Remediation of VOCs in High-Rise Residential Buildings

A Source- and Pathway-Based Guide to Reducing VOC Exposure: Strategy Selection, Source Control, Pressure Correction, Ventilation, Filtration, Verification, and Occupant Protection

Companion addendum to Investigating VOCs in High-Rise Residential Buildings. Continues that handbook's Part, Chapter, and Appendix numbering (Parts XIV–XXIII, Chapters 46–76, Appendices N–Y).

Prepared for residents, indoor-air investigators, industrial hygienists, remediation contractors, building engineers, physicians, attorneys, housing officials, regulators, journalists, and neutral third-party reviewers.

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Disclaimer

This document is for educational and investigative-reference purposes only. It is not medical advice, legal advice, engineering advice, or a substitute for evaluation by qualified professionals. Remediation of building materials and systems may be governed by building, fire, electrical, and environmental codes and may require licensed contractors and permits. Some interventions described here can temporarily increase contaminant concentrations or create hazards if performed improperly. Readers should consult licensed physicians, certified industrial hygienists, professional engineers, licensed contractors, or attorneys for guidance specific to their circumstances.

Executive Summary

The companion handbook, *Investigating VOCs in High-Rise Residential Buildings*, explains how to identify the source of a volatile organic compound (VOC) problem, the pathway by which it reaches an occupant, and the weight of evidence supporting that determination. This addendum begins where investigation ends. It assumes a source and pathway have been identified, or at least narrowed to a small set of supported hypotheses, and it describes how to reduce exposure durably and verifiably.

The central principle of remediation mirrors the central principle of investigation: **a contaminant problem is defined by a source, a pathway, and a receptor, and durable remediation must address the specific source and pathway that the investigation identified.** Replacing flooring inside a unit will not solve infiltration from an adjacent garage if the pathway remains open. Sealing a wall penetration will not help if a single-hose portable air conditioner continues to depressurize the unit and pull contaminants through every remaining opening. Running an air purifier will not remove a source that is still actively emitting. Remediation that is not matched to the attribution finding tends to fail, and a failed remediation can be mistaken for evidence that no problem ever existed.

This handbook organizes remediation around a hierarchy of durability. Eliminating or substituting a source is the most reliable intervention. Correcting the pressure relationships and sealing the pathways that transport a contaminant is next. Ventilation, climate control, and gas-phase air cleaning are supporting measures that reduce concentration but do not, on their own, remove a source. Personal protective equipment and administrative scheduling are the least durable options and are generally inappropriate as the primary response in a residence.

Three themes recur throughout. First, **remediation work can itself cause exposure**: disturbing materials, applying new sealants and coatings, and operating equipment can release VOCs, sometimes at concentrations higher than the original problem. Second, **sensitized occupants**—those whose reaction threshold has been lowered by prior exposure—may react to concentrations that do not affect the general population, which changes remediation targets, protective measures, and verification thresholds. Third, **verification is not optional**: without baseline measurement before work and comparison measurement after work under the same conditions, there is no objective basis for concluding that remediation succeeded.

As in the companion handbook, the tone throughout is investigation-focused, evidence-based, and non-accusatory. The goal is to reduce exposure, to document the work in a way that withstands review by physicians, engineers, housing officials, and courts, and to prevent recurrence.

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PART XIV

Remediation Foundations

Remediation is the deliberate reduction of VOC exposure below levels that cause harm, accomplished by controlling or eliminating the source and the pathway the investigation identified. This part defines remediation, establishes a hierarchy of interventions ordered by durability, connects each remediation strategy to the corresponding attribution finding, and addresses the timing question of when to act and when to gather more evidence first.

Chapter 46. What Is VOC Remediation?

Remediation is a coordinated sequence of actions intended to reduce VOC exposure below harmful levels and to prevent the problem from recurring. It is distinct from investigation, which determines what is happening and why, and distinct from mitigation in the narrow sense of temporarily reducing symptoms. Durable remediation changes the underlying conditions so that the exposure does not return once the intervention is complete.

Effective remediation addresses three interconnected elements, the same three that define any exposure: the **source** (the material, product, or activity releasing the contaminant), the **pathway** (the route by which it travels to the occupant), and the **exposure point** (where the occupant encounters it). Addressing only one element rarely succeeds. Removing a source does not help if contaminated air still infiltrates from a neighboring space; sealing a pathway does not help if the source remains active and an alternative pathway exists; cleaning the air at the exposure point does not help if the source emits faster than the cleaner can remove.

> **CORE PRINCIPLE**
>
> The remediation strategy is determined by the attribution finding, not by the symptom. The question is never simply “how do we lower VOCs?” It is “which source, reaching the occupant through which pathway, must be controlled, and what is the most durable way to control it?”

The U.S. Environmental Protection Agency states the general order of effectiveness plainly: the best way to address indoor air pollution is to control or eliminate the sources of pollutants and to ventilate with clean outdoor air, with air cleaning as a supplement rather than a substitute (EPA, *Guide to Air Cleaners in the Home*, EPA 402-F-08-004; EPA, *Residential Air Cleaners: A Technical Summary*, 3rd ed., EPA 402-F-09-002, July 2018). This handbook applies that order to the specific conditions of high-rise residential buildings, where pathways are numerous, pressures shift continuously, and occupants frequently do not control the spaces where sources originate.

Chapter 47. The Remediation Hierarchy

Interventions differ in how reliably and how permanently they reduce exposure. The following hierarchy orders them from most durable to least. A remediation plan should begin as high in the hierarchy as the situation allows and use lower-tier measures only to supplement, not to replace, higher-tier control.

