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Case Report

Asthma Following Household Exposure to Hydrofluoric Acid

Alfred Franzblau, MD[1]* and Nancy Sahakian, MD, MPH[2]

Background *Almost all reports of respiratory health effects of hydrofluoric acid are derived from industrial settings and usually involved massive and conspicuous exposures. In the present report we describe a case of adult-onset asthma immediately following use of a household rust stain remover that contained an 8–9% aqueous solution of hydrofluoric acid (HF).*

Methods *This is a case-report. A literature search of hydrogen fluoride, and reactive airways dysfunction syndrome (RADS) was performed.*

Results *A previously healthy 26-year-old woman developed asthma immediately following inhalation exposure to hydrofluoric acid from a household cleaner, consistent with reactive airways dysfunction syndrome. The circumstances of exposure and possible mechanism of disease are discussed.*

Conclusions *It is likely that this patient's use of the rust stain remover resulted in inhalation exposure to hydrofluoric acid well above any applicable standard, and hence constituted a 'high level' irritant exposure capable of inducing reactive airways dysfunction syndrome. In our opinion, the presence of this concentration hydrofluoric acid in a consumer product may be unduly hazardous.* Am. J. Ind. Med. 44:321–324, 2003.

KEY WORDS: hydrofluoric acid; HF; reactive airways dysfunction syndrome; RADS; asthma; CAS #7664-39-3; household products; inhalation injury

INTRODUCTION

Fluorine compounds are derived primarily from mining of two ores: fluorspar (calcium fluoride) and phosphate rock [ATSDR, 2001]. Most hydrogen fluoride (HF) is produced by the reaction of sulfuric acid with calcium fluoride. HF is used to produce a variety of chemicals and in a variety of industrial processes including: refrigerants, herbicides, pharmaceuticals, high-octane gasoline, aluminum production, plastics, electrical components, fluorescent light bulbs, pickling of stainless steel, glass etching, metal coatings, and quartz purification [ATSDR, 2001]. The largest single use of HF (60%) is in production of fluorocarbon compounds [ATSDR, 2001].

HF is a weak acid (pKa = 3.2 at 25°C) with a molecular weight of 20.0 Da [ATSDR, 2001]. The boiling point of anhydrous HF is 19.51°C, it is miscible with water, and HF fumes strongly in moist air [ATSDR, 2001]. The vapor pressure of anhydrous HF is 400 mm Hg at 2.5°C [ATSDR, 2001]. The odor threshold is reported to be 0.5–3.0 parts per million (PPM).*

* 1 PPM = 0.82 mg/m^3 of HF [ATSDR, 2001].

[1]Associate Professor of Occupational Medicine, Department of Environmental Health Sciences, University of Michigan School of Public Health, Washington Heights, Ann Arbor, Michigan

[2]Occupational Medicine Resident, Department of Environmental Health Sciences, University of Michigan School of Public Health, Washington Heights, Ann Arbor, Michigan

Dr. Sahakian is currently affiliated with the Division of Respiratory Disease Studies, National Institute of Occupational Safety and Health, Morgantown, West Virginia.

*Correspondence to: Dr. Alfred Franzblau, Department of Environmental Health Sciences, University of Michigan School of Public Health, 1420 Washington Heights, Ann Arbor, MI 48109-2029. E-mail: afranz@umich.edu

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The permissible exposure limit (PEL) for HF set by the Occupational Safety and Health Administration (OSHA) is 3.0 PPM [OSHA, 2002]. The 8-hr time weighted average (TWA) recommended exposure limit (REL) of the National Institute for Occupational Safety and Health (NIOSH) is 3.0 PPM [NIOSH, 2002]. The ceiling limit promulgated by the American Conference of Governmental Industrial Hygienists (ACGIH) is 3.0 PPM [ACGIH, 2000]. In addition to a REL for HF, NIOSH has also promulgated a 15-min ceiling limit of 6.0 PPM, and an immediately dangerous to life and health (IDLH) level of 30 PPM [NIOSH, 2002].

