DEVELOPMENTS IN FIRST AID MANAGEMENT OF CHEMICAL SPLASHES
CHEMICALS CAN PRESENT SERIOUS RISKS:

At home, products such as:

- Oven cleaners.
- Drain cleaners.
- Brick cleaners.

All have the potential to cause serious chemical injury.

At work the risks increase significantly because:

- The volume of chemical increases.
- The concentration of the chemical increases.
- The variety of chemicals increases.

All have the potential to cause serious chemical injury.
CHEMICALS CAN PRESENT SERIOUS PROBLEMS:

The problems are:

- Being able to identify them.
  (In liquid form most chemicals look the same)
- The lack of knowledge regarding their mechanisms.
  (We know that chemicals can damage the tissue and cause pain but how?)
- The lack of synergy between the chemical and the management.
  (What is the reaction between the washing solution and the chemical?)

This can result in misunderstanding and fear for the users of chemicals.

To discuss these problems, this presentation is divided into 2 parts:

1. Firstly we will study the problems linked to the use chemicals and the chemical burn itself.

2. Secondly we will explain the first aid requirements necessary to decrease sequela after a chemical splash with corrosive or irritant products
THE CHEMICAL BURN

THE CONSEQUENCES

Skin burn due to an acid

Eye burn due to caustic soda
THE RISK: THE DIVERSITY OF CHEMICALS

- 50,000 Chemicals circulated in quantities higher than 1 tonne
- 600,000 Molecules used in industry each year
- 35,000,000 Molecules registered
- 50,000 Chemicals circulated in quantities higher than 1 tonne
What type of products cause chemical burns?

- CORROSIVE
- IRRITANT
THE CHEMICAL BURN

THE DIFFERENCE BETWEEN CORROSIVE AND IRRITANT AGENTS

CORROSIVE

Highly concentrated acids or bases...

- STRONG REACTION
- IRREVERSIBLE EFFECTS

IRRITANT

- WEAK REACTION
- REVERSIBLE EFFECTS

Solvents, oils, ...

Risk of poisoning
THE CHEMICAL BURN

THE BASIC MECHANISM: THE EXCHANGE CAUSING THE BURN

Degree of burn  >

Number of molecules
Type of modification

THE CHEMICAL BURN
THE CHEMICAL BURN

THE AGGRESSED PART: THE EYE AND THE SKIN

- Proteins (enzymes), amino acids ....
- Lipids
- Mineral salts
THE 6 AGGRESSIVE CHEMICAL REACTIONS

- Acids
- Bases
- Oxidizers
- Chelating Agents
- Reducing Agents
- Solvents

THE CHEMICAL BURN
THE DIFFERENT STEPS OF THE CHEMICAL BURN

A few seconds to a few minutes
Sequelae often reversible

Sequelae often irreversible

THE CHEMICAL BURN

THE PENETRATION AS KEY FACTOR OF THE SERIOUSNESS

Anterior chamber

Épithélium

Stroma

Endothélium

Vitrous humour

Crystalline lens

Corneal layer

Epidermis

Dermis

Sebaceous Gland

Sweat Gland
THE CHEMICAL BURN

THE RESULT ON THE CELLS - AN EXAMPLE WITH CAUSTIC SODA

It shows the speed of cell destruction

0.5 mol NaOH-Lösung
THE CHEMICAL BURN

THE FACTORS THAT WILL INFLUENCE PENETRATION

Type of product and concentration

Temperature

Length of time of contact
To remove the product from the surface and avoid the development of a burn
Large quantities of water can quickly remove the chemical product from the surface.

The chemical burn - **FIRST AID: WATER**

**THE MECHANICAL EFFECT**

Reduces penetration
The chemical burn - FIRST AID: WATER

THE DILUTION

THE EXAMPLE OF THE pH

Decreases the concentration

Reduces the aggressiveness

Reduces penetration
Water acts in the same way on all aggressive chemicals

NO RISK OF MISTAKES
THE PROBLEM WITH HIGHLY CONCENTRATED PRODUCTS

The penetration of the product is so rapid that water has not time to remove it. Resulting need for secondary care.

