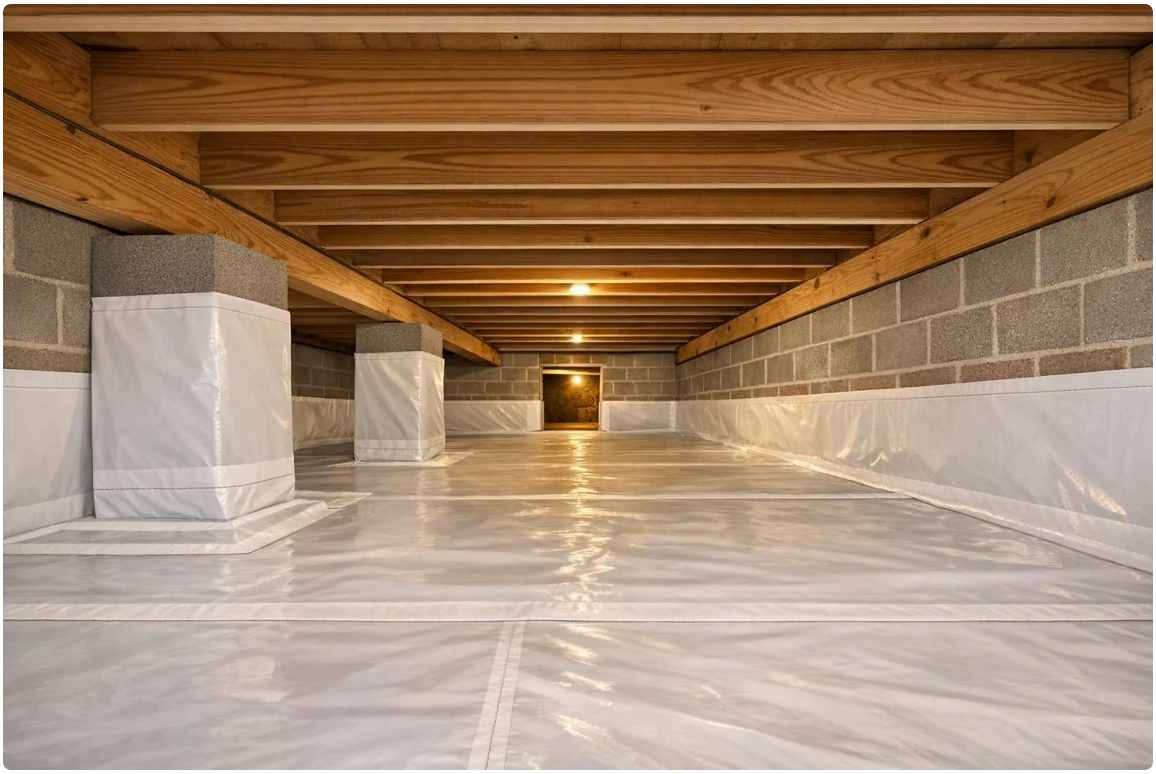
CRAWL SPACE SCIENCE · WHITE PAPER

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Odor in Encapsulated Crawl Spaces

Contaminated materials, wet soil under fully sealed ground liners, and the case for pinned vapor barriers in the humid coastal Southeast



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1 Summary

Homeowners regularly report that an encapsulated crawl space smells, sometimes strongly enough to reach the living space, even when crawl space humidity is controlled. In my inspections this has two main causes.

The first is contamination left in place. Encapsulation controls moisture; it does not clean. Mold-affected framing, old fiberglass floor insulation, and contaminated duct insulation keep producing odor after the crawl space is dried.

The second is the fully sealed ground liner itself. When the soil under a liner that is taped at every seam and sealed to the foundation walls becomes wet, the liner restricts both drying and gas exchange. Saturated soil runs out of oxygen, microbial activity shifts to anaerobic processes, and those processes produce odorous compounds. Because a taped liner is not airtight, the gases reach the crawl space and, at times, the house.

A pinned vapor barrier, with full coverage, overlapped untaped seams, sod staples, and edges lapped but not sealed at the walls, combined with sealed vents and a drying system, avoids that condition. Advanced Energy's field research found that this type of assembly kept framing in the same dry wood-moisture range as fully sealed systems.

> **Recommendation.** For normally drained, existing crawl spaces in the humid coastal Southeast without an identified soil-gas hazard: remove contaminated materials, control bulk water, seal the vents and air leaks, install a pinned vapor barrier, provide a drying system, and verify performance by measuring humidity and wood moisture.

