CONCEPT ACHTERGRONDDOCUMENT BIJ ADVIES GESPOTEN PUR-SCHUIM
Overzicht van studies naar blootstelling en studies naar gezondheidsklachten na woningisolatie met gespoten PUR-schuim

Table 3. Studies reporting exposure during and after spray polyurethane foam insulation

Table 4. Case reports

Table 3. Studies reporting exposure during and after spray polyurethane foam insulation

Author (year of publ) *Sponsor*	**Setting**	**SPF type**	**Conditions (ventilation, etc)**	**Measurement site**	**Sampling time**	**Exposure measures**
Measurements during and immediately after SPF isolation						
Bello (2019), *Center for Construction Research and Training through NIOSH Cooperative Agreement*	Spray polyurethane foam insulation at 14 sites in New England, of which 7 existing homes; 3 new homes, 3 training centers, 1 apartment in USA	Open and closed cell	Variable depending on site	Inhalation and dermal samples of sprayers, helpers, inside, and outside area. Biomonitoring.	During spraying 2h on average	Isocyanates in air and (MDA) urine biomonitoring
Bello (2018)	Four SPF insulation sites and one foam removal site in USA	Open and closed cell	Spraying and shaving of the foam. Foam removal.	Personal inhalation exposure and dermal exposure	During SPF insulation	flame retardants in air, and biomarkers of flame retardants in urine.
Bilan (1989)	Spray polyurethane foam application in three roofs, two barns, walk-in cooler, Quonset hut, horse stalls, Canada	Rigid foam (closed?)	Passive air flow (assumed)	Sprayer, helper, fixed distances from spray operation	During spraying; 60 to 190 minutes	MDI
Brennan (2013)	Two new residential constructions, USA	Open cell	No mechanical ventilation present during measurements	Application area and adjacent hallways	2h and 9h post-application area samples	MDI and amine catalyst
Crespo (1999)	Indoor (semi-open) and outdoor spray polyurethane foam insulation at 17 construction sites, Spain	Unknown	Passive air flow (assumed)	Sprayer, helper	During spraying; 3-7h	Airborne MDI
Estill (2019)	SPF at various commercial and	Open and closed cell	Preparation of spray area, spraying and	Air sampling (outside respirators) on	During entire work shift.	TCPP in air and hand wipes

	residential sites by 6 businesses		cutting of the foam, cleaning spray area	two consecutive days. Hand wipe samples before and after shift on day two.		
Havermans (2014)	Sprayed polyurethane foam insulation of 1 crawl space under concrete floor, the Netherlands	Closed cell (assumed)	Forced ventilation during and up to 30 in after isolation	Air samples in crawl space, living room, outdoor	During and after spraying; Up to 144h after insulation	(Di)isocyanates; Amine catalysts; Blowing agents
Hosein (1981) *Construction Safety Association Ontario*	Sprayed polyurethane foam at 7 sites representative of work by insulation companies (two new barns, retrofitting barn, truck, crawl space, new residential building), Canada	Unk	Varying room sizes	Air sampling in proximity of sprayer, 2m and 3m of sprayer.	During spraying; 105-442 min	TDI
Lesage (2007)	SPF application on basement walls or inside exterior walls in 5 single-family homes in US and Canada	Closed cell. Not reported but based on blowing agent and density	Passive air flow (assumed)	Applicators and assistants, various distances from application (1-3; 3-6; 6-12m)	During spraying up to 24h after completion	Airborne MDI monomer and and blowing agent
Robert (2012)	SPF application to first floor kitchen addition, attic, basement, garage of three existing homes, USA	Medium-density closed cell	With and without mechanical ventilation at 20-60 Air Changes per Hour	In application area and adjacent areas	During and 1h post-application	MDI, amine catalysts, flame retardants, blowing agents, and VOC's.
Robert (2014) *BASF*	SPF application on wall and roof in two homes under construction and a laboratory spray booth, USA	Open cell	SPF application and trimming. Natural ventilation via door and windows	Worker exposure	During and after SPF application. Trimming immediate after application, one	MDI, flame retardant, total volatile organic hydrocarbons, amine catalysts

