

Skin exposure to epoxy in the pipe relining trade—an observational study

George Fillenham, Carola Lidén and Ingegärd Anveden Berglind

Institute of Environmental Medicine, Karolinska Institutet, SE-171 77 Stockholm, Sweden

doi:10.1111/j.1600-0536.2012.02065.x

Summary

Background. Epoxy resin systems (ERSs) are frequent causes of occupational allergic contact dermatitis. Epoxy pipe relining has become a widely used alternative to replacing old and worn drain pipes in housing, and involves a high risk of skin exposure to ERSs.

Objectives. To map out work methods, protective measures and skin and surface contamination among workers involved in epoxy pipe relining, as a basis for prevention of occupational skin disease.

Methods. Twenty-one employees in eight relining companies in Stockholm County were observed. Contact and contamination with ERSs and the use of personal protective equipment during relining work were noted.

Results. Contamination by uncured ERSs on gloves, personal and shared tools and work areas was identified during mixing, wetting, installation, and cleaning. The gloves used were often inadequate for handling ERSs.

Conclusions. Relining pipes poses an extensive risk of uncured ERS exposure, and contamination was identified during the whole work process. Shared and personal tools and work areas were extensively contaminated. Changes in work routines and logistics for handling ERSs are essential, and knowledge among both employers and employees regarding the risks caused by ERS exposure is vital to create a safe work environment and prevent contact allergies.

Key words: contact dermatitis; epoxy resin systems (ERSs); exposure; observation; occupational skin disease; personal protective equipment; pipe relining; prevention.

Epoxy resin systems (ERSs) are frequent causes of occupational allergic contact dermatitis (1–4). Epoxy pipe relining has become a widely used alternative to replacing old and worn drain pipes in housing, and involves a high risk of skin exposure to ERSs (Fig. 1) (5).

The aim of the present study was to record work methods, protective measures and skin and

surface contamination among workers in epoxy pipe relining, as a basis for prevention of occupational skin disease.

Subjects and Methods

Study population

The study group consisted of 21 employees, in 10 workplaces of eight companies, working in epoxy pipe relining in apartment buildings and other housing in Stockholm County. The mean age of the participants was 32.2 years (range 19–64 years), and their mean length of experience in the relining trade was 2.8 years (range 2 months to 12 years). The study was performed between November 2010 and May 2011.

Correspondence: Ingegärd Anveden Berglind, Unit of Occupational and Environmental Dermatology, Institute of Environmental Medicine, Karolinska Institutet, Box 210, SE-171 77 Stockholm, Sweden. E-mail: ingegard.anveden.berglind@ki.se

Conflicts of interest: The authors have declared no conflicts. *Funding:* Financial support in the form of grants from AFA Insurance and the Swedish Council for Working Life and Social Research.

Accepted for publication 1 January 2012



Fig. 1. The photographs show epoxy pipe relining work: a temporary worksite (a), a worker mixing the epoxy resin systems (ERSs) with the bucket between his feet (b), one worker holding the liner and the other worker pouring the mixed ERSs into the liner (c), and a prepared liner being inserted into the inversion drum (d).

Relining method in the study

The general principle of relining is to create a new pipe within the existing one. Different methods, materials and techniques are used. In the present study, only the liner method, the most frequently used method in Sweden, was used. A resin-impregnated felt/polyester liner is inserted into the existing pipe (Fig. 1). First, the pipes are inspected and cleaned of any corrosion and debris. Depending on the type of pipe, two different techniques are used (Fig. 2). When longer pipes, such as a building's main pipe, are relined, the epoxy-impregnated liner is inserted with the aid of an inversion drum. Here, epoxy is poured into the liner and then evenly rolled out along the length of the liner (Fig 1b). The liner is then placed into the inversion drum and inserted into the pipe with compressed air. A bladder-like calibration hose is then inserted into the pipe and inflated to ensure that the liner is properly bonded to the pipe.