2
main causes of odor after encapsulation

>50%
of fully taped, perimeter-sealed liners I inspect have this odor

Rarely
with pinned liners

~11%
average wood moisture, unsealed-lap group (Advanced Energy, Aug. 2004)

2 Cause 1: The Crawl Space Was Never Cleaned

Consider a crawl space that was vented for thirty years. Every summer, hot, humid outdoor air entered through the foundation vents. Where that air met cooler surfaces, relative humidity rose and moisture condensed, and mold developed on the framing.

A contractor then seals the vents, puts plastic on the ground, and installs a dehumidifier. Humidity drops to 50 percent. The moisture problem is corrected, but nothing has been cleaned, and the contaminated materials continue to produce odor. Three materials are most often left behind:

- **Wood framing** with mold growth that was never cleaned.
- **Fiberglass floor insulation** twenty to thirty years old, exposed to high humidity, rodents, dirt, and repeated moisture problems. It is often sagging or stained and smells.
- **Duct insulation** on flex duct and trunk lines that spent decades in a humid environment. Severely affected insulation needs to be replaced.

> **First checks when an encapsulated crawl space smells:** Was the wood cleaned? Was the old floor insulation removed? Was contaminated duct insulation replaced?



Figure 1. A new liner installed under old fiberglass floor insulation. Encapsulation dried the space but left the original insulation in place.

50%

relative humidity does not remove odor sources already in the crawl space

20–30 yrs

typical age of the floor insulation left behind

3 Cause 2: The Field Pattern

When the contractor did everything right, with the framing cleaned, the old insulation removed, and the ductwork replaced, and the crawl space is dry with low wood moisture, some crawl spaces still smell. The odor is distinctive: strong, swampy, and mildew-like, sometimes sour, like stagnant water, damp soil, or cat urine and ammonia. It is different from the musty smell of old fiberglass.

In my inspections, more than half of crawl spaces with **fully taped, perimeter-sealed ground liners** have some degree of this odor. With **pinned vapor barriers**, where seams overlap and the liner is not sealed to the walls, I rarely encounter it. This is based on thousands of inspections in coastal Virginia, currently more than 600 crawl spaces a year.

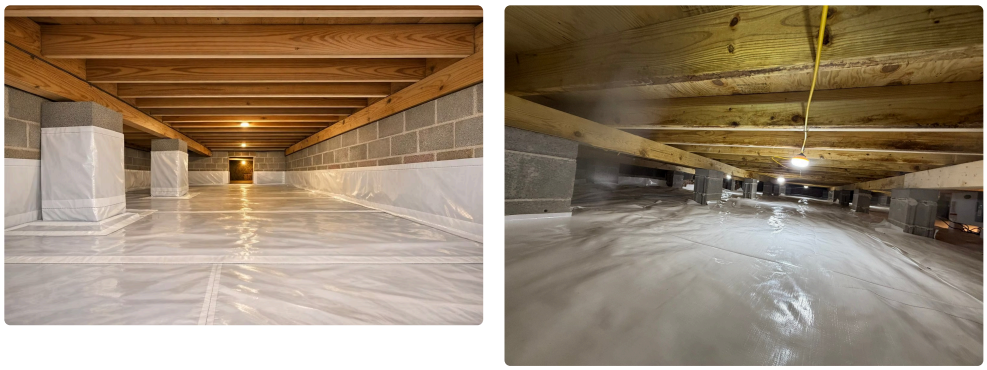


Figure 2. Left: a fully sealed ground liner with taped seams, run up the walls and around the piers. Right: a pinned vapor barrier with overlapped seams, lapped loosely at the walls and piers.

Limitation. These are field observations, not a controlled study, and I have not kept a formal database of every odor and liner installation. Until a regional study compares the two systems, observations from thousands of inspections are among the most directly relevant evidence available for this climate.

>50%
fully sealed liners with some degree of the odor

Rarely
the same odor with pinned liners

600+
crawl spaces inspected per year

4 The Mechanism: Wet Soil Under a Sealed Liner

A house in coastal Virginia receives three inches of rain over two days in midsummer. Depending on soil, groundwater, and drainage, some of that water reaches the soil under the crawl space.

A liner taped at every seam and sealed to the foundation walls is very effective at keeping water vapor out of the crawl space air. Moisture movement works in both directions, however: the same liner restricts the soil's ability to dry upward. Once the soil is wet, it can stay wet for an extended period.

