Environmental Research 134 (2014) 295–300

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Health effects associated with faulty application of spray polyurethane foam in residential homes ☆

Yuh-Chin T. Huang [a,*], Wayne Tsuang [b]

[a] Department of Medicine, Duke University Medical Center, 1821 Hillandale Road, Suite 25A, Durham, NC 27705, USA
[b] Respiratory Institute, Cleveland Clinic Foundation, Cleveland, OH, USA

ARTICLE INFO

Article history:
Received 25 April 2014
Received in revised form
21 July 2014
Accepted 23 July 2014

Keywords:
Building related illness
Reactive airway disease
Isocyanates
Volatile organic compounds
Indoor air

ABSTRACT

Background: Spray polyurethane foam (SPF) has become a popular form of home insulation in the United States, but there have been adverse health effects reported by home owners.
Methods: We summarized adverse health effects in 13 adults from 10 households (age: 33–82) whose homes were improperly retrofitted with SPF. Subjects either were not asked to leave the premise or were told to return too early. In some cases, proper ventilation was not used or the foams were sprayed using the improper mixing technique. We correlated symptoms with volatile organic compounds (VOCs) in indoor air samples.
Results: All subjects reported fishy odors and developed acute watery and burning eyes, burning nose, sinus congestion, throat irritation, cough, dyspnea and chest tightness. Twelve subjects (92.3%) reported acute neuropsychiatric symptoms, including headache, dizziness, forgetfulness, difficulty in concentrating and insomnia. Three subjects (23.0%) had nausea, vomiting and abdominal cramps and three (23.0%) developed skin rash. Subjects continued to experience symptoms long after SPF was done. These symptoms subsided after they left homes, but recurred upon returning. All subjects eventually vacated their homes. The methacholine challenge test was negative in 5 of 7 patients. Analysis of indoor air and headspace gas from the foams showed increased concentrations of VOCs derived from SPF and common indoor air pollutants. The levels of VOCs decreased after SPF was completely removed.
Conclusions: Faulty application of SPF was associated with acute and persistent pulmonary and extrapulmonary symptoms. These symptoms may be associated with SPF-derived compounds as well as increased concentrations of indoor VOCs.

1. Introduction

Spray polyurethane foam (SPF) is a spray-applied insulating material that has been a popular "green" solution for insulation for residential homes and office buildings in the United States. SPF provides high levels of *R*-values (insulation efficiency), is less expensive than other insulating materials, such as fiberglass, and was eligible for federal energy tax credits in 2011.

There are three main types of SPF products: two-component high-pressure system, two-component low-pressure system and one-component foam system, each of which has different applications. The two-component high-pressure SPF is most commonly used for residential and building insulation. It contains isocyanates, primarily methylene diphenyl diisocyanate (MDI), on side A and polyols, amines or metal catalysts, fire retardant and surfactants on side B. Sides A and B are pumped through heated hoses from supply tanks into a nozzle where the two components react to produce foams.

When SPF is correctly applied and cured, it is usually considered to be relatively inert; however, environmental factors, such as humidity and temperature, may impact curing rates. When SPF is not applied properly, however, chemicals derived from SPF may migrate to hard and/or soft surfaces in the surrounding environment contaminating the entire building. Continuous offgassing of chemicals from SPF and house fixtures would increase the potential for hazardous exposure to home owners. We have reported two cases from the same household who developed airway hyperreactivity after faulty application of SPF (Tsuang and Huang, 2012). Since then, many home owners have described symptoms that the occupants related to the spray foams with some appearing in news media

Abbreviations: MDI, methylene diphenyl diisocyanate; SPF, spray polyurethane foam; TDI, toluene diisocyanate; VOC, volatile organic compound

☆Portions of this manuscript were presented at the 2013 American Thoracic Society National Conference, Philadelphia, Pennsylvania.

* Corresponding author. Fax: +1 919 684 3199.
E-mail address: huang002@mc.duke.edu (Y.-C. Huang).

http://dx.doi.org/10.1016/j.envres.2014.07.015
0013-9351/

(http://www.wftv.com/news/news/local/action-9-investigates-hidden-dangers-some-homes/nS7W3/; http://www.cbc.ca/player/Shows/Shows/Marketplace/ID/2414463492/).

In this report, we described a group of home owners who developed adverse health effects after they retrofitted their residential homes with SPF. We also evaluated volatile organic compounds (VOCs) in the indoor air samples as an initial attempt to investigate the mechanisms for the adverse health effects.

2. Methods

2.1. Patient population

Between 7/1/2012 and 6/30/2013, we had seen half a dozen patients in the clinic who had reported symptoms after their residential homes were retrofitted with SPF to improve energy efficiency. We also had received referrals from other physicians and home owners who developed symptoms after SPF was installed in their homes. In this study, we only enrolled subjects who had signed the consent before 6/30/2013. These subjects provided informed consent before participating in the study. The study protocol was approved by the Institutional Review Board of Duke University Medical Center (Pro00037197).

2.2. Data collection

We obtained demographic information, such as age and gender, residential home location, surroundings and interior of the houses, detailed exposure history, and symptoms. Some of these individuals were seen at the Duke Asthma Airway Center. For others who were not seen by us, we conducted a phone interview to obtain the above information. We also reviewed any outside medical records, including the pulmonary function test, the methacholine challenge test and laboratory tests, if available. These records were provided to us either by fax or e-mail.