When shorter pipes and connections between branch lines and main lines (top-hat liners) are relined, the liner is installed with a calibration hose. Epoxy is poured directly

onto the liner and distributed evenly, and the liner is then threaded onto the calibration hose. A thin plastic rod is used to ensure that the liner is positioned correctly on the hose. Tape or thin wire is then tied around the liner to keep it in place when it is inserted into the pipe. In some cases, the liner is threaded onto the hose and then doused in epoxy. Before insertion into the pipe, the calibration hose is deflated. Once in place, the liner is inflated, bonding it to the existing pipe. When the resins have cured and the liner has become solid, the hose is removed. Between installations, before lunch breaks, and at the end of the work day, the work areas are cleaned. The cleaning procedure involves wiping off work surfaces and removing contaminated building plastic, buckets, personal protective equipment (PPE), and tools.

Workplaces

The workplaces in the study were either mobile or temporary. The mobile workplaces were containers or trailers remodelled into workshops that could be moved from worksite to worksite. This is where preparations before



Fig. 2. Flow chart of the main stages in epoxy pipe relining work.

installation were carried out, and where tools and equipment were kept. The temporary workplaces were areas made available in the building where the relining was performed.

Observing and recording work and exposure

A trained observer (G.F.) performed all observations. A framework for the observations was established after visiting a number of workplaces, prior to the actual observations. The process was divided into four stages: mixing, wetting, installation, and cleaning (Fig. 2). The wetting and installation stages were further divided into relining with a calibration hose and relining with an inversion drum.

The FIT software system (J. Held, Swiss Federal Institute of Technology, Zurich, Switzerland) was used for data collection (6). On a hand-held computer (Palm®), we used the software to calculate and store start and stop times for the observations, as well as the frequency with which the various labelled fields were activated. Contact with uncured ERSs and use of gloves and other PPE were also registered. Areas on the computer screen corresponded with incidents to be recorded: direct contact with ERSs on gloves, contamination of shared/personal tools and work areas, contact with previously observed contaminated shared/personal tools and work area, number of gloves used simultaneously, and use of solvents.

Items such as pliers, electric screwdrivers, drills, compressed air gauges, inversion drums, mixing buckets and work surfaces were defined as shared tools. Tools that the worker carried at all times such as knives, tape measures, mobile phones, hearing protectors, and respiratory protective masks, were defined as personal tools.

In addition, an observation diary was kept. The diary was used to document the exact glove types used by the workers, as well as information regarding other PPE used, such as respiratory protective masks, hearing protectors, and aprons. Furthermore, data regarding the particular work area and work methods used under observation were recorded. Also, any errors registered on the hand-held computer during observations were noted.

Results

Workplaces

The area of workshops was approximately 8 m² each (Fig. 1d). Nine of the 10 observed workplaces were containers or trailers. The interiors, although varying in finish, were similarly equipped with draws, shelves, and a workbench used for wetting and other preparations. Three workshops had a mixing area fitted with a spatter shield, and one worksite utilized a second container for mixing and storing used buckets and other equipment. The workshops were all similarly contaminated, with visible traces of epoxy resin on walls, floors, doors, drawer handles, worktops, and electrical switches. Relining equipment such as calibration hoses, inversion drums, air-pressure gauges and buckets for mixing were visibly contaminated, as were power drills, knives, and pliers. At one firm, the workplace consisted of a van for storing tools, work with ERSs being carried out in an available area at the worksite, either in a basement or in proximity to the pipes being restored. None of the workplaces were equipped with adjacent washrooms, but nine out of 10 of the workplaces had access to a washroom in the building where the relining was performed.

Two worksites were equipped with ventilation systems placed over the workbench where wetting and other preparations was performed. In the workshops without ventilation systems, workers would open the entrance door when mixing and wetting. This was only done briefly, as temperatures were often below 0°C during observations. During the last observations, when temperatures were warmer, the workers aired the workshops more extensively. On these warmer days, mixing was performed outside the container. The workplace that used a separate container for mixing lacked a ventilation system, and was often aired more thoroughly.

PPE and contamination

Gloves and other PPE. Table 1 shows the observed use of gloves and other PPE during the different stages of relining. Glove use varied from no gloves to combinations including a multilaminated, chemical-protective glove (called a multilaminated glove; see below). All of the workers wore long trousers and a long-sleeved jumper throughout the workday. Respiratory protective masks and hearing protectors were available at most of the worksites, but were used irregularly. When masks and hearing protectors were used, the workers, when communicating during installations, would often remove them. Clean work clothes were not available at the workplaces. None of the workers used protective aprons, which were available at one of the observed worksites. Further details on how contamination occurred are given in the description of the observed mixing, wetting, installation, and cleaning.

