

Recommendations for Future Research

It is recommended that further research should be done on finding a better methods for treating dermal exposure to hydrofluoric acid. Future dermal-based research studies should use pig models for subjects because of the similarity between pig and human skin.

Future research should be performed using current treatment methods for dermal exposure to hydrofluoric acid and should expand on using more than one treatment methodology. The research should also include the use of pig models and a number of different treatments that have not been mentioned in this study, such and calcium acetate or Hexafluorine. Future researches should consider a wide spectrum of exposure periods and treatment methodologies prior to making any recommendations in the treating of dermal exposure to hydrofluoric acid.

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Appendix A

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Marianne,
First, thank you for responding so quickly.
There is
a total of
three figures. Two of which are from the same
articles.

1.) Comparative Effectiveness of Topical
Treatments for
Hydrofluoric
Acid Burns
Journal of Occupational Medicine Vol. 27, No.
10 /
October 1985
pages 733-739
-Table 1 Effectiveness of Topical Burn
Treatment
at Various
Times After HF Application (on page 736)

2.) Hydrofluoric Acid Dermal Burns - An Assessment
of
Treatment Efficacy
Using an Experimental Pig Model
Journal of Occupational Medicine Vol. 34, No. 9
/
September 1992
pages 902-909

-Figure 1 Mean Efficacy Scores for
Hydrogen
Fluoride Exposure
Skin Receiving Various Treatments (on page 905)

3.) Hydrofluoric Acid Dermal Burns - An Assessment of
Treatment Efficacy
Using an Experimental Pig Model
Journal of Occupational Medicine Vol. 34, No. 9
/
September 1992
pages 902-909

-Figure 3 Representative skin lesions
induced
by exposure to
38% aqueous hydrogen fluoride for a 15 min period.
(on page
907)

Thank you so much.
Joshua Alters