While there is an extensive literature describing the human health effects of inhalation exposure to HF, almost all of these reports are derived from industrial settings and usually involved massive and conspicuous exposures [ATSDR, 2001]. There is only one report of adverse health effects from inhalation exposure to a consumer product containing HF [Bennion and Franzblau, 1997]. This report described a single case of chemical pneumonitis and adult respiratory distress syndrome following household use of an HF-containing rust stain remover. In the present report we describe a case of adult-onset asthma immediately following use of the same household rust stain remover.

CASE REPORT

At the time of the incident the patient was a 26-year-old lifetime non-smoker with no prior history of asthma or other chronic respiratory illness as a child or adult. She had no history of allergies to drugs, foods, pets, dusts, or pollens; and no history of hayfever, seasonal allergies, or eczema. She had never been employed in settings that might have exposed her to respiratory irritants or sensitizers. Prior to the exposure episode she liked to roller blade and to participate in exercise classes; such activities caused no undue respiratory problems. There was no family history of asthma.

In the late spring of 1999, she used the HF-containing rust stain remover to clean her toilet. She squirted approximately one-third to one-half of the contents of a 10 ounce bottle around the rim of her porcelain toilet bowl, waited 15 s, and then vigorously scrubbed the area with a toilet brush. She was positioned on her knees with her head near the toilet rim so as to assure that she was spraying the stain remover over the rust stains. Her bathroom was approximately 8 by 11 feet, with a ceiling fan, which was in operation, a small window opening, and an open door to the bathroom. She was wearing blue water-repellent gloves (probably nitrile) which covered her arms up to the level of her elbows.

After scrubbing for approximately 1½–2 min, she experienced a burning sensation in her eyes, nose, and mouth and she developed chest tightness, and dyspnea. She immediately left the bathroom, closing the bathroom door behind her, and went out on her porch for 12–15 min. When she returned inside the house, she was still able to smell the scent of the cleaning agent. She had watering of her eyes but no eye redness. She denied having any subsequent problems with bleeding of her nose, peeling of her skin or skin rash. The burning of the nose and mouth continued the remainder of that day and she had a minimal cough but no hemoptysis for the next 2 days. She had persistent problems breathing for the next month or two, consisting of wheezing (particularly with exertion) and difficulty taking a deep breath, and she finally saw her personal physician in late August.

On examination she had a prolonged expiratory phase but no wheeze or rhonchi. Spirometry performed at the time of the first exam demonstrated a mild obstructive pattern with $FEV_1/FVC = 70\%$ of predicted. She was prescribed Flovent 110 mcg two puffs BID, Serevent two puffs BID, and Proventil two puffs every 4 hr as needed. She returned for follow-up in 1 week with symptomatic improvement. Her lungs demonstrated good airflow. Another spirometry test was performed, which showed normalization of her previously borderline study. A chest radiograph was normal. She continued to have symptoms with exertion, and nocturnally, and so approximately 2 months later she was seen by a pulmonologist, who labeled her asthma as reactive airways dysfunction syndrome (RADS) secondary to exposure to the use of the rust stain remover. Her spirometry was again normal. The Flovent was increased to 110 mcg four puffs BID.

In the spring of 2000, she reported that she continued to experience wheezing with exertion. She underwent a methacholine challenge, which demonstrated a 30% decline in FEV_1 following a cumulative dose of 50 mg of methacholine.

As of 2002, she was still using the medications prescribed in August, 1999. She continued to experience intermittent wheezing with exertion, and prominent nocturnal symptoms. She had not required any emergency room visits or hospitalizations due to acute exacerbations of asthma. A methacholine challenge test was repeated, and was still positive. She denied onset of sensitivity to common aeroallergens (e.g., pollens, dusts, pets, hayfever, or seasonal allergies) since the onset of her asthma, but has not had formal skin testing.

The bottle of rust stain remover had been purchased the week before the incident from a local drug store. She had not used this cleaning agent previously. This bottle contained an aqueous solution of 8–9% hydrogen fluoride. She denied using any other cleaning agents concurrently or directly prior to using the rust stain remover. She had used toilet bowl deodorizers that clamped onto the rim of the toilet in the past but had not used one of these recently.