Contact and contamination. Table 2 shows incidents of observed contact with ERSs by gloves, tools and other surfaces during the different stages of pipe relining. Contact with uncured ERSs on gloves was registered in 28 of 36 of the mixing stages, and in 38 of the 44 installations observed. Contact with ERSs without any glove protection was also observed. Contamination of personal and shared tools or work areas was observed during all working stages. Furthermore, contact with previously contaminated tools and work areas was especially observed during cleaning.

Mixing

Thirty-six mixing sessions were observed. The mean duration was 9 min. The ERS components were mixed by use of a bucket and power drill, and the components were poured by hand into a bucket and weighed to establish the correct composition. In seven workplaces, workers mixed with the bucket between their feet, either in the workshop or outside, depending on the weather.

Weighing machines were covered with plastic film to protect them from spillage in all observed worksites. When the ERS was poured into the mixing bucket, the base and hardener would often trickle down the outside of the containers, contaminating the containers and the workers' hands in the process. Despite this contamination, a glove change was only recorded in three of 36 observed sessions, and ERS was often transferred onto the power drill. Also, contact with ERSs occurred regularly when the workers transported the mixing buckets, as these were often recycled and visibly contaminated, on both the inside and the outside. In the workplaces where mixing was performed without a shield, ERS

spatter would often contaminate nearby surfaces, and on two occasions the workers' trousers were contaminated. Furthermore, on three occasions the bucket escaped the workers' grasp during mixing, with spillage and contact with ERSs occurring. In the mixing areas with a spatter shield, epoxy spatter was visible on walls, the shield door, and the upper edge of the shield, where workers put their hands when opening and closing the shield.

Wetting

Twenty-four wetting sessions with a calibration hose and 13 with an inversion drum were observed. The average times for the wetting stages were 9 and 6 min, respectively. The amount of ERS used was 1–40 kg, depending on the length and width of the pipe.

Calibration hose. Nine of 10 workplaces wetted the liner in the workshop on a work table, which was protected by building plastic. The ERS mixture was then poured onto the felt liner and massaged in by hand to ensure that the ERS was evenly drawn into the liner. Excess ERS was then squeezed out, either back into the mixing bucket or directly onto the protective building plastic. The liner was then threaded onto the deflated calibration hose. At one workplace, wetting was performed in the area next to the pipes to be restored. Here, the workers placed the liner in a tub and then poured the ERS into the tub.

When a liner was wetted before installation with a calibration hose, it was not possible to avoid glove contact with the ERS (Table 2). When the plastic rod was used, it became completely covered in epoxy. Pliers and personal knives used for cutting wire and tape often became contaminated, as did spray cans used for marking connection points on the liner.

Inversion drum. Three of seven workplaces that relined with an inversion drum used a funnel for pouring the ERS mixture into the liner. At the remaining workplaces, one worker held the liner upright while a second poured in the mixture, sometimes spilling ERS onto the worker holding the liner and contaminating the exterior of the mixing bucket. The ERS mixture was then distributed evenly with a roller or by hand. When excess ERS was rolled out into a plastic glove or mixing bucket, contact between the ERS and the workers' hands was common. Furthermore, hand-held drills used for fastening the liner to the inversion drum nozzle were contaminated with ERSs.

Installation

Thirty installation sessions with a calibration hose and 14 with an inversion drum were observed. The average

Table 1. Use of gloves and other personal protective equipment (PPE) during mixing, wetting, installation, and cleaning in epoxy pipe relining

Type of PPE and its usage	Number of work sessions in which PPE was used or not					Cleaning (n = 36)
	Mixing (n = 36)	Wetting		Installation		
		Hose (n = 24)	Drum (n = 13)	Hose (n = 30)	Drum (n = 14)	
Gloves						
No gloves	1	1	0	0	0	6
One pair of thin gloves ^a	9	4	2	13	4	27
Two or more pairs of thin gloves ^b	19	12	11	9	10	3
Combination including a pair of butyl rubber gloves	1	5	0	5	0	0
Combination including a pair of multilaminated gloves	6	2	0	3	0	0
Other protective equipment (hearing or respiratory)						
No respiratory, no hearing	11	14	4	4	4	36
Hearing, no respiratory	1	0	0	5	0	0
Respiratory, no hearing	4	8	9	6	0	0
Respiratory and hearing	20	2	0	15	10	0

Drum, relining method with an inversion drum. Hose, relining method with a calibration hose. n, number of work sessions observed.