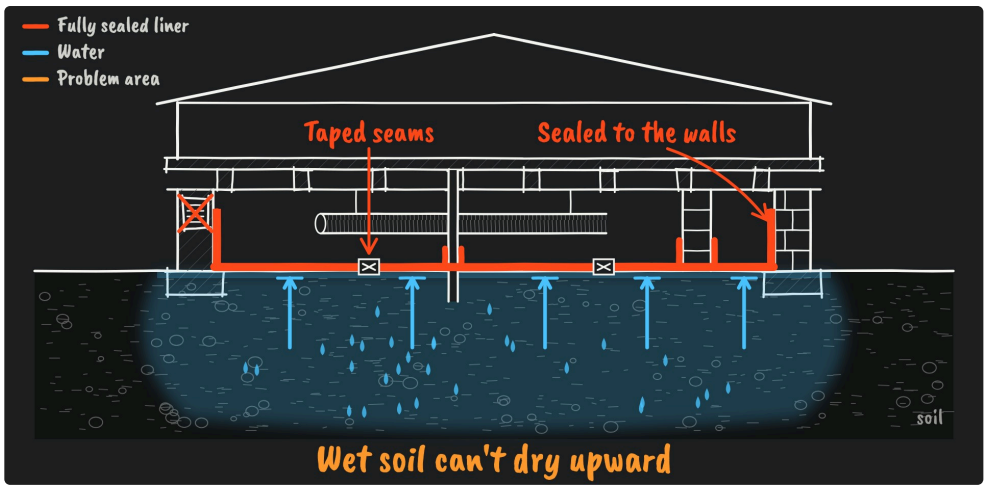


Figure 3. A fully sealed liner (red) over wet soil. The liner keeps vapor out of the crawl space but also prevents the soil from drying upward.

Soil contains bacteria and fungi that break down organic matter and consume oxygen. Under normal conditions, air in the pore spaces between soil particles replaces that oxygen. When the soil is saturated, the pores fill with water, and oxygen diffuses through water roughly ten thousand times more slowly than through air. Microorganisms consume the available oxygen and portions of the soil become anaerobic.

3 in.
of rain over two days in midsummer

~10,000
slower oxygen diffusion through water than through air

When oxygen is depleted, different microbial processes take over. They produce gases and volatile compounds, including organic acids, that can smell swampy, sour, earthy, or stagnant.

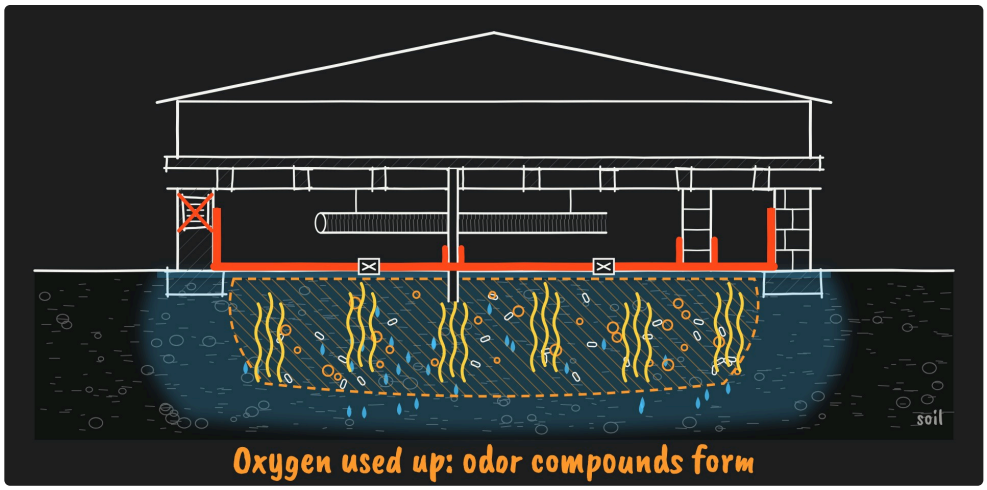


Figure 4. Saturated soil under a sealed liner. Microbes consume the oxygen, an anaerobic zone forms (hatched), and odor compounds build up under the plastic.

