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EXPERIMENTAL STUDY OF THE FLUORINE IRRITATION ON THE ANTERIOR SEGMENT OF THE HUMAN EYE

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ABSTRACT

The article examines cases of complaints of 14 people with temporary anterior eye irritation when working with glass and ceramic furnaces using fluorine-containing minerals such as cryolite and fluorite. Subsequent eye examinations have not shown any corneal changes. Air inspection in the work areas made with headspace gas chromatography indicates that sudden fluorine releases from the furnace are observed. The ophthalmological study is performed by slit-lamp examination and the level of fluorine in the air is determined by the HSGC method.

KEYWORDS: Fluorine, eye irritation, anterior eye segment, slit-lamp examination, HSGC.

INTRODUCTION

Fluorine F2 (CAS Registry No. 7782-41-4) is a yellow-greenish gas with a molecular weight of 37, 99. It has a highly irritating odor. Its melting point is -219.61°C and the boiling point is -188.13°C. Steam pressure is 1 mm Hg at -223°C> 10 atm at 20°C.[1] Its density amounts to 1,695 g / cm3 (air = 1.29).[2] It is the most electronegative element in the periodic table, which is why it is the strongest oxidizing agent. It reacts violently with all oxidizable substances at room temperature. Under the influence of humidity in the air it reacts to hydrogen fluoride, oxygen difluoride, hydrogen peroxide, sulfur and ozone.[3] The alkaline capture of fluorine and its derivatives in air often make it difficult to ascertain the form in which it has been present.

It is obtained by electrolysis of an electrolyte containing fluorinated hydrogen (HF) and sodium fluoride (NaF) and its main application is UF6 production for the needs of the nuclear industry in the extraction of U235 from the onion isotope U238, also for some rocket fuels and the production of Teflon.[4] Fluorine and hydrogen fluoride are released in the production of aluminum from bauxite. For some reason, the production of glass and glass ceramics for the needs of art or consumer items does not fall within the scope of research.

Generally, there is no evidence of people who died of inhaled fluoride. It is known that fluoride at low concentrations can strongly irritate the eyes and mucous membranes of the nasal cavities. The sensory sensitivity threshold lies somewhere at 0.10-0.20 ppm.[5,6] Exposure to 10 ppm over 15 minutes has no effect, but if the exposure is repeated for 3-5 minutes every 15 minutes for 2-3 hours the irritation in the eyes and nose is already felt but there are no breathing difficulties.[7]

When the concentration reaches 15-25 ppm, the irritation in the eyes and nose is clearly felt; it is the eyes which react first.[8] Studies in a group of 61 workers exposed systemically to air concentration of fluorine in the work environment (range <0.1 to 24.7 ppm) show no changes during the ophthalmic examinations.[9] In animals, the LC_{50} concentration is respectively 30 ppm for mice, 47ppm for rats and 71 ppm for rabbits.[**Error! Bookmark not defined.**] For 60 minutes exposure, it is considered that the process is described by the formula:

$C^n.t=k$

Where

C – concentration in ppm

t – ppm time in minutes

k – constant ≈ LD_{50} $1,10^5$

n – ppm exponent ≤ 2

The classical chromatographic method for determining fluorine is that of Fresen et.al.[10] It has outstanding advantages over the electrochemical and diffusion methods. The sensitivity (DL) for this detector reaches 0.01 mg / dm3 / ppm. Here the Cox reaction is used.[11] It is an ion exchange between trimethylchlorosilane and fluorine in the hydrochloric acid medium:

$(CH_3)_3SiCl + H_2O = (CH_3)_3SiOH + HCl$

$(CH_3)_3SiOH + H^+ + F^- = (CH_3)_3SiF + H_2O$

Later, the nature of work and the need for rapid analysis have led to the creation of a rapid headspace gas chromatographic method, where the sample preparation was almost unnecessary, with DL = 0.01 ppm and RDS = 2%, it is feasible with air, food, beverages, biological samples, industrial products, e.g. in all matrices.[12] Later, this methodology has been used in the materials science and analysis of combat poisonous substances.[13,14]

MATERIALS AND METHODS

The research comprised 14 people who worked in two shifts of 7 in a glass factory. They handled glass-melting ovens for manual glassblowing and mold pressing of specific products. No one showed average fluorine level in body liquids (blood plasma and urine) above 0.5 mg/l. Samples were taken right after full melting of glass material and after first opening of oven door so that to avoid resorption of fluorine in the bones. The same levels were found in a control group of 10 people. The variations were between 0,4-0,5 mg/l. Analysis were performed by Head Space Gas Chromatography method with sensitivity of 0,01mg/l limit of detection.