Tier	Intervention	What it does and its limits
1	**Source elimination**	Physically removes the emitting material or stops the emitting activity. Most durable; ends emission at the origin. Requires access to the source and may require landlord cooperation when the source is building-installed.
2	**Substitution**	Replaces a high-emitting material with a low- or no-emitting equivalent serving the same function. Durable when the substitute is verified low-emitting by recognized testing, not by marketing claims.
3	**Pathway and pressure control**	Seals penetrations and corrects the pressure relationships that drive infiltration (for example, eliminating the negative pressure created by a single-hose portable AC). Durable for transport-driven problems; does nothing if the source is inside the occupied space.
4	**Ventilation and dilution**	Introduces clean air to lower concentration. Effective only when replacement air is genuinely clean; in a depressurized high-rise unit, “more ventilation” can draw in *more* contaminated air. Reduces concentration but never removes the source.
5	**Air cleaning (gas-phase)**	Adsorbs gaseous VOCs with activated carbon or chemisorptive media. A supplement to source control and ventilation, never a substitute. Media saturate and must be replaced.
6	**Administrative measures**	Scheduling high-emission activities for low-occupancy periods, temporary occupant relocation, restricting use of an affected room. Reduces exposure without solving the problem.
7	**Personal protective equipment**	Respiratory protection is appropriate for workers performing remediation but is not a residential solution. Occupants should not be expected to live in respirators.

The hierarchy is a default ordering, not a rigid rule. A pressure-driven infiltration problem (Tier 3) may take priority over removing a minor in-room source (Tier 1) when the infiltration is the dominant exposure. The investigation finding governs which tier is the correct starting point.

Chapter 48. Linking Remediation to Source Attribution

The differential attribution matrix and decision tree in the companion handbook (Chapters 40–42) produce a supported source-and-pathway hypothesis. Remediation strategy follows directly from that hypothesis. The table below maps common attribution findings to their primary remediation response.

Attribution finding	Primary remediation	Supporting measures
In-room source (new flooring, adhesive, furniture, sealant within the unit)	Remove or substitute the material (Tier 1–2); ventilate to clear residual emissions	Gas-phase air cleaning during off-gassing; temperature control to avoid accelerating emissions while occupied
Building-installed in-unit source (e.g., off-gassing tape or sealant applied by maintenance on in-unit equipment)	Written request for removal/ substitution by management; substitute with verified low-emitting, code-compliant material	Document communications; interim air cleaning and ventilation
Adjacent-space source reaching the unit by **pressure-driven infiltration** (garage, trash room, neighbor, hallway)	Correct the negative pressure first (Tier 3); seal the specific penetrations carrying the air	Address the adjacent source through management; verify with pressure measurement
Single-hose portable AC creating negative pressure that draws contaminants inward	Reconfigure or replace the AC (dual-hose or window unit) or add make-up air (Tier 3)	Seal the AC penetration properly; re-measure pressure with the unit running
Stack-effect transport through a vertical shaft or utility chase	Seal the unit’s connections to the shaft/chase (Tier 3); compartmentalize	Building-level pressure management is a management responsibility; document the request
HVAC-distributed contamination	Source control within the HVAC system (filter, coil, drain pan, duct) by qualified personnel	Upgrade filtration where appropriate; this is generally a building responsibility

> **WHY THIS MATTERS**
>
> A remediation that is not matched to the attribution finding can fail visibly—new flooring installed to “fix” a garage-infiltration problem will not work—and that visible failure is sometimes offered as evidence that the occupant’s complaint was unfounded. Matching remediation to attribution protects both the occupant’s health and the evidentiary record.

Chapter 49. When to Remediate vs. Continue Investigating

Remediation and investigation are not strictly sequential. Sometimes acting quickly is warranted even before attribution is complete; sometimes acting prematurely introduces new VOCs and wastes the opportunity to confirm the source.

Factors favoring prompt action

- **Acute symptoms correlated with building occupancy.** Symptoms that consistently appear during occupancy and resolve on leaving, especially repeated exposure-recovery cycles, support acting on the best-supported hypothesis without waiting for perfect certainty.
- **Measurements exceeding health-based guidance.** Air sampling showing VOC concentrations above recognized health benchmarks supports prompt action.

- **Physician documentation.** A treating physician's documentation of exposure-related effects and advice to reduce exposure supports prompt action and may support temporary relocation (Chapter 73).
- **A sensitized occupant with a known, removable source.** Because a sensitized occupant can react at low concentrations (Chapter 72), removing a known source promptly has a favorable benefit-to-risk ratio.

Factors favoring further investigation first

- **No source identified.** Acting before the source is known risks remediating the wrong thing and disturbing the building unnecessarily.
- **Mild, sporadic symptoms without supporting measurement.** When the signal is weak, targeted sampling and logging are usually a better next step than construction work.
- **The remediation itself would introduce VOCs.** Adhesives, sealants, coatings, and spray foams emit VOCs during application and curing—potentially as harmful to a sensitized occupant as the original problem. When the planned fix is itself a VOC source, confirming the target first is especially important.

In all cases, document existing conditions *before* any remediation: photographs of the materials to be removed or modified, baseline air sampling at the exposure points under the conditions that trigger symptoms, odor logs for the preceding weeks, and medical records. This baseline serves two purposes: it allows post-remediation comparison (Chapter 65), and it preserves the evidentiary record before conditions change irreversibly.

PART XV

Source Control

Source control is the most durable form of remediation. This part covers the four principal source-control strategies—removal, substitution, encapsulation, and penetration sealing—with attention to the high-rise complication that sources are often installed by building management or located in spaces the occupant does not control.

Chapter 50. Source Removal

Source removal is the most direct intervention: physically removing the material or product generating the emissions. Common candidates in high-rise residential settings include off-gassing tapes on HVAC components and AC hoses, high-VOC adhesives beneath flooring or countertops, sealants and caulks at penetrations, spray foam around pipes and conduits, deteriorated mastics, and pressed-wood products that continue to off-gas (ATSDR, *Toxicological Profile for Formaldehyde*, 2010; Katsoyiannis et al., *Materials*, 2021).

The high-rise complication: control of the source

Unlike a single-family home, a high-rise unit frequently contains materials the occupant did not install and cannot remove unilaterally, and the source may lie entirely outside the unit. Three situations recur:

- **Source inside the unit, installed by the occupant.** The occupant can remove or replace it directly, observing the precautions below.
- **Source inside the unit, installed by management.** The occupant should request removal in writing, specify the material and location, and retain all communications (see Appendix U). Removing building-installed materials without authorization can create liability and is generally inadvisable.
- **Source outside the unit.** Removal must be requested through management. The occupant's direct remediation is limited to pathway and pressure control (Part XVI).