What the agricultural research shows

Agriculture uses this process on purpose. In anaerobic soil disinfestation (ASD), growers add a carbon source, cover the soil with plastic, and saturate it. Virginia Cooperative Extension describes the irrigation as filling soil pore spaces, which "will limit oxygen in soil by filling air pockets with water," and stresses sealing the plastic at the edges "to avoid an exchange of gases" [1]. The result is anaerobic soil and the production of "organic acids and volatile compounds" [1]. Field and greenhouse trials have documented the shift to anaerobic conditions under impermeable film, changes in the soil microbiome, and the organic acids produced [2, 3].

These are agricultural studies, not crawl spaces, and the soil is deliberately amended. The physics is the same: wet soil, sealed plastic, limited gas exchange, oxygen consumed, and odor-producing compounds formed.

ASD

anaerobic soil disinfestation: plastic + saturated soil, used to create anaerobic conditions on purpose



Figure 5. Illustration. Wet soil sealed under plastic film (left) versus uncovered soil (right).

5 Why the Odor Reaches the Crawl Space

A taped liner is not an airtight liner. It has seams, connections around piers, pipe penetrations, and terminations on rough masonry walls. People crawl across it to inspect and service equipment. Over time, tape loosens, adhesives deteriorate, fasteners open gaps, and the plastic is punctured. Air pressure differences move gases through those openings.

The result is the worst of both outcomes: the liner is tight enough to restrict drying and oxygen exchange and create anaerobic conditions, but not tight enough to contain the gases that result.

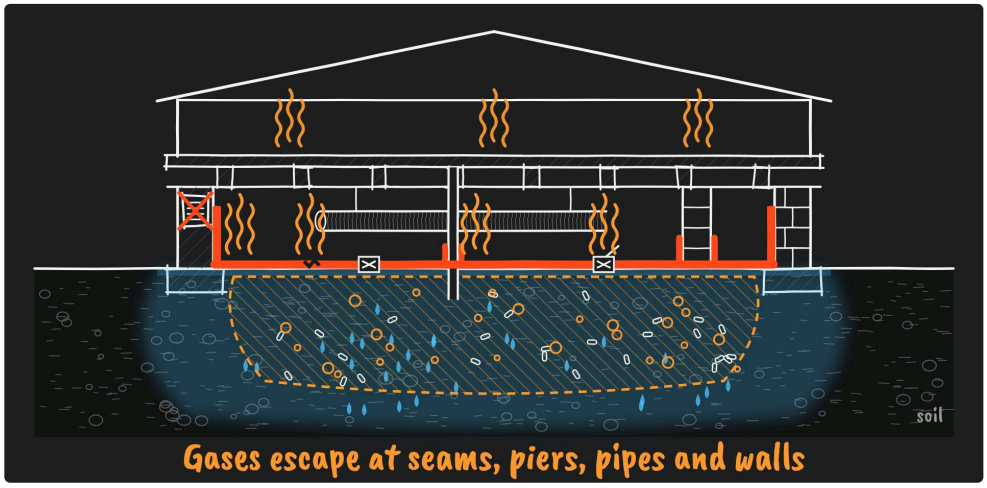


Figure 6. Gases from the anaerobic zone escape through ordinary imperfections at seams, piers, pipe boots, and wall terminations, into the crawl space and the living space.

> **It is not the plastic. It is the sealing of the plastic.**

4

common leak points: seams, piers, pipe penetrations, wall terminations

6 The Pinned Vapor Barrier

A pinned vapor barrier still covers essentially the entire ground with polyethylene. The difference is in how it is installed:

- Sheets overlap; seams are not taped.
- The plastic is secured with metal sod staples.
- At the foundation walls, the plastic is lapped against the masonry, not fastened and sealed.
- Foundation vents are still sealed and major air leaks are addressed.
- A drying system, a dedicated dehumidifier or conditioned supply air, removes moisture.

This is not a return to a vented crawl space. Only the ground liner detail changes. The overlaps and open edges allow some moisture to escape from under the plastic after heavy rain and allow some air exchange near the seams and edges. The drying system removes that moisture. A pinned liner does not have to stop every bit of evaporation; it has to reduce ground moisture enough that the drying system keeps the wood dry.