^aOne pair of nitrile rubber, natural rubber latex rubber, vinyl, or polythene gloves.

^bTwo or more pairs of nitrile rubber, natural rubber latex, vinyl or polythene gloves.

The workers were observed and the use of PPE was recorded on a hand-held computer. When the degree of protection varied during an observation, the lowest degree of protection is given.

Table 2. Contact with epoxy resin systems (ERSs) and contamination of gloves, tools and other surfaces during mixing, wetting, installation and cleaning in epoxy pipe relining

Type of contact with uncured ERSs	Number of work sessions with ERS contact					
	Mixing (n = 36)	Wetting		Installation		Cleaning (n = 36)
		Hose (n = 24)	Drum (n = 13)	Hose (n = 30)	Drum (n = 14)	
Contact with gloves	28	24 ^a	10	29	9	10 ^a
Contaminating shared or personal tools or work surfaces	22	17	6	17	5	3
Contact with previously contaminated shared or personal tools or work surfaces	10 ^a	0	2	6	3	21 ^b

Drum, relining method with an inversion drum. Hose, relining method with a calibration hose. n, number of work sessions observed.

^aOne account of observed contact with ERSs without any glove protection.

^bThree accounts of observed contact with ERSs without any glove protection.

The workers were observed and incidents of contact with ERSs were recorded on a hand-held computer.

times were 13 and 8 min, respectively. When installing, the workers accessed the pipes through the kitchen or bathroom drains or via the attic or basement, depending on the task. Working space was limited, with the workers crouched down on their knees during installations. Toilets, washbasins and such had been removed earlier, and building plastic or cardboard had been put down to protect floors.

Calibration hose. The prepared liner was transported from the workshop to the pipe by hand, wrapped in building plastic. Once in the wet room, the calibration hose was connected to a compressed air hose, deflated, and then pushed down the drain. The workers then tried to correctly align the top hat with the branch connection. If this took too long, the ERS would begin to harden and the liner

would have to be removed, to prevent it blocking the pipe. To manoeuvre the liner into place, the workers continuously pushed and pulled at the calibration hose and air-pressure hose, almost always coming in contact with the ERS-soaked liner and contaminating parts of the air-pressure hose. During installations, the workers took off layers of gloves, but seldom replaced them with new ones. Frequent communication between the workers when they were manoeuvring the liner resulted in visibly contaminated mobile phones and hearing protectors.

Inversion drum. After the liner was wetted and inserted into the inversion drum, it was transported by hand to the open pipe in the attic or basement. Pipes connecting apartments to the main were accessed via the kitchen sink (drain). At the pipe (access point), a compressed air

hose was attached to the inversion drum. The worker aimed the inversion drum nozzle into the open pipe and applied air pressure, 'pushing' the liner into the pipe. When inserting the calibration hose, to ensure that the liner bonded properly, the workers would often come in contact with the ERS-soaked liner.

Cleaning

In total, 36 cleaning sessions were observed, with a mean duration of 10 min. The cleaning procedure regularly involved contact with contaminated building plastic, work surfaces, buckets, tools, and PPE. When cleaning off ERSs, workers used Scrubs[®], an alcohol-soaked cloth.

Discussion

Pipe relining carries obvious risks of ERS skin exposure. No observational study regarding relining work, as far as we know, has previously been presented.

The workshops were without access to an adjacent washroom, and the working space was never more than a few square metres, which impaired the ability to work safely. The workshops were all similarly contaminated with traces of ERSs everywhere, which may imply further contacts with uncured ERSs that were not captured in this study. In addition, tools were visibly contaminated, underlining the difficulties in avoiding exposure. In the workshops without ventilation systems, workers opened the entrance door briefly when mixing and wetting. Despite the lack of sufficient ventilation, respiratory protective masks were used during only half of the wetting sessions.