Precautions during removal

Disturbing an emitting material temporarily increases airborne concentrations—sometimes sharply—as bound chemicals are released and dust is generated. Accordingly:

- Occupants, and especially sensitized occupants, should vacate during removal and remain out until the space has been thoroughly ventilated and, where warranted, re-tested (Chapter 65).

- The work area should be ventilated continuously during and after removal.
- For sensitized occupants, removal should be performed by professionals with the occupant temporarily relocated (Chapter 73).
- Removed materials should be bagged and taken out of the unit promptly to prevent re-contamination; absorbent contents that have taken up VOCs may also need removal in severe cases.

Chapter 51. Substitution with Low-Emitting Materials

When a material must be replaced rather than simply removed—a seal, a tape, an adhesive, a coating—substitution with a verified low-emitting equivalent prevents trading one VOC source for another. The key is to verify emissions by recognized testing rather than by product category or marketing language.

Recognized low-emission criteria

The most widely recognized North American emissions standard for interior products is the California Department of Public Health method, **CDPH/EHLB Standard Method V1.2 (January 2017)**, "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers" (often referenced as "Section 01350"). It evaluates modeled indoor concentrations against health-based limits —for example, formaldehyde at or below 9 µg/m³ and benzene at or below 1.5 µg/m³—and underlies common certifications such as LEED v4 Low-Emitting Materials, FloorScore, and product labels that report "CDPH SM V1.2 compliant" (CDPH, 2017). Independent certification marks that reference this method (for example, UL GREENGUARD Gold) provide a verifiable basis for substitution.

Practical substitution example: HVAC and AC closure tape

Generic cloth "duct" tape and many foil-scrim-kraft (FSK) tapes are not rated for permanent duct or HVAC sealing, degrade with heat and time, and can themselves off-gas. The code-compliant alternatives for sealing HVAC ducts and connectors are tapes **listed to UL 181**: **UL 181A-P** pressure-sensitive foil tape for rigid duct and duct board, and **UL 181B-FX** for Class 1 flexible ducts and connectors. Model mechanical codes (e.g., IMC/IRC duct-sealing provisions) state that unlisted duct tape is not permitted as a duct sealant (UL 181A/181B; IMC M1601). Note an important boundary: UL 181 tapes are designed for *duct and connector* closure, not for sealing *building penetrations* through walls and floors—those require sealants or firestop systems, not tape of any kind (Chapter 53).

> **BEFORE SPECIFYING A SUBSTITUTE**
>
> Request the Safety Data Sheet (SDS) and any emissions certificate in advance. Confirm the actual chemical composition (SDS Section 3) and emissions testing (CDPH SM V1.2 or equivalent) rather than relying on the product type. A "low-VOC" label that refers only to regulatory VOC *content* for air-quality permitting is not the same as tested *emissions* into indoor air.

Chapter 52. Encapsulation

Encapsulation applies a barrier coating over an emitting surface to reduce—not eliminate—VOC release. It is a fallback for situations in which removal is impractical, such as structural pressed-wood assemblies or adhesives whose removal would cause greater damage. The EPA advises that when a formaldehyde-emitting source such as paneling cannot be removed, all exposed surfaces should be sealed with a material designed for that purpose (EPA, *An Introduction to Indoor Air Quality*; ATSDR, *Toxicological Profile for Formaldehyde*, 2010).

Limitations of encapsulation

- It reduces but does not stop emissions; the source remains present.
- The encapsulant itself may emit VOCs during application and curing.
- Coatings degrade and may require reapplication; emissions can “break through” over time.
- It is generally less reliable than removal or substitution and should be treated as interim where removal is feasible.

Application practice

Select an encapsulant documented as effective for the specific contaminant (for example, products marketed and tested for formaldehyde containment) rather than a general-purpose sealer. Occupants should vacate during application and allow full cure before returning, with verification sampling for sensitized occupants. Record the product, SDS, lot, application date, and conditions for the remediation log (Appendix V).

Chapter 53. Penetration Sealing

Every unsealed hole in a wall, floor, or ceiling is a potential transport pathway (companion handbook, Chapters 11–15). In a high-rise unit, a comprehensive penetration-sealing program is frequently the single most effective intervention for pressure-driven infiltration, because it closes the routes by which contaminants from adjacent spaces enter.

Sequence of work

1. **Document.** Photograph each penetration before work; record location and type.
2. **Remove degraded material.** Strip out failed tape, hardened foam, or cracked caulk that may itself be a VOC source.
3. **Select the correct material.** Match the sealant to the penetration type and fire-rating requirement (below).
4. **Apply and cure.** Ventilate during application; allow full cure before reoccupancy; vacate sensitized occupants.
5. **Verify.** Re-photograph; confirm closure with differential-pressure measurement where the penetration was a suspected pathway (companion handbook, Chapter 24).

Fire-rated assemblies

In multi-family high-rises, walls and floors between units and along shafts are commonly fire-rated assemblies. Penetrations through them must be sealed with **listed firestop systems**—intumescent sealants, firestop putty, or rated collars tested as a system for that penetration type. Non-rated materials in a fire-rated assembly create a code violation and liability and may not be permitted without a licensed contractor and permit. Confirm fire-rating requirements before sealing.

Common penetrations and appropriate treatments

Penetration	Appropriate treatment
AC hose opening (window panel or wall)	Replace temporary tape (FSK/duct) with a fitted panel or plug and a durable low-VOC sealant or weatherstrip around the hose; see Chapter 56 for AC-removal sealing
Utility chase access panel	If no access needed, seal completely; if access required, fit gaskets and weatherstripping rather than leaving open (major stack-effect pathway)
Plumbing sleeves through floors/walls	Fire-rated sealant or intumescent collar sized to the penetration
Electrical outlets on exterior/shared walls	Foam gaskets behind cover plates; child-safety plugs in unused receptacles reduce cavity airflow
Pipe and conduit penetrations in cavities	Fire-rated sealant or firestop; avoid tape, which degrades and off-gasses

PART XVI

Pressure and Pathway Correction

When a contaminant reaches a unit by pressure-driven infiltration, sealing penetrations alone is incomplete: the pressure that drives air through any remaining opening must also be corrected. This part addresses diagnosing and correcting negative pressure, reconfiguring portable air conditioners (the most common occupant-controlled cause of unit depressurization), and sealing properly after an AC is removed.