In the course of work, Top Con, model SL-D7, 30W halogen slit-lamp with Galileo optical system, magnifications of 6X, 10X, 16X, 25X and 40X was used. A modified specular microscopy with a filter is used to evaluate the wetting of ocular surface because possible damage of lipid tear glands may affect the tear breakup time and lead to unstability and poor regeneration of the tear film with prolonged late eye discomfort. This is a restriction for contact lens wear which is often important in young population.[15]

In the headspace vial are mixed 1 cm^3 sample (including adsorbents tubes) and 1 cm^3 1:1 hydrochloric acid and closed by the special seal. Then the mixture is shaken and 5 µl Tri-Methyl-Chlorosylane are added in the vial septum by a GC syringe and charged in to the headspace device. A Perkin-Elmer HS-6 headspace sampler was used attached to Sigma 1 GC. The equilibration took place at 80 C^o for at least 10 minutes. The gas chromatograph is equipped with 2 m 30% Apiezon L glass column. Temperatures of the column, injection port and FID detector are 60 C^o, 150 C^o and 200 Co respectively. The quantitative analysis is made by external standard with concentration 1 mg/ml F^- diluted by factor of 5, 10 or 100.

Experimental

Ocular chemical injuries are a true ocular emergency and require immediate and intensive evaluation and treatment.

The examination of patients with complaints of irritation has not detected changes in the anterior segment by slit-lamp examination, which correlates with former observations. [**Error! Bookmark not defined.**] The people examined by an ophthalmologist report discomfort, redness, tearing, also itching and slight edema of the eyelid. All these complaints are transient and self-limiting. In single cases, corneal epithelial involvement is observed, which is detected by discreet dyeing with fluorescein.

All 14 examined patients are assigned to grade I or even lower according to the most common classifications.

Classification schemes regarding the extent of the initial injury were initially developed in the mid 1960's first by Ballen[16] and then modified by Roper-Hall.[17] The Roper-Hall classification system was largely based on the degree of corneal haze and the amount of perilimbal blanching/ischemia.

Grade	Prognosis	Cornea	Conjunctival limbus
I	Good	Corneal epithelial damage	No limbal ischemia
II	Good	Corneal haze, iris details visible	<1/3 limbal ischemia
III	Guarded	Total epithelial loss, stromal haze, iris details obscured	1/3-1/2 limbal ischemia
IV	Poor	Cornea opaque, iris and pupil details obscured	>1/2 limbal ischemia

Phase	Time	Characteristics
Immediate phase	1 day	Key elements of prognosis: the total area of the corneal epithelial defect The area of the conjunctival epithelial defect The number of clock hours or degrees of limbal blanching The area and density of corneal opacification Evidence of increase IOP on presentation Loss of lens clarity.
Acute phase	1-7 days	the tissues rid themselves of contaminants while re-establishing the superficial protective layer of corneal epithelium

		The epithelium prevents corneal thinning and progression from tears' enzymes; It modulates stromal regeneration and repair Significant inflammatory mechanisms begin to evolve on the ocular surface and inside the eye Rise in IOP in a bimodal manner
Early reparative phase	8-20 days	Acute inflammatory events give way to chronic inflammation, stromal repair and scarring Corneal ulceration tends to occur. Stromal ulceration due to action of digestive enzymes such as collagenase, metalloproteinase and other proteases released from regenerating corneal epithelium and polymorphonuclear leukocytes.
Late reparative phase and sequelae	>21 days	Completion of healing with good visual prognosis (Grade I and II) and complications in those with guarded visual prognosis (Grade III and IV) The late complications of chemical burns include poor vision, corneal scarring, dry eyes, symblepharon, glaucoma, uveitis, cataract, adenexal abnormalities

Pfister's classification system varies from mild, mild-moderate, moderate severe, severe and very severe based upon pictures and photographs demonstrating corneal haze and perilimbal ischemia.[18]

Dua *et al*. worked according to a scheme based upon clock hour limbal involvement as well as a percentage of bulbar conjunctival involvement.[19]

Grade	Prognosis	Clinical findings	Conjunctival involvement (%)	Analogue scale (%)
I	Very good	0 clock h of limbal involvement	0	0/0
II	Good	<3 clock h of limbal involvement	<30	0.1-3/1-29.9
III	Good	>3-6 clock h of limbal involvement	>30-50	3.1-6/31-50
IV	Good to guarded	>6-9 clock h of limbal involvement	>50-75	6.1-9/51-75
V	Guarded to poor	>9-<12 clock h of limbal involvement	>75<100	9.1-11.9/75.1-99.9
VI	Very poor	Total limbus (12 clock h) involved	100	12/100

It is very important to note the amount of limbal, corneal and conjunctival involvement at the time of the initial injury and to document changes in the examination as the patient is followed. Grading of the severity may provide the patient with a general idea of the prognosis.

After chemical impact, the goal of therapy is to restore a normal ocular surface and corneal clarity. Once the emergency treatment, incl. irrigation with isotonic saline or clean tap water, and evaluation are completed, the challenging task of healing the injured eye begins. The treatment goals are reestablishment and maintenance of an intact and healthy corneal epithelium, control of the balance between collagen synthesis and collagenolysis and minimizing the adverse sequelae that often follow a chemical injury.[20] In our case promotion of reepithelization with tears' substitutes and oral ascorbate 2-3g/day for a week were effective enough to give back comfort and ensure full recovery.