- 98% Sulphuric acid,
- 50% caustic soda, phenol

The product penetrates.
The washing must start extremely quickly (first 10 seconds).

The product penetrates.
THE DURATION OF THE RINSING

- 15 minutes under a safety shower: risk of hypothermia

- Difficulty of opening the eye
AN ACTUAL RESULT: OF AN ACCIDENT DUE TO HIGHLY CONCENTRATED SULPHURIC ACID

94% Sulphuric Acid

- Splash on the legs
- Immediate rinsing with water
- 3 days in the hospital and 45 days of medical care at home
- More than 6 months of work loss
- Cheloïd scars and psychological difficulties

unreliable washing results
Water penetrates quickly into the tissue, thus increasing the penetration of the chemical product through the different layers.
ILLUSTRATION OF THE HYPOTONICITY WITH A MICROSCOPE

The consequences for the cells
THE IDEAL PRODUCT

• **Good points** to retain from water:
  
  The mechanical washing effect
  
  A single protocol

• **Weaknesses** to be overcome:

  To have **reliable rinsing**
  
  To increase the **intervention time**
  
  To improve the **comfort of the rinsing**
CHARACTERISTICS AND ADVANTAGES

• **Liquid**: retains the mechanical effect

• **Absorption Capacity**: stops the aggressiveness of the product and retains the polyvalence

• **Hypertonicity**: stops the penetration

First Aid: DIPHOTERINE® Solution

The chemical burn - First Aid: Water - The ideal product - DIPHOTERINE
The chemical burn - First Aid: Water - The ideal product - DIPHOTERINE
The hypertonic solution has an osmotic pressure higher than that of the body, and quickly draws out the chemical product.
NEW DECONTAMINATION METHOD TO STUDY THE PENETRATION OF A CHEMICAL

EX VIVO model on cornea

First Aid: Water - The ideal product

DIPHOTERINE®: a hypertonic solution

The chemical fully penetrates the cornea

The penetration of the chemical is stopped

FIRST AID: DIPHOTERINE® Solution
The chemical burn - First Aid: Water - The ideal product - DIPHOTERINE® Solution
RESULTS IN THE INDUSTRY: COMPARISON BETWEEN WATER & THE DIPHOTÉRINE® SOLUTION IN THE MARTINSWERK FACTORY, GERMANY

Martinswerk: 45 splashes due to caustic soda

A more reliable rinsing.

Simplification of the secondary care:

- **Water**: 75% required medical care
- **Diphoterine®**: 100% - no medical care

The chemical burn - First Aid: Water - The ideal product - DIPHOTÉRINE
ALCOA AUSTRALIA - Study conducted by Dr. Donaghue

The study began in 2006, published in 2010 – 3 Alumina refineries
180 cases of alkali skin splashes (ammonia/caustic soda)

<table>
<thead>
<tr>
<th>Severity scale and associated signs</th>
<th>FIRST AID EMERGENCY SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (no sign)</td>
<td>First washing with DAP of Diphoterine®</td>
</tr>
<tr>
<td></td>
<td>73 cases (52.9%)</td>
</tr>
<tr>
<td>2 (erythema)</td>
<td>54 cases (39.1%)</td>
</tr>
<tr>
<td>3 (blisters)</td>
<td>10 cases (7.2%)</td>
</tr>
<tr>
<td>4 (more serious)</td>
<td>1 case (0.7%)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>138 cases (100%)</td>
</tr>
</tbody>
</table>

Conclusions of the study:

No sign of chemical burn for more than 50% of the cases rinsed with the DIPHOTERINE® solution, compared to only 21.4% rinsed with water.

Decrease in the rate of injury needing medical care, of 24.7%.

Clinical results significantly better with a first rinsing using DIPHOTERINE® solution.