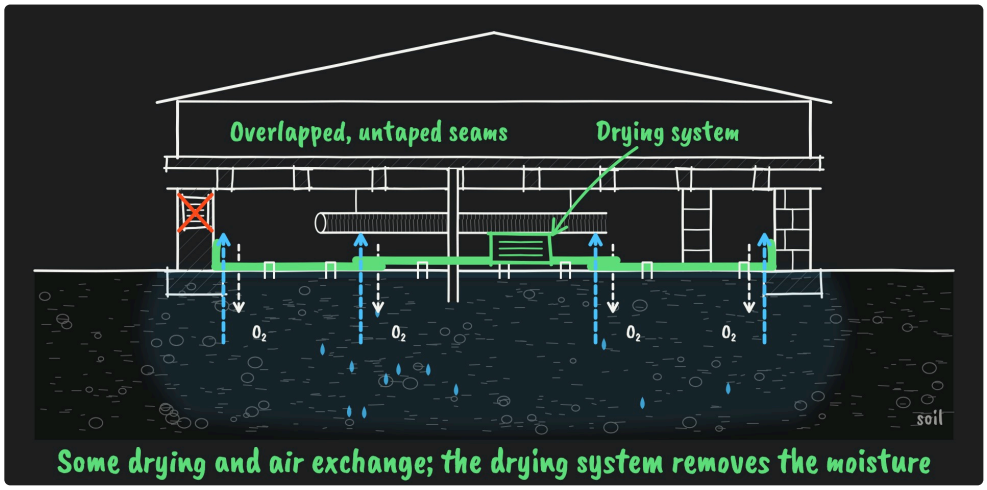


Figure 7. Pinned vapor barrier (green). Overlapped, untaped seams and lapped edges allow limited drying and oxygen exchange; the drying system removes the added moisture.

0
taped seams

0
wall terminations sealed

100%
ground coverage

7 Advanced Energy Tested This Assembly

Advanced Energy's crawl space field study for the U.S. Department of Energy included a closed crawl space group with an **overlapped, unsealed ground liner and no wall liner** [4]. Vents were plugged and sealed, a 6-mil polyethylene liner covered all exposed ground with seams overlapped 6 to 12 inches and not sealed, the liner was pinned with 6-inch turf staples, and drying was provided by about 35 CFM of conditioned air from the supply trunk.

Group (Advanced Energy, Aug. 2, 2004)	Average wood moisture	Maximum
Unsealed-lap ground liner, no wall liner	**≈ 11.0%**	**≈ 12.4%**
Sealed liner, R-19 floor insulation	≈ 10.7%	≈ 12.6%
Sealed liner, R-13 wall foam	≈ 10.4%	≈ 13.9%
Wall-vented control	≈ 14.5%	≈ 16.8%

Values are approximate readings from Figure 50 of the final report [4].

The unsealed-lap group stayed in the same dry range as the fully sealed groups. Its peak reading was not higher than theirs. With a small number of houses, minor differences between homes are expected, and this does not show that sealed liners make wood wetter. It shows that the two approaches kept framing comparably dry. Fully sealed systems could reach lower crawl space humidity under some conditions, but the additional sealing did not produce a meaningful improvement in wood moisture.

> **Conclusion.** For normally drained crawl spaces, fully sealing the ground liner adds cost, makes inspections and repairs harder, especially where the liner runs up walls and around piers, and creates the conditions for the odor problem, for the same wood-moisture performance.

≈11%
average wood moisture, unsealed laps

12.4%
peak, unsealed laps

12.6–13.9%
peaks, fully sealed groups

8 How Much Moisture Does a Pinned Liner Add?

The obvious objection is that untaped seams let in too much moisture. In a separate technical paper comparing pinned and fully sealed ground liners, my engineering screening estimates for a representative 1,500-square-foot crawl space in our coastal climate are:

- About **2 pints per day** of additional moisture in an average summer.
- About **3 pints per day** during a particularly wet week with repeated rainfall.

That is roughly the additional daily moisture load of one houseguest, who adds moisture by breathing, sleeping, showering, and cooking. A home's heating and cooling system already handles changes of that size. A dedicated crawl space dehumidifier has far more removal capacity, and a properly designed conditioned-supply system manages it as well, consistent with the Advanced Energy results.

If that moisture can be handled without a wood-moisture problem, there is no reason to seal the ground so tightly that it creates a different problem underneath. The purpose of a vapor barrier is to control moisture, not to eliminate every bit of evaporation.

~2 pints
per day, average summer

~3 pints
per day, wet week

≈ 1
houseguest's daily moisture load

9 Two Exceptions

Bulk water

If significant groundwater enters the crawl space after heavy rain, neither a pinned nor a fully sealed liner solves it. The solution is drainage: exterior grading, a perimeter drain, or a sump pump. A vapor barrier controls vapor, not bulk water. Sealing the plastic tighter does not make the water disappear; it only restricts drying further.