Mixing regularly resulted in contamination, even when a separated area for mixing was used. When wetting during relining with a calibration hose is performed, contact with ERSs on gloves is expected, as intense manual handling of the equipment and ERSs is required, and this was therefore registered separately. It is noteworthy that some of the workers used only a pair of thin gloves when wetting, and 1 individual was in contact with the soaked liner with his bare hands. Installations were sometimes complicated and stressful, with frequent communication between the workers via mobile phones at the same time as they were manoeuvring the liner in the pipe. These simultaneous tasks resulted in peeling off of gloves, reduced protection, and recurrent contamination.

Contact with previously contaminated tools and work areas was predominately registered during mixing and cleaning. The level of glove protection during cleaning was generally low. Cleaning was probably not perceived by the workers as being a hazardous part of the work process.

Gloves and other PPE used were inadequate for handling ERSs (7). Multilaminated gloves, which constitute an excellent protective measure when properly used, were not regularly used. Gloves were peeled off and the level of glove protection tended to decline during the observed work sessions. A single pair of thin gloves, especially when made of polyvinyl chloride, provides insufficient protection, owing to rapid penetration of ERSs (7). Solvents that were frequently used during the cleaning sessions can shorten the penetration time. Thick butyl gloves generally offer better protection than thin gloves, but were reused during the day, which might increase the risk of contamination. The work clothes used constitute an insufficient level of protection, and, in addition, no clean clothes were available.

Thus, the work methods and the level of protection in the relining trade cause skin exposure to uncured ERSs on a daily basis. The present study shows that hazardous exposure took place throughout the relining process. Changes in work routines and logistics for handling ERSs are essential to reduce the risk of skin exposure, sensitization, and contact dermatitis. Examples of measures for exposure reduction could be as follows: not recycling used buckets; the use of pre-prepared liners; automating the filling and mixing of ERSs; having a separated, closed mixing area; and instituting a structured cleaning procedure. In addition, better knowledge regarding ERS exposure among both employers and employees is vital to create a safe work environment.

The most common cause of contact allergy to ERSs is diglycidyl ether of bisphenol-A (epoxy resin MW 340) (2, 3). In addition, the reactive thinners and the polyamine hardeners contain strongly sensitizing chemicals (8, 9). Thus, for examination of relining workers with suspected allergic contact dermatitis, the European baseline series is not sufficient. Furthermore, skin irritation caused by hardeners may facilitate sensitization. Most contact allergies to ERSs are considered to be type IV allergy, but contact urticaria has been reported (9, 10).

In a recent German study of the building trades, epoxy allergies were shown to have increased in the past 10 years (4). The consequence for the individual of developing allergic contact dermatitis caused by ERSs is considerable (11). In our recent study, 7 of 8 patients had to leave their work in the relining trade owing to eczema caused by allergy to ERSs (5). They had experienced strong and widespread eczematous reactions, and they were not able to avoid eczema. Individuals who develop airborne contact allergy to ERSs are, in some cases, unable to visit worksites where ERSs are being used.

According to the work environment regulations in Sweden regarding thermosetting plastics, an employee

exposed to ERSs must undergo medical examination prior to employment, and be further examined if symptoms attributable to contact with ERSs appear (12). Apparently, the relining work assessed in the present study is not performed in accordance with the regulations.

For study of skin exposure in the epoxy pipe relining trade, with limited previous knowledge of the processes involved, non-participant observation is a suitable method. It allows the researcher not to rely only on second hand information, but to understand how and when the workers become exposed. We found the observation method used in this study to be well adapted and easy to use. It is, however, both time consuming and resource consuming, although it has a previously documented high level of reliability (13–15).

The purpose of the observations was to study work methods during the course of a normal work day. The presence of the observer in the cramped work area may have altered the work process. Furthermore, the workers received information regarding the objectives of the study, which might have influenced the workers to be more safety conscious. All observations were performed during the winter, when temperatures in Sweden are often below freezing. During this period, the relining workers always wear long sleeved sweaters, and sometimes jackets. During the warmer summer months, the work tempo is much

higher, with sometimes only 10 min between preparations and installations before the ERSs begin to cure. However, the workers reported that, during summer, they often wear T-shirts, leaving the arms more exposed.