DISCUSSION

RADS, or irritant induced asthma without latency, is characterized by the immediate onset of asthma following a single exposure (or possibly several exposures) to irritating

vapor, fume, or smoke [Brooks et al., 1985; Chan-Yeung, 1995; Alberts and do Pico, 1996]. In most cases the exposure is conspicuous to the victim. Persons with pre-existing asthma (and possibly atopy) are usually excluded from the diagnosis of RADS, since an irritant exposure will usually lead to a transient exacerbation of their underlying disease. Another important feature of RADS is the persistence of symptoms for at least 3 months after the acute insult, and possibly permanently.

The patient described in this report developed adult-onset asthma based on her history of symptoms, improvement with medications, and the repeatedly positive tests for non-specific bronchial hyperreactivity. Her asthma had immediate onset following the use of the rust stain remover, and has persisted for at least 3 years. She is a non-smoker, with no previous history of respiratory or allergic disease. Therefore, based on the history and medical findings she appears to fit the criteria for RADS. However, what is unusual in this case is the apparently innocuous nature of her exposure, and whether it constitutes a 'high level' irritant exposure.

There is no question that HF is a potential respiratory irritant; the question in this case is whether the exposure was adequate to produce RADS. Obviously, no air measurements are available from the actual exposure episode, but published literature on the physical chemistry of HF provides important insight. Brosheer et al. [1947] published empirical results of the vapor pressure of HF over aqueous solutions containing 2–30% HF. Table I lists results for the vapor pressure of HF over a range of aqueous solutions at 25°C. The vapor pressure ranges from 63.2 PPM for a 2.00% HF solution to 336.8 PPM for a 9.86% solution. The rust stain remover she used consisted of an 8–9% aqueous solution of HF. If one assumes that the HF concentration was 8.5%, and that the ambient temperature was 20°C (it was late spring and the bathroom window was open), then the vapor pressure of the HF in the rust stain remover solution would have been at least 170 PPM, which is 50 times greater than the PEL, REL, and TLV, and more than five times greater than the IDLH. These estimates assume a roughly linear relationship between the HF concentration in the solution, ambient temperature, and the vapor pressure of HF. The HF would have been diluted to some extent when it mixed with the water in the toilet bowl, however, the spray and scrubbing activity of the toilet brush would be expected to have enhanced the vaporization (and possible aerosolization) of HF. Her level of activity would have increased her respiratory rate, and may have contributed to mouth breathing, which serves to bypass the protective effect of partial absorption of soluble vapors in the mucous membranes. Furthermore, she was positioned with her head immediately over the toilet bowl. Overall, it is likely that this patient's use of the rust stain remover resulted in inhalation exposure to HF well above any applicable standard, and hence constituted a 'high level' irritant exposure capable of inducing RADS.

TABLE I. Vapor Pressure of HF Over Aqueous Solutions of HF at 25°C

Concentration of HF in aqueous solution (%)	Vapor pressure of HF (PPM[a])
2.00	63.2
3.96	114.5
6.02	172.4
9.86	336.8
12.80	500.0

From Brosheer et al. [1947].

[a]These values have been converted from millimeters of Hg using a conversion factor of 1 mm Hg = 1315.8 PPM.

It is well known that inadvertent mixing of certain common household cleansing agents can result in chemical reactions and liberation of hazardous concentrations of irritant vapors capable of producing chemical pneumonitis and/or airway disease [Faigel, 1964; Jones, 1972; Murphy et al., 1976; Reisz and Gammon, 1986]. However, our patient consistently denied use of any other cleaning agents. Furthermore, as the preceding discussion illustrates, the HF alone, at the given concentration, was adequate to produce a respiratory hazard.

The particular bottle of rust stain remover used by our patient was unusual in that it was manufactured many years earlier, prior to a major reformulation by the manufacturer. The present formulation of the rust stain remover has a reduced concentration of HF, only 2%. However, even at this lower concentration, the vapor pressure of HF is 63.2 PPM (at 25°C), more than twice the IDLH. In our opinion, the presence of this concentration HF in a consumer product may be unduly hazardous.

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