Radon and other soil gases

Radon has no smell, so it has to be tested for. Where radon or another hazardous soil gas requires mitigation, a sealed membrane is appropriate, but a sealed liner alone is not a mitigation system. The proper approach is **submembrane depressurization**: a sealed membrane with a designed exhaust system that draws gas from beneath it and discharges it outdoors. That is a different purpose from moisture control.

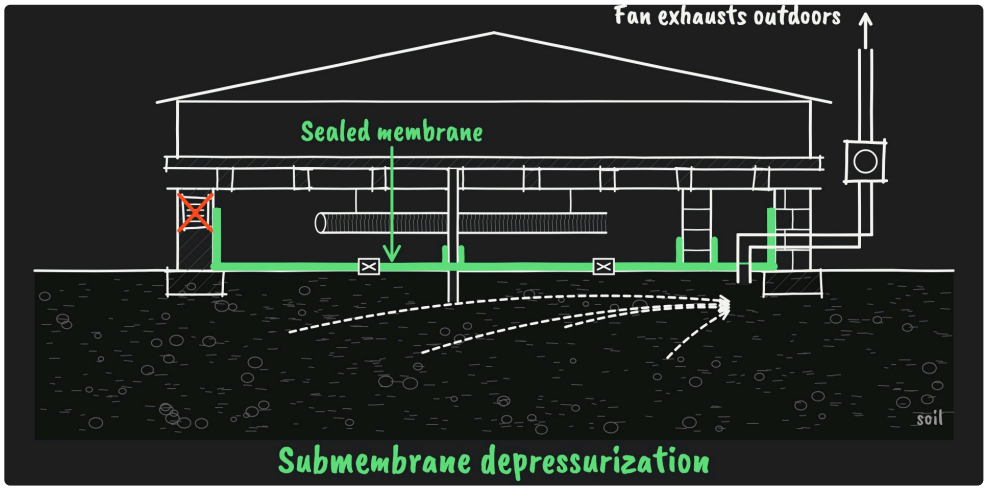


Figure 8. Submembrane depressurization: a sealed membrane (green) with a fan drawing soil gas from beneath it and exhausting it outdoors.

For normally drained crawl spaces without an identified soil-gas hazard, sealing every seam and wall connection should not be the starting point.

Test

for radon; it has no smell

10 Recommendations

6
steps

For low, existing crawl spaces in southeastern Virginia and the humid coastal Southeast:

1. **Remove contaminated materials.** Clean the wood, remove old musty floor insulation, and replace contaminated ductwork and duct insulation.
2. **Control bulk water.** Correct grading and add drainage where groundwater enters.
3. **Seal the foundation vents and major air leaks.** In this climate, humid outdoor air through vents is a much larger summer moisture load than vapor through a pinned liner.
4. **Install a durable pinned vapor barrier:** full coverage, overlapped seams, sod staples, lapped but not sealed at the walls.
5. **Provide a drying system,** a dedicated dehumidifier or properly designed conditioned supply air.
6. **Verify performance** by measuring crawl space humidity and wood moisture content.

Other climates, below-grade conditions, site-specific soil-gas hazards, and applicable building codes can require different details.

11 Judging a Crawl Space System

Crawl space systems should be judged by what they accomplish:

- Does the wood stay dry?
- Is the crawl space clean?
- Can the foundation be inspected?
- Is the system affordable and easy to maintain?
- Does the crawl space smell the way a clean, dry crawl space should?

The purpose of encapsulation is to solve problems, not create new ones.

12 Research Needed

A regional field study comparing fully sealed and pinned ground liners in normally drained crawl spaces in the humid Southeast would settle the question this paper raises. Useful measurements would include soil moisture and soil-gas oxygen under each liner type after significant rainfall, odor assessment in the crawl space and living space, crawl space humidity, and framing moisture content over at least one full summer.

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About the Author



Robbie McCarty owns Patriot Crawl Space Repairs in southeastern Virginia. He personally inspects more than 600 crawl spaces a year and has inspected thousands over his career, which gives him a long view of how crawl space systems perform five, ten, and twenty years after installation.

He is a Virginia Class A residential building contractor, a licensed pest control operator, a licensed master plumber, and a MICRO certified mold remediation contractor. Before focusing on crawl spaces, he spent roughly two decades in Virginia real estate, including fifteen years as a full-time broker, where nearly every transaction involved a crawl space inspection.

He teaches crawl space building science on his video series, *Crawl Space Science*.

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