Another relining technique, less often used in the Stockholm area, is the spray method. Instead of a liner being used, the existing pipe is coated with three thin layers of ERS, by use of a hose with a spray brush on the end. Vinyl toluene and polyurethanes are sometimes used as an alternative to ERSs. The spray method involves possible risks of ERS exposure.

In conclusion, epoxy pipe relining leads to an extensive risk of ERS exposure. Heavy contamination by uncured ERSs was identified during the whole work process. Shared and personal tools and work areas were extensively contaminated. The gloves used were often inadequate for the task. Changes in work routines and logistics for handling ERSs are essential to reduce the hazardous exposure. In addition, better knowledge and understanding, among both employers and employees, regarding risks caused by ERS exposure are vital to create a safe work environment and prevent contact allergies.

Acknowledgements

Financial support was received from AFA Insurance and the Swedish Council for Working Life and Social Research.

References

- Pontén A, Carstensen O, Rasmussen K, Gruvberger B, Isaksson M, Bruze M. Epoxy-based production of wind turbine rotor blades: occupational contact allergies. *Dermatitis* 2004; **15**: 33–40.
- Pontén A, Bruze M. Contact allergy to epoxy resin based on diglycidyl ether of bisphenol F. *Contact Dermatitis* 2001; **44**: 98–99.
- Jolanki R, Kanerva L, Estlander T, Tarvainen K, Keskinen H, Henriks-Eckerman M-L. Occupational dermatoses from epoxy resin compounds. *Contact Dermatitis* 1990; **23**: 172–183.
- Geier J, Krauthelm A, Uter W, Lessmann H, Schnuch A. Occupational contact allergy in the building trade in Germany: influence of preventive measures and changing exposure. *Int Arch Occup Environ Health* 2011; **84**: 403–411.
- Anveden Berglind I, Lind M-L, Lidén C. Epoxy pipe relining – an emerging contact allergy risk to workers. *Contact Dermatitis* Epub ahead of print 24 February 2012.
- Held J, Manser T. A PDA-based system for online recording and analysis of concurrent events in complex behavioural processes. *Behav Res Methods* 2005; **37**: 155–164.
- Forsberg K, Keith L H. *Chemical Protective Clothing Performance Index*, 2nd edition: New York, John Wiley & Sons 1999.
- Geier J, Lessmann H, Hillen U et al. An attempt to improve diagnostics of contact allergy due to epoxy resin systems: first results of the multicentre study EPOX 2002. *Contact Dermatitis* 2004; **51**: 263–272.
- Jolanki R, Estlander T, Kanerva L. 182 patients with occupational allergic epoxy contact dermatitis over 22 years. *Contact Dermatitis* 2001; **44**: 121–123.
- Kanerva L, Pelttari M, Jolanki R, Alanko K, Estlander T, Suhonen R. Occupational contact urticaria from diglycidyl ether of bisphenol A epoxy resin. *Allergy* 2002; **57**: 1205–1207.
- Cahill J, Keegel T, Dharmage S, Nugriaty D, Nixon R. Prognosis of contact dermatitis in epoxy resin workers. *Contact Dermatitis* 2005; **52**: 147–153.
- Swedish Work Environment Authority. Thermosetting plastics – ordinance issued by the Swedish Work Environment Authority, containing provisions on thermosetting plastics and general recommendations on implementation of the provisions, 2005. AFS: 2005:18.
- Anveden I, Alderling M, Lidén C, Meding B. Skin exposure in geriatric care – a comparison between observation and self-assessment exposure. *Contact Dermatitis* 2007; **57**: 253–258.
- Wiktorin C, Mortimer M, Ekenvall L, Kilbom L, Hjelm E W. HARBO, a simple computer-aided observation method for recording work postures. *Scand J Work Environ Health* 1995; **21**: 440–449.
- Anveden I, Alderling M, Lidén C, Meding B. Self-reported skin exposure, validation of questions by observations. *Contact Dermatitis* 2006; **55**: 186–191.