Chapter 54. Diagnosing and Correcting Negative Pressure

Air flows from higher pressure to lower pressure through every available opening. When a unit is negatively pressurized relative to hallways, adjacent units, shafts, or below-grade spaces, it draws air—and any contaminants that air carries—inward. Correcting that pressure relationship is often the decisive remediation for infiltration problems.

Common causes of negative pressure in a unit

- Single-hose portable AC units exhausting room air outdoors (Chapter 55)
- Exhaust fans (bathroom, kitchen) operating without adequate make-up air
- HVAC systems pulling more return than they supply to the unit
- Winter stack effect drawing air upward through the building core
- Open windows on the leeward face, or exhaust without a compensating inlet

Diagnosis

Measure differential pressure between the unit and each adjacent space (hallway, neighboring unit, wall cavity, shaft-adjacent closet) using a digital micromanometer, under the exact conditions when symptoms occur: all exhaust devices running, portable AC operating, and ideally during the weather that correlates with complaints (companion handbook, Chapter 24). A unit that reads negative relative to a contaminated adjacent space confirms a pressure-driven pathway.

Correction, in order of preference

1. **Eliminate the depressurizing device.** Replacing a single-hose portable AC with a dual-hose or window unit removes the net air removal entirely (Chapter 55). This is usually the most effective single step an occupant can take.
2. **Provide make-up air.** Where exhaust must continue, supply make-up air from a clean source so the unit is not forced to draw replacement air from contaminated spaces.

3. **Seal the pathways.** Close the specific penetrations through which infiltration occurs (Chapter 53), reducing the air the unit can draw from contaminated spaces.
4. **Confirm building systems.** Where hallway pressurization or garage exhaust is designed to keep contaminants out of occupied spaces, verify with management that those systems are functioning; their failure is a building-level cause of unit infiltration.

Chapter 55. Portable Air Conditioner Reconfiguration

Single-hose portable air conditioners are a frequent cause of VOC infiltration in high-rise apartments without central cooling. Because they exhaust room air outdoors through a single hose, they create a net removal of air from the room; the replacement air enters through the path of least resistance, which may be a garage, a trash room, a neighboring unit, a hallway, or a wall cavity (U.S. Department of Energy, Federal Register, Vol. 80, No. 228, Nov. 27, 2015). Reconfiguring or replacing the unit removes this mechanism.

> **CAUTION DURING AC WORK**
>
> Disturbing an AC installation—especially one sealed with deteriorated tape—can briefly spike VOC concentrations. Sensitized occupants should not be present during modification.

Options, most to least preferred

- **Dual-hose portable unit.** Draws outdoor air for the condenser through a second hose, so it does not exhaust room air and does not create the negative pressure that pulls contaminants in. Comparable in cost to single-hose models. The window panel must still be sealed properly around both hoses.
- **Window-mounted AC.** Rejects condenser heat directly outdoors without removing room air; no hoses. Requires a compatible window and careful sealing of the installation gap.
- **Removal where climate allows.** If cooling is not essential, removing the unit and sealing the penetration (Chapter 56) eliminates the pathway entirely.
- **Make-up air as a last resort.** If a single-hose unit must remain, provide make-up air from a clean source to offset the exhaust, recognizing this is less reliable than the options above.

Chapter 56. Sealing After AC Removal

When a portable or window AC is removed, the opening left behind is a direct pathway to the wall cavity, adjacent space, or outdoors and must be sealed durably—not with adhesive tape, which degrades and can off-gas.

1. Remove all old tape, foam, and debris from the opening, and confirm none of the residual material is itself an active source.
2. Fit an appropriate rigid plug or panel sized to the opening.
3. Seal the perimeter with a durable low-VOC sealant; for a fire-rated assembly, use a listed firestop system (Chapter 53).

4. Allow full cure with ventilation; vacate sensitized occupants until cured and, where warranted, re-tested.
5. Confirm the seal with a differential-pressure check; a properly sealed opening should no longer show airflow into the unit.

PART XVII

Ventilation and Dilution

Ventilation lowers VOC concentration by replacing contaminated air with clean air. In a high-rise, the qualifier “clean” is decisive: opening pathways in a depressurized unit can draw in contaminated air rather than fresh air. This part covers ventilation principles for high-rise units, practical natural and mechanical strategies, and the bake-out technique with its strict limitations.

Chapter 57. Ventilation Principles in High-Rise Units

Ventilation dilutes and removes VOCs, and the EPA identifies ventilation with clean outdoor air, alongside source control, as a primary means of improving indoor air quality (EPA 402-F-09-002, 2018). But the benefit depends entirely on where the replacement air comes from. In a negatively pressurized unit, increasing openings can increase infiltration from contaminated adjacent spaces—the opposite of the intended effect. The first ventilation question is therefore not “how much air?” but “clean air from where?”

ASHRAE Standard 62.2 establishes minimum ventilation rates for dwelling units, including multifamily units, based on floor area and number of bedrooms (ASHRAE, ANSI/ASHRAE Standard 62.2, current edition). Buildings falling short of these rates tend to accumulate indoor VOCs over time. Confirming whether the unit meets 62.2, and whether designed make-up air is actually delivered, is part of any ventilation-based remediation.

Chapter 58. Natural and Mechanical Ventilation Strategies

Natural ventilation

- Open windows on the **upwind** face during periods of good outdoor air quality and low traffic, so that incoming air is clean and the unit is pushed toward positive pressure.
- Avoid leeward windows and windows near pollution sources (garage exhaust, loading docks, restaurant exhaust outlets, vents), which can admit contaminated air.
- Recognize that opening windows changes the unit’s pressure relationships; the goal is to make the unit positive relative to contaminated spaces, not merely to “air it out.”

Mechanical ventilation

- Where natural ventilation is insufficient or outdoor air is poor, balanced mechanical ventilation—such as an energy or heat recovery ventilator (ERV/HRV)—supplies filtered outdoor air while exhausting stale air, maintaining neutral-to-positive pressure.
- Ensure exhaust devices (bath, kitchen) have adequate make-up air so they do not depressurize the unit (companion handbook, Chapter 25).
- Filtration on supply air should match the contaminant: higher-MERV filters capture particles but do not remove gaseous VOCs (Chapter 60).

