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Assessment and Remediation of Misapplied Spray Polyurethane Foam

Citation

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ABSTRACT

Misapplication of spray polyurethane foam (SPF) insulation may result in occupant complaints associated with persistent odor. SPF installed in homes may fail to completely cure when the contractor does not follow specified procedures (e.g., with respect to the depth of individual layers, timing between layer application, ratio, temperature, and mixing of SPF components). Few data are available on emissions from misapplied spray polyurethane foam (MSPF), and field practices used to control odors have not been validated. This paper discusses strategies for resolving MSPF odor concerns and suggests an assessment/mitigation protocol for field use pending further research. MSPF is suggested by a persistent "fishy" type of odor after installation. A visual inspection looking for discoloration and discontinuities may be helpful in confirming the presence of MSPF and estimating its extent. Limitations in the sensitivity and selectivity of air sampling methods available to field practitioners may preclude the identification of contaminants associated with MSPF emissions. Emissions testing of bulk samples facilitates the identification of airborne contaminants under more concentrated conditions, but data interpretation is subject to considerable uncertainty. Interim exposure reduction pending remediation can be achieved by site isolation and ventilation. A mitigation process has been suggested for resolving odors associated with MSPF

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that involves the removal of MSPF, cleanup, resealing the substrate with properly cured SPF, and ventilation. Verification of odor control can be based on systematic evaluation under specified conditions. Recommendations for refining and validating assessment and mitigation protocols are presented. Additional research is needed to better understand and resolve potential health risks. Tertiary amines associated with SPF catalysts are significant contributors to MSPF odor. Lower-emitting catalysts are now being introduced into SPF products with a potential to reduce MSPF odors.

Keywords
spray polyurethane foam, indoor air quality, remediation, odor, amine, assessment

Introduction

This paper addresses situations in which the misapplication of spray polyurethane foam (SPF) interferes with the curing process and unreacted components are released that produce persistent odors. This is an infrequent event, occurring when product application requirements are not followed (e.g., layers of SPF exceed a specified thickness, insufficient time is allowed between layer application, the ratio between the two product components is incorrect, the temperature is outside the specified range, etc.) [1]. Slight odors may be detected from properly applied SPF immediately after installation. MSPF is suggested when a "fishy" type of odor is initially strong or continues to be detected beyond a few weeks. This odor gradually diminishes over time but has been reported to persist for more than a year.

Although protocols have been established for resolving sources of indoor air pollutants such as asbestos, mold, and corrosive drywall [2–4], efforts to control odors from misapplied spray polyurethane foam (MSPF) have not been standardized or validated. Protocols for restoring sites affected by other sources of contamination have included the following elements:

- Problem identification based on observation of suspect conditions
- Inspection to characterize site conditions
- Project objectives based on target contaminant concentrations, odor elimination, etc.
- Interim site management to minimize exposure pending mitigation
- Mitigation measures to restore site
- Inspection or sampling to clear site for reoccupancy, or both

SPF is widely used to insulate and air seal new structures and weatherize older buildings. Diisocyanates, the component presenting the most widely recognized health concern, are only briefly airborne and have not been detected within a few hours after application [5–7]. Industry guidance requires that occupants be protected from exposure by vacating the structure during and immediately after application [8–10]. Similar to other building materials, installed SPF emits various volatile

organic compounds (VOCs) that diminish over time [5–7]. SPF installation may increase preexisting ambient concentrations of VOCs by reducing air infiltration.

Methodology

The scope of this paper is limited to odor concerns associated with MSPF (potential health effects are not addressed). Findings are based on published literature and the author's field experience evaluating indoor air quality (IAQ) complaints attributed to SPF. There are few published journal papers on this subject, with conference papers and industry publications providing much of the available information. Recommended procedures for assessment and mitigation are modeled after protocols established for the restoration of other types of indoor contamination. The discussion is generally applicable to most open- and closed-cell SPF products but not to single-component SPF sealants.

Emissions from Misapplied SPF

MSPF emissions may include unreacted catalysts (e.g., amines), flame retardants (e.g., organophosphates), blowing agents (e.g., hydrofluorocarbons), and polyols [1,7,9]. Because incomplete curing increases heat generated by the process, other volatile reactants may also be emitted [1].