When analyzing raw material from silicate and fluorescent material before and after heat treatment, it can be seen that the drop in the fluorine content exceeds 50%. However, the fluorine content itself does not exceed 5-10% of the total mass of the material to be treated.

Figure 1 shows a chromatogram expressing changes in the treated fluorine-containing material.

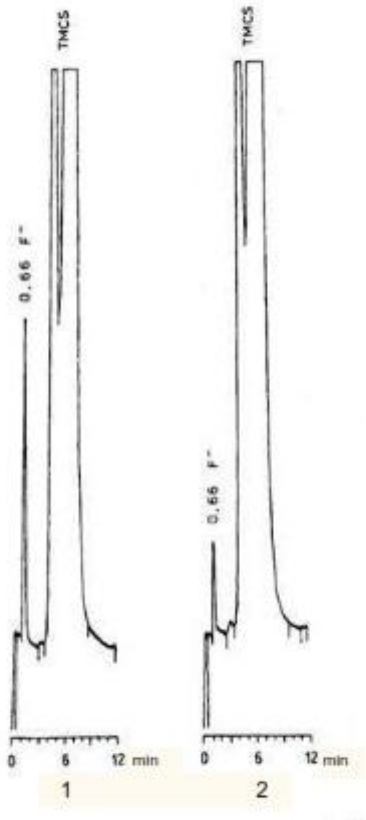

Fig. 1: Fluorine content in fluorinated material before and after thermal treatment.

1) 0.13 g heat-resistant NaF coating before strong heating -9,40 mg / kg F-

2) 0.09 g of the same coating after heating - 3.92 mg / kg F-

(Data from the archive of V. Tashkov)

When heating and opening the furnace, concentrations of 1 to 20 ppm may occur. The worker feels the irritating effect, but no changes are found in the ophthalmic examination.

RESULTS AND DISCUSSION

Given the low concentration of fluorine that occurs for a moment around the furnace at the time of opening, the actual concentration reaches irritating levels, but this does not affect the health status of the workers. From a data view of the LC_{50} values for mouse (20g), rat (100g) and rabbit (100g), it can be stated that the dependence follows the curve in Figure 2:

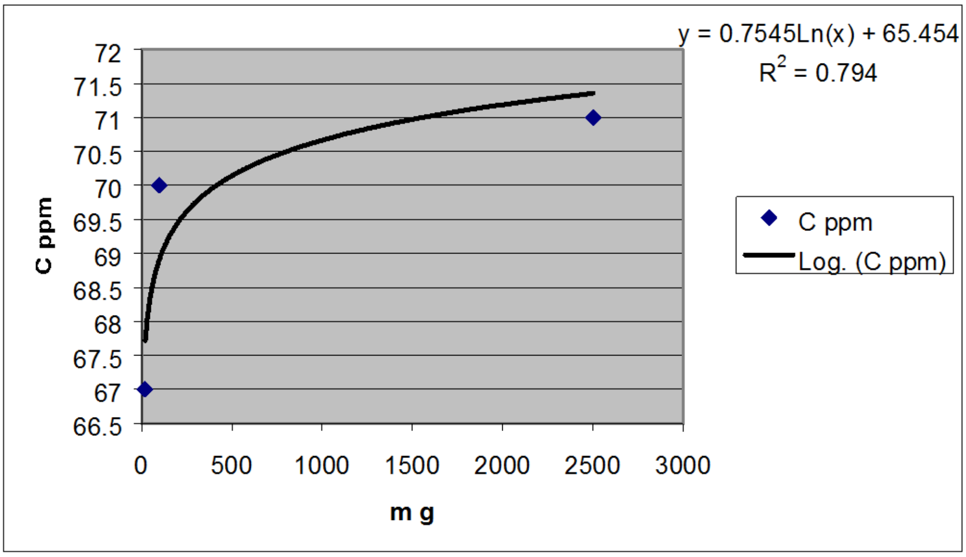

Fig. 2: Mathematical dependence of LC_{50} on the weight of mammals.

In the equation y≈0.75 ln x + 65 with correlation R = 0.794≈0.8, a person weighing 70 kg = 70 000 g produces an LC_{50} ≈74 ppm. Obviously, when working with a melting furnace on silicate materials, such a concentration cannot be reached within an hour.

CONCLUSIONS

Following safety recommendations there are no significant threats for anterior eye surface condition of workers exposed to the above shown fluorine levels in glass industry and manual molding and blowing output. Eye irritation is mild, transitory, self- limiting, without long term consequences. Promotion of reepithelization with lubricant drops and oral ascorbate in appropriate dosage precipitates eye comfort.

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