The chemical burn - First Aid: Water - The ideal product - DIPHOTERINE
IN CASE OF A DELAYED RINSING TO THE EYE

- An eye burn due to ammonia, washed with Diphotérine® Solution after 1 hour
- Examination after 1 hour: serious burn
- Final examination: visual acuity 14/20 after 6 months of specific care

Diphotérine® Solution still offers beneficial effect of improved healing

Note: See Scientific Report
FIRST AID: DIPHOTERINE® Solution

THE DIPHOTERINE® SOLUTION CURRENTLY

- References:
  - Swedish Work Environment Authority (Karolinska Institute) 2011
  - Book on Intoxications, First Aid Management, France 2011
  - Zeitschrift für praktische Augenheilkunde (ZPA on DOG in 2010) and the French Journal of Ophtalmology (JFO during SFO in 2008)

- Medical Devices in conformity with the standard EN 15154-3 and -4

- A list of tested products > 1000 substances and mixes

- A continuous research, especially for delayed washing
ILLUSTRATION OF THE DIFFERENCE BETWEEN WATER & DIPHOTERINE® SOLUTION WITH A pH EXPERIMENT

The chemical burn - First Aid: Water - The ideal product - DIPHOTERINE
DIPHOTÉRINE® SOLUTION FOR A MORE RELIABLE RINSING

- Efficient on all chemical products
- Longer reaction time
- Improves the comfort of the rinsing

the First Aid is MORE RELIABLE
PACKAGES ADAPTED TO THE RISK

- to the working place (individual or collective)

- to the level of risk (laboratory or warehouse)

THE USE

Improved time of reaction

The chemical burn - First Aid: Water - The ideal product - DIPHOTERINE – THE USE
HOW TO USE IT

Like a classical rinsing solution

For the EYES:
(ergonomic eyecup)

For the SKIN:
(Aerosols & Showers)
The chemical burn - First Aid: Water - The ideal product - DIPHOTERINE – THE USE

TO DECONTAMINATE THE EYE AND SKIN

500 ml (eyewash) / 200 ml (skin spray) for an intervention within the first minute

LMPE.DAS
TO DECONTAMINATE THE EYE

SIEW

50 ml (eyewash) for intervention within the first 10 seconds

The chemical burn - First Aid: Water - The ideal product - DIPHOTERINE – THE USE
TO DECONTAMINATE THE SKIN

Micro & Mini DAP

200ml/100ml spray for intervention within the first minute

The chemical burn - First Aid: Water - The ideal product - DIPHOTERINE – THE USE
TO DECONTAMINATE THE SKIN

DAP

5 litre Portable Shower for intervention within the first minute

The chemical burn - First Aid: Water - The ideal product - DIPHOTERINE – THE USE
IMPORTANT:

DIPHOTERINE® SOLUTION IS NOT SUITABLE FOR USE ON
- HYDROFLUORIC ACID
Hydrofluoric acid (HF) has a double action:

- Corrosive at surface due to the $\text{H}^+$ ions
- Toxic at depth due to deep penetration of the $\text{F}^-$ ions
THE CHEMICAL BURN

THE CONSEQUENCES OF A BURN DUE TO HYDROFLUORIC ACID
PATHOLOGY OF THE BURN DUE TO HF

Other hazardous forms:
Lewis acids (BF$_3$...): Mixed acids – Acids/Fluoride

- Na$^+$Cl$^-$: Sodium Chloride
- Na$^+$F$^-$: Sodium Fluoride
- H$^+$Cl$^-$: Chlorhydric acid

- H$^+$F$^-$: Hydrochloric acid

Corrosion and necrosis by intracellular calcium chelation
CLASSIFICATION OF HF BURNS

0 - 20 %  >  Pain and rednesssses may appear only after 24 hours following the contact

20 - 50 %  >  Pain appears between 1 and 8 hours following the contact

> 50 %  >  Immediate feeling of pain and destruction of the tissues
### Classification of HF Burns: Lethal Risks