					day and one week after application.	
RPS Advies en ingenieursburo (2014) *Kennisplatform Gespoten PUR-schuim*	SPF-isolation in 7 crawl spaces of homes with concrete or wooden floor, the Netherlands	Closed cell	One or two layers of SPF of different thickness, humidity, crawl space volume, forced post-ventilation 30-60min. Mechanical ventilation with air exchange rates from 50-200, but poorly executed in three homes.	Area air sampling in crawl space, at access to crawl space and nearest living area	Spray time 30-180min. Sampling during and up to 74h after spraying	Isocyanates (MDI and breakdown products), blowing agents, (amine)catalysts, flame retardant
Tian (2018)	SPF application on interior and exterior façade of a three-story single-family house in West Virginia, USA	Unk	Not reported	Sampling locations in 3 bedrooms and in the center of the attic	During and up to 24h after spraying (MDI). Other chemicals up to 3 months after spraying. Spraying took 4 days.	Airborne MDI, VOC's, flame retardants, blowing agents and airborne particles. Flame retardant accumulation in materials (carpet and drywall)
TNO-rapport R11049 (2013) *Nuon Isolatie B.V.*	SPF application in crawlspace in 3 test homes. Forced ventilation during and up to 30min after isolation. The Netherlands	Closed cell (assumed based on blowing agent)	Condition A: 1.0/0.9 MDI/polyol proportion. B: closed crawl space. C: normal procedure. Forced ventilation.	Living room, crawl space (after 144 only), outside air.	Before, during and after spraying; up to 144h after insulation. Spray time 45-60min.	Isocyanates, blowing agents, catalysts
Wood (2017)	Industrial hygiene study in a 11.2 m^3 chamber with 3 different commercial	Low-density high-pressure open-cell formulation; medium-density	Ventilation rates 10.4, 233, 598 Air changes per hour. NB: 10.4 Air	Air samplers in breathing zone of the spray applicator, and	15 min of spraying;	VOC's, MDI, flame retardants, amine catalysts,

Center for the Polyurethanes industry	SPF formulations. USA	high-pressure closed-cell formulation; low-pressure closed-cell kit formulation	changes per hour is seen as representative for residential setting	0.6m behind applicator	Sampling during and 30 min after spraying	blowing agents, aldehydes
Measurements long after SPF isolation						
	Spray polyurethane foam insulation in homes at east coast US. Attic only or attic, side walls and crawl space.	Closed cell but potentially also open.	Faulty application; subjects stayed home during application, returned too early, no ventilation was applied, or improper mixing technique.	Attic and family room	10 months after spraying attic; 3 months after spraying entire house	VOC's in indoor air samples and in vitro SPF samples
LBP sight rapport (2019) *Kennisplatform Gespoten PUR-schuim*	SPF isolation of crawl space. The Netherlands	Closed cell		Living room, crawl space, sample of SPF.	~30y after isolation	VOC, formaldehyde, MDI, biological agents
Poppendieck (2017) *National Institute of standards and technologies*	Furniture-free residential test facility with 15m^2 SPF in basement. Microchamber tests. USA	Open cell in residential setting. Open and closed cell in microchambers	Unfurnished house without carpet (TCPP source is SPF only)	Samples taken in basement (n=12) and on first floor (n=9), and outdoor	2y after application	Flame retardant: TCPP
TNO-rapport R10642 (2013) *Nuon Isolatie BV*	SPF isolation of crawl space. The Netherlands	Closed cell		Living room, crawl space	4 to 28 months after isolation. Median: 8/9 months.	Isocyanates, blowing agents, catalysts

MDA: 4,4'-methylenedianiline; MDI: methylene diphenyl diisocyanate; SPF: Sprayed polyurethane foam; TCPP: Tris-(1-chloro-2-propyl) phosphate; TDI: toluene diisocyanate; VOC: Volatile Organic Compounds.