Chapter 59. Bake-Out Procedures

A bake-out elevates indoor temperature and maximizes ventilation to accelerate off-gassing from new materials before occupancy, driving emissions out over a short, controlled period. It is a specialized technique with narrow applicability.

When a bake-out is and is not appropriate

- **Applicable** only to sources *within* the unit (newly installed materials that are off-gassing). It does nothing for contamination infiltrating from outside the unit.
- **Not appropriate** where elevated heat could damage finishes or equipment, in occupied spaces, or where occupants are already sensitized—the procedure produces high short-term concentrations.
- Should be performed by professionals; improper execution risks re-exposure and damage.

General procedure (professional)

1. Remove temperature-sensitive contents and electronics.
2. Elevate the space to roughly 90–95°F with maximum ventilation (continuous exhaust to outdoors) for 24–72 hours.
3. Return gradually to normal conditions.
4. Verify by air sampling rather than odor; some VOCs are odorless or have high odor thresholds, so the absence of smell does not confirm success.

PART XVIII

Air Cleaning and Filtration

Air cleaning is a supplement to source control and ventilation, never a substitute. Gaseous VOCs require gas-phase media—activated carbon or chemisorbents—because particle filters do not remove them. This part covers the fundamentals of gas-phase filtration, media types, how to evaluate a residential purifier against specifications rather than marketing, and the devices to avoid.

Chapter 60. Gas-Phase Filtration Fundamentals

Standard HEPA and high-MERV filters capture particulate matter but do not remove gaseous VOCs (EPA 402-F-09-002, 2018). Controlling gaseous VOCs requires **gas-phase media**—most commonly activated carbon—which adsorbs VOC molecules onto its enormous internal surface area. The EPA is explicit that air cleaning supplements, and does not replace, source control and ventilation with clean outdoor air; a purifier sized and used correctly can lower concentration while the source is being addressed, but it cannot substitute for removing the source.

Chapter 61. Activated Carbon and Chemisorptive Media

Activated carbon (adsorption)

Activated carbon adsorbs a broad range of VOCs. Its effectiveness depends on:

- **Mass of carbon.** More carbon means more capacity and longer service life. Effective units contain multiple pounds of carbon, not a thin coated screen.
- **Pore structure.** A range of pore sizes adsorbs a wider spectrum of VOCs.
- **Contact time.** A deeper carbon bed and slower face velocity give molecules time to adsorb; thin sheets passed at high speed do little.
- **Operating conditions.** Moderate temperature and lower humidity favor adsorption.
- **Saturation.** Once saturated, carbon can release adsorbed chemicals back into the air; media must be replaced before saturation, sooner in high-VOC environments.

Chemisorptive media (chemical binding)

Chemisorbents bind specific VOCs irreversibly through chemical reaction. Potassium-permanganate-impregnated media, for example, target formaldehyde and certain other low-molecular-weight aldehydes that plain carbon adsorbs poorly. Chemisorbents last longer for

their target compounds but cost more and are compound-specific. Zeolites selectively adsorb by molecular size. A purifier intended for a formaldehyde problem should include media appropriate to formaldehyde, not carbon alone.

Chapter 62. Selecting a Residential Air Purifier

Marketing claims are a poor basis for selection. Evaluate against specifications:

- **Gas-phase capacity.** Multiple pounds of activated carbon (and chemisorbent if formaldehyde is the target), in a true bed rather than a thin sheet.
- **Published gas performance.** A clean-air delivery rate (CADR) for gases or independent test data, not only a particle CADR.
- **Contact time.** A bed configuration that allows adequate dwell time.
- **Pre-filtration.** A particle pre-filter protects the gas media from clogging.
- **Room sizing.** Sized to achieve roughly 4–6 air changes per hour in the actual room; an undersized unit in a large room accomplishes little.
- **Replaceable media on a schedule.** Plan to replace carbon before saturation; budget for replacement.

Placement and operation

Place the unit where exposure is highest—near the bed or desk, or near the pathway opening—with clear airflow around it rather than tucked into a corner or behind furniture. Run it continuously during periods of exposure; intermittent operation gives intermittent benefit.

Chapter 63. Devices to Avoid

Several marketed “air cleaning” technologies are ineffective for VOC gases or actively harmful. The EPA and the California Air Resources Board caution against devices that intentionally or incidentally generate ozone (EPA, *Ozone Generators That Are Sold as Air Cleaners*; CARB, *Regulation for Limiting Ozone Emissions from Indoor Air Cleaning Devices*).

- **Ozone generators.** Intentionally produce ozone, a lung irritant, and can generate harmful secondary pollutants including formaldehyde and ultrafine particles. Not recommended for occupied spaces.
- **Photocatalytic oxidation (PCO) devices.** Can generate aldehyde byproducts; performance for real-world VOC mixtures is inconsistent.
- **Ionizers / electrostatic devices.** Move or charge particles; do not remove gaseous VOCs and some emit ozone.
- **Thin carbon “filter” sheets.** Insufficient carbon mass and contact time to meaningfully adsorb VOCs.

CARB maintains a list of air-cleaning devices certified as meeting its ozone-emission limit; selecting from certified devices avoids the ozone-emitting category.

PART XIX

Monitoring and Verification

Remediation is not complete until it is verified. Without a baseline measured before work and a comparison measured after work under the same conditions, there is no objective basis for claiming success. This part covers baseline sampling, post-remediation verification, and ongoing monitoring.

Chapter 64. Baseline Sampling

Before any remediation, establish baseline air quality at the occupant's primary exposure points—where the occupant sleeps or works, and near any suspected pathway—using recognized analytical methods with documented chain of custody (companion handbook, Chapters 26–27).

- **Total VOCs (TVOC)** as a screening value, and **speciated analysis** if a specific source is suspected, to identify and quantify individual compounds.
- **Target compounds** the investigation points to (for example, formaldehyde by DNPH/HPLC; benzene, toluene, xylene by sorbent tube and EPA Method TO-17).
- Sampling under the **conditions that trigger symptoms** (AC on, exhaust running, the relevant weather), since episodic exposures are missed by off-condition sampling.