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Contact on a Body Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anhydrous</td>
<td>&gt; 1%</td>
</tr>
<tr>
<td>&gt; 70 %</td>
<td>&gt; 5%</td>
</tr>
<tr>
<td>50-70 %</td>
<td>&gt; 7%</td>
</tr>
<tr>
<td>20-50 %</td>
<td>&gt; 10%</td>
</tr>
<tr>
<td>&lt; 20 %</td>
<td>&gt; 20%</td>
</tr>
</tbody>
</table>

Specific cases:
- Inhalation \([HF] > 5\%\)
- Ingestion \([HF] > 5\%\)
Water penetrates quickly into the tissue, thus increasing the penetration of the chemical product through the different layers.

The chemical burn - FIRST AID: WATER
**WHY USING CALCIUM GLUCONATE?**

- Treatment to fix fluorine and favour the regeneration of calcium
- Reduce Hypocalcemia

**BUT...**

- Limited efficacy on H+ ions
- Need for several applications (pain)
- Relative reliability
- No possible application in the eye
FIRST AID: WATER & CALCIUM GLUCONATE

AN ACTUAL RESULT: EXAMPLE OF AN ACCIDENT DUE TO HIGHLY CONCENTRATED HYDROFLUORIC ACID IN AVESTA

70% Hydrofluoric Acid

- Splash of 70% HF
- Immediate washing with water during 15 min
- Application of calcium gluconate (IV + gel)
- Hypocalcemia
- Ventricular fibrillation
- 4 Resuscitations
- 1 year of work loss
OBJECTIVES FOR AN OPTIMAL EFFICACY

Firstly

Remove HF from the surface to avoid its penetration in the tissues

Ideally

Stop the corrosive action of $H^+$ ions
Stop the toxic action of $F^-$ ions
CHARACTERISTICS AND ADVANTAGES

- **Liquid:** retains the mechanical effect
- **Absorption capacity:**
  - Stops the corrosive action of $H^+$ ions
    (3 ions fixed by each molecule)
  - Stops the toxic action of $F^-$ ions
    (6 ions fixed by each molecule)
- **Hypertonicity:** stops the penetration
- **Application:** on the eye and the skin
Decontamination of HF
Results on the pH

IN VITRO COMPARISON OF WASHING WITH - WATER - CaGLU - THE HEXAFLUORINE® SOLUTION ON A SOLUTION OF 0.2% HF:- RESULTS ON THE pH

The chemical burn - First Aid: Water & Calcium Gluconate - Objectives - HEXAFLUORINE®
IN VITRO COMPARISON OF WASHING WITH - WATER - CaGLU - THE HEXAFLUORINE® SOLUTION ON A SOLUTION OF 0.2% HF:- RESULTS ON THE pH

The chemical burn - First Aid: Water & Calcium Gluconate - Objectives - HEXAFLUORINE®
THE HEXAFLUORINE® Solution

Latest results

An ex vivo study (EVEIT model) about HF diffusion and decontamination in the cornea

Diffusion of 2.5% Hydrofluoric acid in the rabbit cornea

With the use of OCT Optical coherence tomography

The diffusion of HF through the cornea is achieved within 4 minutes

Schrage F, Frentz M, Spöler F, Först M, Kurz H. Accepted for publication in Burns
THE HEXAFLUORINE® Solution: ex vivo study

Burn = Corneal opacification

Influence of different washing solutions on HF penetration through the cornea

- 20s of contact,
- 25μl of 2.5% HF,
- 15 minutes of washing

Schrage F, Frentz M, Spöler F, Först M, Kurz H. Accepted for publication in Burns
Comparative Experimental Decontamination of concentrated hydrofluoric acid (HF) in an ex vivo human skin model

Mathieu L1, Lati E2, Burgher F1, Gasser P2, Hall AH3, Peno-Mazzarino L2, Maibach HI4, Blomet J1