Table 4. Case studies

Author (year of publication)	Setting	Exposed person (incl. medical history)	Time of symptoms, location	Symptoms	Medical diagnosis	Exposure measurement
Dietemann-Molard (1991)	Domestic use of commercial polyurethane foam for insulating a window and, 24h later, drilling of dry foam	38-year old men, bronchospasm after burning polyurethane packs, symptoms disappeared after changing jobs	Acute during insulation and drilling.	Asthmatic reaction while insulating window, facial swelling while drilling	Four months later, high levels of blood eosinophilia and specific IgE against isocyanates. Skin-prick tests negative, patch tests with foam and MDI positive. Bronchial provocation test with TDI negative. Realistic test with foam containing MDI induced acute bronchospasm.	none
Huang (2014)	Spray polyurethane foam insulation in home at east coast US. Faulty application; subjects stayed home during application, returned too early, no ventilation was applied, or improper mixing technique.	13 adults from 10 households	Acute, and long after application. At home only, all subjects eventually vacated their homes.	Fishy odors, watery and burning eyes, burning nose, sinus congestion, throat irritation, cough, dyspnea, chest tightness (n=13). Neuropsychiatric symptoms including headache, dizziness, forgetfulness, difficulty in	Metacholine test after >6 months in 7 subjects of which one was positive. This subject had a history of mild intermittent asthma. IgE for isocyanates was negative for 4 subjects who had the test done after >5 months.	Increased concentrations of SPF-derived and indoor VOC's in indoor air samples (5 houses, at least 6 months after application) and in vitro SPF samples (from 3 houses). Indoor air VOC decreased after SPF removal (2 houses)

				concentration, insomnia (n=12). Nausea, vomiting abdominal cramps (n=3), skin rash (n=3)		
Lacroix (1984)	Polyurethane insulation and room humidification (on doctor's advice) after first symptoms	Two girls, aged 1,5 and 3,5 years	Some after insulation, most after room humidification was started.	Child 1.5 year old: Breathing problems and pneumonia. Asthma after humidification. Child 3.5 year: breathing problems and pneumonia after humidification. Both girls have anorexia, headache, nausea and vomiting after humidification. Symptoms disappear after humidification stopped.		Water and mold on walls. Characterization of molds
Redlich (2013)	Polyurethane foam application in homes of 4 families	Subjects and family members	After application, home-related	Upper airway, mucosal and central nervous system symptoms, distinct odor	No new onset asthma or sensitization to MDI	Qualitative reporting of high total VOC (above recommended levels), detection of amine catalysts, siloxanes, blowing agents, fire retardants, aldehydes, polyols up to 20 months. No MDI detected.

Tsuang (2012)	SPF insulation of a residential home, USA	36-y old men and 38-y old women of the same household without significant medical history, non-smoking, office-based professions.	Acute at returning home after SPF application (4 hours after completion of application). And chronic.	Acute and persistent: noxious odor, cough, dyspnea, dizziness, nausea, headache, watery eyes.	Positive methacholine challenge test. Asthma or reactive airway dysfunction syndrome diagnosis induced by exposure to isocyanates. Bronchodilators and inhaled steroids treatment	none
Verschoor (2013)	SPF insulation of crawl space in residential homes, the Netherlands	11 persons from 7 households	Acute or chronic (?) in home. Symptoms disappeared when leaving home.	(reported more than once) Dyspnea: 6 Eye complaints: 5 Cough: 4 Sore throat: 4 Concentration problems: 2 Swallowing complaints: 2 Feel miserable: 3 Stomach/gut complaints: 2 Skin rash: 3 Irritation mouth/tongue/throat: 3 Headache: 3 Muscle pain: 2 Tired: 2		None
Verschoor L (2013)	SPF insulation of cavity wall	62-y old men	Day 2 after isolation	Acute: odor Day 2: tired, dyspnea. Chronic: stuffy nose, skin complaints,	Diagnosed as allergic or anaphylactic reaction. Bronchial hyperreactivity.	Measurements done but results not reported.

				allergic reaction to other compounds.	Allergic astma or COPD.	

MDI: methylene diphenyl diisocyanate; SPF: Sprayed polyurethane foam; VOC: Volatile Organic Compounds