Methodology should follow established chamber and sampling references (e.g., ASTM D5116 for chamber emissions characterization; EPA TO-17 for sorbent-tube sampling) so results are defensible. Without pre-remediation data, it is impossible to demonstrate that remediation changed anything.

Chapter 65. Post-Remediation Verification

After all work is complete and any new materials have fully cured, repeat sampling at the **same locations under the same operating conditions** (same HVAC and AC status, comparable weather) and compare to baseline. Premature sampling—before sealants and coatings cure—can show elevated readings from the remediation materials themselves and misrepresent the outcome.

Document the comparison in a **remediation completion report** (Chapter 75; Appendix W): the actions taken, dates, contractors, products and SDS, and pre/post concentrations at each location with the completion criteria met or not met. This report is the evidence used for medical follow-up, regulatory review, or legal proceedings.

> **SETTING COMPLETION CRITERIA**
>
> For the general population, completion criteria are typically referenced to recognized health-based guidance for the compounds of concern. For a sensitized occupant, criteria should be set lower, in consultation with the treating physician (Chapter 72). Define the criteria *before* sampling so the result is not reverse-engineered.

Chapter 66. Ongoing Monitoring

Even after successful remediation, conditions change: maintenance and seasons shift pressures, encapsulated sources continue emitting at reduced levels and can break through, sealants degrade, and new sources are introduced. Sensitized occupants may react to changes others do not detect. A modest ongoing-monitoring plan catches recurrence early:

- **Continuous low-cost monitoring** (PID-based or consumer IAQ monitors) to track TVOC trends and flag increases for follow-up. Treat consumer-grade readings as trend indicators, not regulatory measurements.
- **Periodic professional speciated sampling** (annually or semi-annually, or after any building event) to detect changes in the chemical profile.
- **Continued logging** of symptoms and conditions (companion handbook, Chapter 43) so any recurrence is documented contemporaneously.

PART XX

Professional Services

Some remediation requires licensed professionals; some contractor practices are red flags. This part covers when to engage professionals, how to select them, and how to write a scope of work that defines what will be done, by whom, with what materials, and how success will be verified.

Chapter 67. When to Engage Professionals

- Source identification requiring laboratory analysis or speciated sampling.
- Sealing fire-rated penetrations with listed firestop systems.
- HVAC modifications, duct work, or any work on shared building systems.
- Bake-out procedures, particularly in or near shared systems.
- Removal of regulated hazardous materials.
- Any remediation where a sensitized occupant must be protected from re-exposure.

Appropriate professionals include certified industrial hygienists (CIH), environmental consultants, and licensed remediation and HVAC contractors. A CIH or comparable professional can oversee sampling, scope, and verification independently of the contractor performing the work.

Chapter 68. Contractor Selection

Red flags

- Recommending air purifiers as the *only* solution (ignores source control).
- Proposing ozone treatment in occupied spaces.
- No references, license, or insurance.
- Skipping pre- and post-remediation sampling, or treating verification as optional.
- Unwillingness to provide product SDS or a written scope.

Positive indicators

- Proposes both pre- and post-remediation sampling tied to written completion criteria.
- Provides a detailed scope of work, product list, and SDS in advance.
- Understands sensitization and plans occupant displacement and ventilation during work.

- Verifiable license, insurance, and references for comparable high-rise work.

Chapter 69. Developing a Remediation Scope of Work

A scope of work is a detailed written plan specifying which sources and pathways will be addressed, by whom, with what materials, and how success will be verified. A complete scope includes:

- The specific sources and pathways to be addressed, tied to the attribution finding.
- The products to be used, with SDS and emissions documentation (CDPH SM V1.2 or equivalent).
- Work procedures, including containment and ventilation during work.
- Occupant protection during the work (displacement, scheduling, access control).
- Post-work cleaning standards.
- The verification sampling plan—locations, methods, conditions.
- The concentration-based completion criteria that define success.

PART XXI

High-Rise-Specific Considerations

High-rise residential remediation raises issues uncommon in single-family homes: divided responsibility between occupant and building, re-exposure during the remediation itself, the physiology of sensitization, and the question of temporary relocation. This part addresses each.

Chapter 70. Responsibility and Landlord Obligations

Who bears responsibility for remediation depends on where the source originated and who introduced it. A source the occupant installed inside the unit is generally the occupant's responsibility; a source the building installed, or one located in common areas, adjacent units, or building systems, is generally the building's responsibility. Many jurisdictions impose an implied warranty of habitability requiring landlords to maintain residential premises in a condition fit for occupancy, which can extend to remediating conditions affecting health.

Written request to management

Where the source or pathway is the building's responsibility, the occupant's remediation often begins with a written request that: identifies the source and pathway and the supporting evidence; specifies the requested actions; requests documentation (SDS, work records) before and after; sets a reasonable response deadline; and references applicable housing codes or the warranty of habitability. Appendix U provides a template. Retain all communications and responses.

If management does not respond

Regulatory pathways vary by jurisdiction. Local building or licenses-and-inspections departments can issue violation notices for unsafe conditions; local or state health departments may investigate habitability complaints involving chemical exposure affecting occupant health. Most residential VOC complaints are handled at the state and local level, and specific programs differ by jurisdiction—for example, both Pennsylvania and New Jersey maintain indoor-air and housing-habitability oversight functions. This is general information, not legal advice; consult an attorney regarding rights and remedies in a specific jurisdiction.

Chapter 71. Re-Exposure During Remediation

Remediation work can itself cause exposure by disturbing emitting materials and by introducing new VOCs from sealants, adhesives, coatings, and foams. Protective measures are therefore part of the remediation plan, not an afterthought:

- Occupants should be displaced until work is complete and the space is ventilated back toward baseline; sensitized occupants should not return until verification sampling confirms acceptable levels.
- Contractors should prioritize low-emitting products, maximize ventilation during work, and use their own respiratory protection in elevated-VOC environments.
- Sequence work to minimize the period of elevated concentration and to avoid trapping fresh emissions in a sealed space before cure.