2.3. Analysis of VOCs

Some home owners had the air in their residential homes analyzed for VOCs. The air samples were collected into Carbotrap tubes for the measurement of VOC (including alkanolamine and alkylamine) using Carbotrap patent by Saskatchewan Research Council (SRC) Analytical Laboratories (Saskatoon, SK, Canada). Air samples were also collected with IsoChek filters for the measurement of isocyanates using High Performance Liquid Chromatography with Postcolumn Fluorescence Derivatization (Galson Laboratories, East Syracuse, NY).

Some subjects also had foams removed from their homes for analysis of VOCs offgassing from the foams in vitro. While the methods varied somewhat, in general, the foams were placed in a large glass jar fitted with a Teflon-lined septum top lid. The headspace samples were heated and the offgassed VOCs were purged into a thermal desorption sorbant tube with Ultra Pure air. The collected headspace samples were analyzed for VOCs by Thermal Desorption/Mass Spectrometry.

These analyses were all based on EPA Compendium Method TO-17 and ASTM D 6196 for VOCs by thermal desorption followed by gas chromatography/mass spectrometry (TD/GC/MS), and EPA Method TO-11A and ASTM D 5197 for selected aldehydes, including formaldehydes, by high performance liquid chromatography (HPLC). The companies that were commissioned to do the measurements were all full-service indoor air quality firms, although they may be biased, or unfamiliar with the assays.

2.4. Statistical analysis

Descriptive statistics was performed to describe the collected data using JMP 9.0.0 (SAS Institute, Inc., Cary, NC).

3. Results

3.1. Study population and clinical manifestations

Thirteen adult subjects from ten households were included (Table 1). Their homes were located on the east coast of the United States from New York to Florida. The mean age was 50 years (range 33–82), and five were female.

All subjects reported smelling unpleasant odors during the spray or when they returned within 48 h after the spray was completed. The descriptive terms used by the subjects included "fishy", "ammonia-like", "chemical", etc. Eleven subjects (84.6%) developed acute watery and burning eyes, burning nose, sinus congestion, throat irritation, cough, dyspnea and chest tightness. These symptoms persisted for as long as they stayed in the house. The other two subjects moved in several months after the spray had been completed and also reported unpleasant odors, throat irritation and sinus congestion acutely. Four subjects (30.8%) had a history of asthma and/or environmental allergy. One of these subjects reported wheezes after the exposure.

Twelve subjects (92.3%) also reported acute neuropsychiatric symptoms, such as headache, dizziness, poor memory, difficulty in concentrating, photosensitivity, myalgia and insomnia. These symptoms were initially thought to be nonspecific by their physicians who attributed them to stress, depression and anxiety. Three subjects (23.0%) reported gastrointestinal symptoms, including nausea, vomiting and abdominal cramps. Three subjects (23.0%) developed skin rashes. The skin rashes were erythematous, some with vesicles, and could be itchy or burning. One of the subjects underwent skin biopsy, which showed lichenoid and perivascular dermatitis consistent with contact dermatitis. The patch test only showed weak positivity to several chemicals.

Seven subjects had methacholine challenge tests done >6 months after the SPF exposure and one was positive with a PC_{20} of 1 mg/ml (Crapo et al., 2000). This subject has a history of mild intermittent asthma, and was only on occasional albuterol HFA before the exposure. She had to take inhaled steroids after the SPF exposure. Serum isocyanates IgE was negative in four subjects who had the tests done at least 5 months after SPF spray (Viracor-IBT Laboratories, Lee's Summit, MO).

3.2. Exposure history

Eleven subjects (84.5%) were either not asked to leave the premise during foam spray or told to return home within 48 h after the spray had been completed (Table 1). In some cases, proper ventilation was not used during the spray or the house was sprayed with improper technique (e.g. wrong mixing ratio of sides A and B). Of note, the spouses of two subjects were not at home during the spray and reported no or minimal symptoms.

All subjects stated that they had to vacate their homes due to persistent symptoms, despite ventilating the house and removing exterior foams. The symptoms improved after the subjects moved out, but when they visited their homes, the symptoms recurred shortly after they entered the houses. Subjects also reported similar symptoms whenever they were in contact with items retrieved from their homes, such as clothes, furniture, shoes, rugs, etc. They stated that they had to discard all the personal belongings from their original homes.

3.3. Analysis of VOCs from the foams

Because of the suspicion that the foams were emitting VOCs, several subjects had the foams removed from their houses for the test of offgassing VOCs. Fig. 1 showed an example of such a test, which used green closed cell foams removed from a house 20 months after the spray. It showed not only VOCs derived from the foams (hexamethyl-cyclotrisiloxane, octamethyl-cyclotetrasiloxane, diethylene glycol, and tripropylene glycol) but also VOCs that are common indoor air pollutants (acetone, toluenes and benzene compounds) (Fig. 1). Table 2 showed the top 10 VOCs in the headspace of a jar containing foams obtained from 3 different houses at least 6 months after the foam spray was completed. In addition to the compounds that derived from the foams (indicated by *), there were VOCs common to all three houses, such as benzene compounds (chlorobenzene). In houses 2 and 3, there