The HEXAFLUORINE® Solution

Morphology at 24h

- Without washing: Total necrosis with grey cytoplasm, pyknotic nuclei and acidophilic cytoplasm in papillary and reticular dermis
- Water + Ca Glu: A lot of edematous cells in basal epidermis with very clear cytoplasm and basal membrane disruption. Pyknotic nuclei and acidophilic cytoplasm in papillary dermis; same lesion but weaker in reticular dermis
- Hexafluorine®: Normal morphology in all layers

The chemical burn - First Aid: Water & Calcium Gluconate - Objectives - HEXAFLUORINE®
RESULTS IN THE INDUSTRY:
USE OF THE HEXAFLUORINE® SOLUTION IN THE INDUSTRIAL ENVIRONMENT

Cases series: Avesta plants (Sweden, 1998-1999)

- 2 accidents 70% HF
- 14 accidents mix HF/HNO₃ (6% / 15%)

Maximum work loss of one day

The chemical burn - First Aid: Water & Calcium Gluconate - Objectives - HEXAFLUORINE®
USE OF THE HEXAFLUORINE® SOLUTION IN THE INDUSTRIAL ENVIRONMENT

Mannesmann Rohrenwerke (Germany, 94-98)

- 6 accidents - 40% HF
- 5 accidents Mix HF/HNO₃ (6% / 15%)

No work losses
No after-effect

The chemical burn - First Aid: Water & Calcium Gluconate - Objectives - HEXAFLUORINE®
ILLUSTRATION OF THE DIFFERENCE BETWEEN WATER & HEXAFLUORINE® SOLUTION WITH A pH EXPERIMENT

The chemical burn - First Aid: Water - The ideal product - DIPHOTERINE
TO DECONTAMINATE THE EYE & SKIN

500 ml for intervention within the first minute

LMPE.FACA

HEXAFLUORINE®

The chemical burn - First Aid: Water & Calcium Gluconate - Objectives - Hexafluorine® – USE
TO DECONTAMINATE THE EYE

500 ml for an intervention within the first minute

LPMF

HEXAFLUORINE®

THE USE

Hexafluorine® - USE

www.prevor.com

The chemical burn - First Aid: Water & Calcium Gluconate - Objectives - Hexafluorine® - USE
TO DECONTAMINATE THE SKIN

- **5 litres** for an intervention within the **first minute**

HEXAFLUORINE®

**THE USE**

**DAP**

**Hexafluorine® – USE**

**60s**

The chemical burn - First Aid: Water & Calcium Gluconate - Objectives - Hexafluorine® - USE
INTERVENTION PROTOCOL

Ask the following:

• When did the accident happen?
• What was the chemical?
• What areas of the body were contaminated?
• If chemical is in the eyes, is the victim wearing contact lenses?
THE IMPORTANT RECOMMENDATIONS

- Do not stop the rinsing when the pain stops!
- Use the complete dose for an optimal efficacy!
- Start the rinsing as quickly as possible!
  - Within the first 10 seconds for the SIEW
  - Within the first 60 seconds for all other packages
INTERVENTION PROTOCOL

IMPORTANT:

Always use the total contents of the product.

Do not stop decontamination just because the pain has stopped.
INTERVENTION PROTOCOL

IMPORTANT:

Because the DIPHOTERINE® & HEXAFLUORINE® Solutions are hypertonic, they may cause a slight dry feeling to the eyes.

This can be eased by washing with AFTERWASH® solution.
INTERVENTION PROTOCOL

• Go away from the danger
• Alert
• Remove contaminated clothing
• Rinse as quickly as possible respecting the DIPHOTERINE® / HEXAFLUORINE® Solution protocol
• Seek medical advice

The chemical burn - First Aid: Water - The ideal product - DIPHOTERINE – THE USE
ADVICE ON SITE

Your partners in the management of your chemical risk

The chemical burn - First Aid: Water - The ideal product - DIPHOTERINE - the use - CONCLUSION