Preliminary results from two limited studies of MSPF emissions have been reported. Genz et al. [1] compared emissions from foam applied per specifications (SPF) to misapplied foam (MSPF). MSPF was created under laboratory conditions using various combinations of deliberately created thick layers, off-specification ratios, and damp conditions. Foam odor was strongest when layers exceeded specified thickness and components were off-ratio and persisted several days after application. Tertiary amines appeared to be the primary source of odor, and the authors suggested that added catalyst compounds may have reacted to form other amines at the elevated temperature of MSPF (foam temperature measured up to 180°C compared to 80°C in SPF applied per specification).

Genz et al. measured emissions from foam samples immediately after application in a test facility at 140 air exchanges per hour. Diisocyanates were sampled per ISO 14382, and VDA 278 was utilized to test for polyols, catalysts (amines), flame retardants (triethyl phosphate), and blowing agents (hydrofluorocarbons). Emissions were then tracked over time [1]. Measured emissions are summarized in **Table 1**.

Although no diisocyanates or polyols were detected in any samples, MSPF emitted higher concentrations of amines, triethyl phosphate, and hydrofluorocarbons. After 10 days, all SPF emissions were below detection limits, whereas MSPF emissions continued [1]. This study was limited in scope, with only one SPF product tested and the analysis limited to listed product components.

The only other available study of MSPF emissions was summarized by a manufacturer that tested off-ratio foam (methodology not specified). No isocyanates were

TABLE 1 Emissions from foam applied per specification (SPF) versus misapplied foam (MSPF).

	Immediately After Application (μg/m³)		10 Days After Application (μg/m³)	
	SPF	MSPF[1]	SPF	MSPF[1]
Diisocyanates	ND	10	ND	ND
Polyols	ND	ND	ND	ND
Amines	2,500	5,000	ND	ND
Triethyl phosphate	2,000	3,500	ND	1,000
Hydrofluorocarbons	1,500	1,500	ND	45,000

Note: From Ref. [1]. ND = not determined.
[1]Maximum concentration from various treatments (e.g., ratio, thickness).

detected within a few hours of application. Several VOCs were found at 24 h but were nondetectable at 72 h. A tertiary amine continued to be measured up to 35 μg/m^3 at 72 h [9].

Available information suggests that tertiary amines are important contributors to SPF odor [1,6,7]. A wide variety of these compounds may be present depending on product formulation. Amine catalysts SPF have traditionally been nonreactive, leaving excess free gas after the A- and B-side SPF components were mixed. Some SPF formulations have recently substituted "reactive" amine catalysts that reduce odor by increased bonding with the other SPF reactants [11–13]. Studies have shown amine emissions from reactive catalysts quickly decrease below the detection limit, whereas emissions continued from nonreactive catalysts [14]. The use of nonreactive catalysts may reduce detectable odor when misapplied.

Recognition of Misapplied SPF

MSPF odor varies in intensity and may not be readily identified without a systematic odor survey. The recognition of MSPF odor is facilitated by closing and warming up the structure before inspection and enlisting an informal panel of individuals capable of detecting common odors. Locating the odor source may be facilitated by noting where suspect odor is strongest after isolating spaces (e.g., closing interior doors or covering an insulated surface with plastic sheeting) and then noting odor intensity.

Odors other than the fishy type of smell may originate from non-MSPF sources. Odor patterns can help distinguish MSPF from other sources. For example, the odor should not have a preexisting SPF application. When used to weatherize existing structures, preexisting odors may increase in intensity because of reduced ventilation. Other odor complaints may be associated with construction off-gassing unrelated to SPF or from increased dampness.

Although ambient air sampling at SPF sites measures the concentration of some contaminants, it cannot be relied on to conclusively identify MSPF or quantify occupant exposure. Indoor air sampling in noncompliant buildings typically

detects >100 compounds [15,16], and contaminants emitted by MSPF may not be readily distinguished from normal background. Furthermore, MSPF emissions with potential IAQ significance may not be detected because of limitations in the sensitivity and selectivity of analyses available from commercial laboratories (e.g., amines). In contrast, the human nose is often capable of detecting and recognizing low concentrations of amines.