Chapter 72. Sensitized Occupants

Chemical sensitization describes a state in which prior exposure lowers the concentration at which an individual reacts to subsequent exposures. A sensitized occupant may experience effects at concentrations that do not affect the general population. This is a physiological response, and it is not resolved by dismissing the complaint as psychological; competent practice investigates environmental conditions independently before considering psychological factors (companion handbook, Chapter 39).

Sensitization changes remediation in three concrete ways:

- **Lower targets.** Completion criteria should be set below general-population guidance, in consultation with the treating physician.
- **Stricter protection during work.** Displacement and verification before return are more important, not optional.
- **Greater weight on removal over partial measures.** Encapsulation and air cleaning, which leave a reduced but continuing source, are less acceptable for a sensitized occupant than full removal or substitution.

Chapter 73. Temporary Relocation

When VOC conditions are severe enough to cause acute health effects, temporary relocation during remediation may be medically necessary. This determination should come from a physician rather than the occupant alone. Documentation supporting relocation typically includes:

- A physician’s letter describing the condition and the recommendation to avoid the exposure.
- A written demand to management with a remediation timeline.
- Air sampling data supporting the medical recommendation.
- Records of management’s response or non-response.

A landlord’s obligation to provide alternative housing or rent abatement depends on state and local law. Many jurisdictions require landlords who created or failed to remediate an uninhabitable condition to provide housing or reduce rent for the affected period. This is general information, not legal advice.

PART XXII

Documentation Standards

Remediation generates its own evidentiary record. This part provides the remediation event log, the completion report, and evidence-preservation guidance—parallel to the documentation standards in Part XII of the companion handbook—so that the work withstands review by physicians, engineers, housing officials, and courts.

Chapter 74. Remediation Event Log

A remediation event log records each remediation action contemporaneously. For every event, capture: date and time; contractor or worker (name, company); work performed; products used with SDS and lot numbers; ventilation measures; occupant presence or absence; odor observations before and after; photographs taken; and whether post-work sampling was conducted. The template is provided in Appendix V. Contemporaneous logging is far more credible than reconstruction after the fact.

Chapter 75. Remediation Completion Report

The completion report documents the full scope and verified outcome, prepared by or with input from the overseeing industrial hygienist. It should include: the investigation findings that led to remediation; a detailed account of all actions with dates and contractors; pre- and post-remediation sampling results compared at each location; whether completion criteria were met; any residual concerns; monitoring recommendations; and supporting documentation (work orders, invoices, product/SDS sheets, before-and-after photographs). The template is provided in Appendix W.

Chapter 76. Evidence Preservation for Remediation

As with investigation, conditions change irreversibly once work begins. Preserve, before and during remediation:

- Date-stamped photographs of materials before removal, penetrations before sealing, and conditions before modification.
- Samples or photographs of removed materials and their labels/lot numbers.
- All product SDS and emissions documentation for materials used.
- All written communications with management and contractors.

- Baseline and post-remediation sampling data with chain of custody.
- Medical records relating symptoms to the conditions before and after remediation.

PART XXIII

Practical Appendices

Checklists, matrices, templates, and reference material. Appendix lettering continues from the companion handbook (which ended at Appendix M).

Appendix N. Remediation Strategy Selection Matrix

Primary (P), Secondary/supporting (S), and Not recommended as a standalone fix (×), by source/pathway type.

Source / pathway	Removal / substitution	Encapsulation	Penetration seal	Pressure / AC fix	Ventilation	Gas-phase cleaning
In-room material (flooring, adhesive, furniture)	P	S	×	×	S	S
Off-gassing tape/ sealant on in-unit equipment	P	×	×	×	S	S
Structural pressed-wood (removal impractical)	S	P	×	×	S	S
Adjacent-space source via pressure infiltration	×*	×	P	P	S	S
Single-hose portable AC depressurization	×	×	S	P	S	S
Stack-effect transport via shaft/chase	×	×	P	S	S	S
HVAC-distributed contamination	P†	×	×	S	S	S

* Source removal applies at the adjacent source, which is typically outside occupant control and pursued through management. † Within the HVAC system, by qualified personnel; generally a building responsibility.

Appendix O. Source Control Checklist

☐ Confirm the source and pathway from the investigation finding before acting

☐ Photograph all materials to be removed or modified; document penetrations and current seal conditions

☐ Obtain pre-remediation air sampling at exposure points and suspected pathways under triggering conditions

☐ Collect maintenance records, product SDS, odor logs, and medical records

☐ Send written request(s) to management for building-installed or out-of-unit sources; retain responses

☐ For substitutions, obtain SDS and CDPH SM V1.2 (or equivalent) emissions documentation in advance

☐ Vacate occupants (especially sensitized) during removal; ventilate continuously

☐ Bag and remove materials promptly; allow full cure of any new materials before reoccupancy

☐ Log the event (Appendix V); schedule post-remediation verification (Appendix S)

Appendix P. Penetration Sealing Checklist

☐ Photograph each penetration before work; record location and type

☐ Determine fire-rating requirement; use listed firestop systems in rated assemblies

☐ Remove degraded existing material (failed tape, hardened foam, cracked caulk)

☐ Select appropriate fire-rated or low-VOC sealant matched to the penetration

☐ Ventilate and vacate occupants during application; allow full cure

☐ Verify closure with re-photography and differential-pressure measurement

☐ Confirm no airflow into the unit at the sealed penetration under operating conditions

Appendix Q. Portable AC Upgrade Checklist

☐ Identify current unit type (single-hose, dual-hose, window)

☐ Measure unit-to-adjacent-space pressure with the AC on and off

☐ If single-hose and depressurizing: replace with dual-hose or window unit, or provide make-up air

☐ Seal the window panel / wall penetration around hoses with durable material (not tape)

☐ If removing the AC: clean the opening, fit a plug/panel, seal the perimeter, allow cure

☐ Re-measure pressure to confirm the negative-pressure mechanism is eliminated

- ☐ Keep sensitized occupants away during any AC modification

Appendix R. Air Purifier Selection Checklist

- ☐ Confirms gas-phase media (activated carbon; chemisorbent if formaldehyde is the target)
- ☐ Contains multiple pounds of carbon in a true bed, not a thin sheet
- ☐ Publishes gas-phase performance (gas CADR or independent test data), not particle-only
- ☐ Includes a particle pre-filter to protect the gas media
- ☐ Sized for 4–6 air changes per hour in the actual room
- ☐ Uses replaceable media with a defined replacement schedule
- ☐ Is not an ozone generator, PCO, or ionizer; ideally CARB-certified for ozone limits
- ☐ Placed at the exposure point with clear airflow; run continuously during exposure