Site Inspection

Where persistent odor is suspected of originating from MSPF, visual inspection can be helpful in confirming the source. MSPF may be identified visually by an inspector familiar with SPF characteristics. Cured SPF has uniform texture and coloration, whereas MSPF may be distinguished by dark stains produced by elevated reaction temperature, discontinuities (e.g., bubbles), or failure to solidify (A and B components applied off-ratio) [17].

Indicators of misapplication may be visible on the surface, but core sampling may be necessary to confirm the presence of discoloration and discontinuities [17]. Core sampling sites should include areas that appear to have the strongest odor. Sealing core samples in plastic bags and then evaluating the headspace for the characteristic odor can be useful in confirming the location of MSPF. From core sample observations, the inspector can evaluate additional surfaces for darkening, bubbles, or failure to solidify and may also be able to determine if layers exceeded specified thickness.

Chamber testing of core samples facilitates the identification of compounds associated with emissions by increasing contaminant concentrations. However, it should be recognized that concentrations measured in chamber tests are not representative of occupant exposure. In addition, contaminants from renovation activities and other sources may be adsorbed and then re-emitted from SPF. Investigators have analyzed MSPF emissions for isocyanates, amines, VOCs, and aldehydes, but interpreting emissions data is subject to the same limitations noted previously for ambient air sampling.

In cases in which MSPF is localized, an inspection may suggest boundaries for foam removal. In other situations, there may not be a clear boundary separating MSPF from properly cured foam, and all SPF in areas with a persistent fishy type of odor may need to be included in the scope of removal. Adjacent porous insulation (e.g., batt fiberglass) may also be designated for removal when it is in contact with MSPF. An MSPF site survey should also note structural and ventilation characteristics of the affected area for developing a mitigation plan.

Interim Management

Careful planning is needed to effectively restore sites affected by MSPF, and occupants may be exposed to emissions until the mitigation process is initiated. MSPF

areas should be isolated and ventilated during this period. Areas adjacent to MSPF can be separated from occupied space by sealing doors or erecting barriers. Plastic sheeting can also be sealed directly over MSPF to retard emissions. Exhaust fans can be operated to prevent odor migration [10], and energy recovery ventilators can be installed to increase air exchange. This reduces exposure and may allow occupants to remain in the home until mitigation (note that additional research is needed to assess occupant health risks). In some cases, this additional period of enhanced ventilation may sufficiently resolve odor concerns. However, if odor persists, removing misapplied foam is necessary.

Mitigation

Some SPF manufacturers and contractors recommend removing and replacing MSPF to resolve odor concerns [1,17]. There are no published procedures for accomplishing this, and the efficacy of foam removal/replacement has not been documented. Techniques have been developed by the industry for identifying defective foam [18] and removing overspray or foam not applied to specifications [17]. Similar to initial foam application, the site must be contained and ventilated, followed by a detailed site cleanup. Substrates are then resealed with properly cured SPF [17].

Protocols used to restore IAQ contaminated by other sources of material off-gassing have employed a variety of steps to facilitate odor elimination, such as:

- Replacement of materials (e.g., removing as much of the contaminant as possible, followed by a complete cleanup)
- Surface treatment (e.g., disinfection or oxidation)
- Ventilation (e.g., air out to accelerate off-gassing)
- Encapsulation (e.g., apply sealant)
- Pathway elimination (e.g., permanently seal off or depressurize source area, or both)

A combination of these steps is often used to ensure restoration, and some may be useful for mitigating MSPF.

Verification

Areas in which indoor contaminants have been mitigated are often cleared for reoccupancy based on inspection or sampling, or both. Inspection generally includes visual confirmation that all specified material has been removed or treated, surfaces are dust-free, and no odor associated with the contaminant is detected.

Limited sampling may not be representative of ongoing conditions, and detected contaminants may originate from sources other than MSPF. There are no generally accepted contaminant standards for IAQ, and clearance is often based on target values suggested by various organizations and individuals. Because of these limitations, the use of sampling to clear mitigation sites is subject to both false-negatives (samples are in compliance but the odor persists) and false-positives (site is restored

but test criteria are exceeded). Verifying odor elimination after MSPF removal should recognize that a slight odor may be detected from properly applied SPF for several days.

Conclusions

1. Following misapplication, SPF may fail to completely cure, producing a persistent odor often described as fishy.
2. Detection of a strong fishy odor continuing for more than a few days after application is generally the initial indicator of MSPF.
3. Visual and tactile inspection, including examining core samples, may be helpful in confirming the presence of MSPF and estimating its extent. Site inspection is also needed to develop a mitigation plan.
4. Limitations in the sensitivity and selectivity of air sampling methods available to field practitioners may preclude the identification of contaminants associated with MSPF emissions. Contaminants detected by VOC sampling may be produced by a variety of sources, making it very difficult to determine whether they are associated with MSPF.
5. Although testing foam emissions in a laboratory chamber facilitates the identification of compounds under more concentrated conditions, data interpretation relative to occupant exposure is subject to considerable uncertainty.
6. Interim exposure reduction pending remediation can be accomplished by using plastic barriers and exhaust ventilation.
7. A mitigation process is suggested by some manufacturers and contractors involving the removal of misapplied foam, cleanup, ventilation, and sealing the substrate with properly cured SPF. The efficacy of this process has not been documented.
8. Verifying odor mitigation can be accomplished by evaluation under worst-case conditions.
9. Amines associated with product catalysts appear to be the primary contributors to MSPF odor. Some SPF product formulations have recently been modified, substituting reactive for nonreactive catalysts, potentially reducing the potential for detectable odor when misapplied.

Recommendations

1. Additional research is needed to characterize MSPF emissions and health risks.
2. Pending further research, experience with restoration at sites with similar contamination suggests that the following steps may be effective in controlling odors from problem foams:
    (a) Conduct a systematic odor survey to facilitate the identification of MSPF. For at least a day prior to the survey, windows and exterior doors should remain closed, and the home or building should be warmed up several degrees above normal temperature. Interior spaces should be isolated by closing doors and sealing areas with plastic sheeting.

(b) Delineate areas for MSPF removal based on the identification of spray-foamed areas in which a fishy odor is detected, observation of foam characteristics indicative of unreacted foam, and detection of a fishy odor in the headspace of foam core samples.
(c) Isolate and ventilate areas with MSPF pending mitigation (i.e., HVAC off, vents sealed, exhaust fans operating, plastic sheeting over contents, tack mats leaving work area). When depressurizing an area, take care not to draw combustion gas back into the building.
(d) Before MSPF removal is initiated, anticipate objects (e.g., fasteners, wires, conduit, plumbing, cross-bracing, ductwork) that may be hidden inside the SPF. After these have been located, turn off the breakers to the AC circuits and power to other wiring and depressurize plumbing and gas lines.
(e) Remove foam in specified areas to the extent feasible.
(f) Clean all potentially affected surfaces until free of visible dust (e.g., consider HEPA vacuuming followed by damp wiping).
(g) Exhaust air until there is no detectable MSPF odor with windows closed and HVAC operating with a normal thermostat setting. If odor is still detected, repeat the above steps as needed.
(h) Reapply SPF (use formulation with reactive catalysts) in a manner that ensures complete curing and seals all substrates previously covered by MSPF.
(i) Re-clean and ventilate the work area.

3. Additional research is needed to refine and validate the assessment and mitigation protocols. The development of a standardized protocol for MSPF mitigation should address the following:
    - Scope of removal. *Is removing as much MSPF as possible, leaving residue in cracks and crevices, sufficient?*
    - Work site containment. *Can the home remain occupied during mitigation?*
    - Ventilation design. *Is a simple exhaust fan sufficient?*
    - Cleanup. *Is HEPA vacuuming needed?*
    - Surface treatment. *Is substrate encapsulation needed?*
    - Re-insulation. *How should new SPF be applied to ensure odor elimination?*
    - Secondary odor sources. *How should nearby porous surfaces that may have adsorbed MSPF emissions be addressed?*
    - Postremoval ventilation. *How long should affected areas be aired out?*
    - Clearance. *How should mitigation be confirmed?*
4. MSPF that generates IAQ complaints can be prevented by adherence to product installation requirements. Under current training and certification programs, the vast majority of SPF applications do not cause IAQ complaints. Expanded efforts to train workers and ensure quality control should be encouraged.

5. Substitution of reactive for nonreactive amine catalysts should be encouraged to reduce amine emissions where SPF is misapplied. Additional research is needed to verify the efficacy of reactive catalysts in reducing odor-causing emissions from SPF and reducing occupant complaints.

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