Appendix S. Post-Remediation Verification Checklist

- ☐ All work complete and all new materials fully cured before sampling
- ☐ Completion criteria defined in advance (lower for sensitized occupants, per physician)
- ☐ Sampling at the same locations and conditions as the baseline
- ☐ Pre- vs. post-remediation comparison for each compound of concern
- ☐ Completion report prepared and shared with the physician/attorney as applicable
- ☐ Ongoing monitoring plan established
- ☐ Any residual concerns documented in writing to management

Appendix T. Contractor Selection Checklist

- ☐ Verify license, insurance, and references for comparable high-rise work
- ☐ Contractor proposes both pre- and post-remediation sampling tied to written criteria
- ☐ Written scope of work and product SDS provided in advance
- ☐ Demonstrates understanding of sensitization and re-exposure risk
- ☐ Has a displacement and ventilation plan for the work period
- ☐ Does not propose ozone treatment or air purifiers as the sole fix
- ☐ Independent CIH or consultant available to oversee scope and verification

Appendix U. Landlord Remediation Demand Letter Template

Customize to the specific investigation findings and applicable local law. This is a template, not legal advice; consult an attorney before sending where stakes are significant.

[Date]

[Property manager / owner name]
[Address]

Re: Request for remediation of indoor air quality / VOC condition — Unit [unit no.], [building address]

Dear [name]:

Background. Beginning on or about [date], I have experienced [symptoms] consistent with VOC exposure in my unit. I have documented these conditions through [odor logs / photographs / daily exposure logs] over the period [dates].

Investigation and evidence. An assessment of the unit indicates [source and pathway finding, e.g., pressure-driven infiltration from [space] through [penetration], or off-gassing from [material]]. Supporting evidence includes [air sampling results / differential-pressure measurements / SDS / physician documentation], copies of which are enclosed.

Requested actions. I request that the following be performed by qualified, licensed personnel: [1) remove/substitute [material]; 2) seal [penetrations] with listed firestop/low-VOC sealant; 3) correct [pressure condition / AC configuration]; 4) conduct pre- and post-remediation air sampling against defined completion criteria].

Documentation requested. Please provide, before and after the work: product names and Safety Data Sheets for all materials used; work orders and contractor information; and the pre- and post-remediation sampling results.

Response requested by. Please confirm in writing within [10–14] business days how and when these actions will be completed. This request is made under [applicable housing code / implied warranty of habitability]. If I do not receive a response, I may refer this matter to [local code/ health authority] and seek legal advice regarding available remedies.

I am available to coordinate access and timing. Thank you for your prompt attention.

Sincerely,
[Name]
[Contact information]
Enclosures: [list]

Appendix V. Remediation Event Log

Date	
Time (start, end)	
Contractor / worker (name, company)	
Work performed (description)	
Source / pathway addressed	
Products used (names, lot numbers)	

SDS obtained (Y/N)	
Emissions documentation (CDPH SM V1.2 / other)	
Ventilation measures during work	
Occupant present / displaced	
Odor before work (character, 1–10)	
Odor after work (character, 1–10)	
Photographs taken (Y/N, description)	
Post-work sampling conducted (Y/N)	
Notes / residual concerns	

Appendix W. Remediation Completion Report Template

1. **Investigation summary.** The source-and-pathway finding that led to remediation, with the evidence supporting it.
2. **Scope performed.** Each remediation action, with dates, locations, contractors, and products (SDS attached).
3. **Baseline results.** Pre-remediation sampling: locations, methods, conditions, concentrations by compound.
4. **Post-remediation results.** Same locations/conditions; concentrations by compound; pre/post comparison table.
5. **Completion criteria.** The criteria defined in advance and whether each was met (note sensitized-occupant thresholds where applicable).
6. **Residual concerns.** Any source not fully controlled; any pathway requiring monitoring.
7. **Monitoring plan.** Ongoing monitoring and re-test schedule.
8. **Attachments.** Work orders, invoices, SDS, before/after photographs, chain-of-custody and laboratory reports.

Appendix X. Glossary of Remediation Terms

Adsorption — Adhesion of gas molecules to a solid surface (e.g., VOCs onto activated carbon); reversible, so saturated media can re-release.

Bake-out — Controlled elevation of temperature with maximized ventilation to accelerate off-gassing of new in-unit materials before occupancy.

CADR (Clean Air Delivery Rate) — Rate at which an air cleaner delivers contaminant-free air; gas CADR (not particle CADR) is the relevant metric for VOCs.

CDPH/EHLB Standard Method V1.2 (2017) — California Department of Public Health chamber method for evaluating VOC emissions from indoor products against health-based limits; basis for common low-emission certifications ("Section 01350").

Chemisorption — Irreversible chemical binding of a contaminant to a medium (e.g., potassium permanganate media for formaldehyde).

Encapsulation — Coating an emitting surface to reduce, not eliminate, VOC release.

Firestop system — A listed, tested assembly for sealing penetrations through fire-rated walls and floors.

Make-up air — Clean air supplied to replace air removed by exhaust, preventing depressurization.

Sensitization — A lowered reaction threshold to a substance resulting from prior exposure; a physiological response.

Source control — Eliminating or substituting the emitting material; the most durable remediation tier.

TVOC (Total VOCs) — Aggregate screening measure of detectable VOCs; speciated analysis identifies individual compounds.

UL 181A-P / 181B-FX — Listings for code-compliant HVAC duct/connector closure tapes (rigid duct board / flexible duct, respectively); not for sealing building penetrations.

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Companion Document

Investigating VOCs in High-Rise Residential Buildings: A Source-Attribution Guide. June 2026. (Parts I–XIII, Chapters 1–45, Appendices A–M.) This remediation handbook is an addendum to that document and continues its numbering.

End of addendum. Remediation of VOCs in High-Rise Residential Buildings — Parts XIV–XXIII, Chapters 46–76, Appendices N–Y. June 2026.