

MoldNews Review

MOLD PREVENTION & STANDARDS
Bridging Industry, Government,
and Academia



THE GOLDEN MICRODOMAIN

MoldNews

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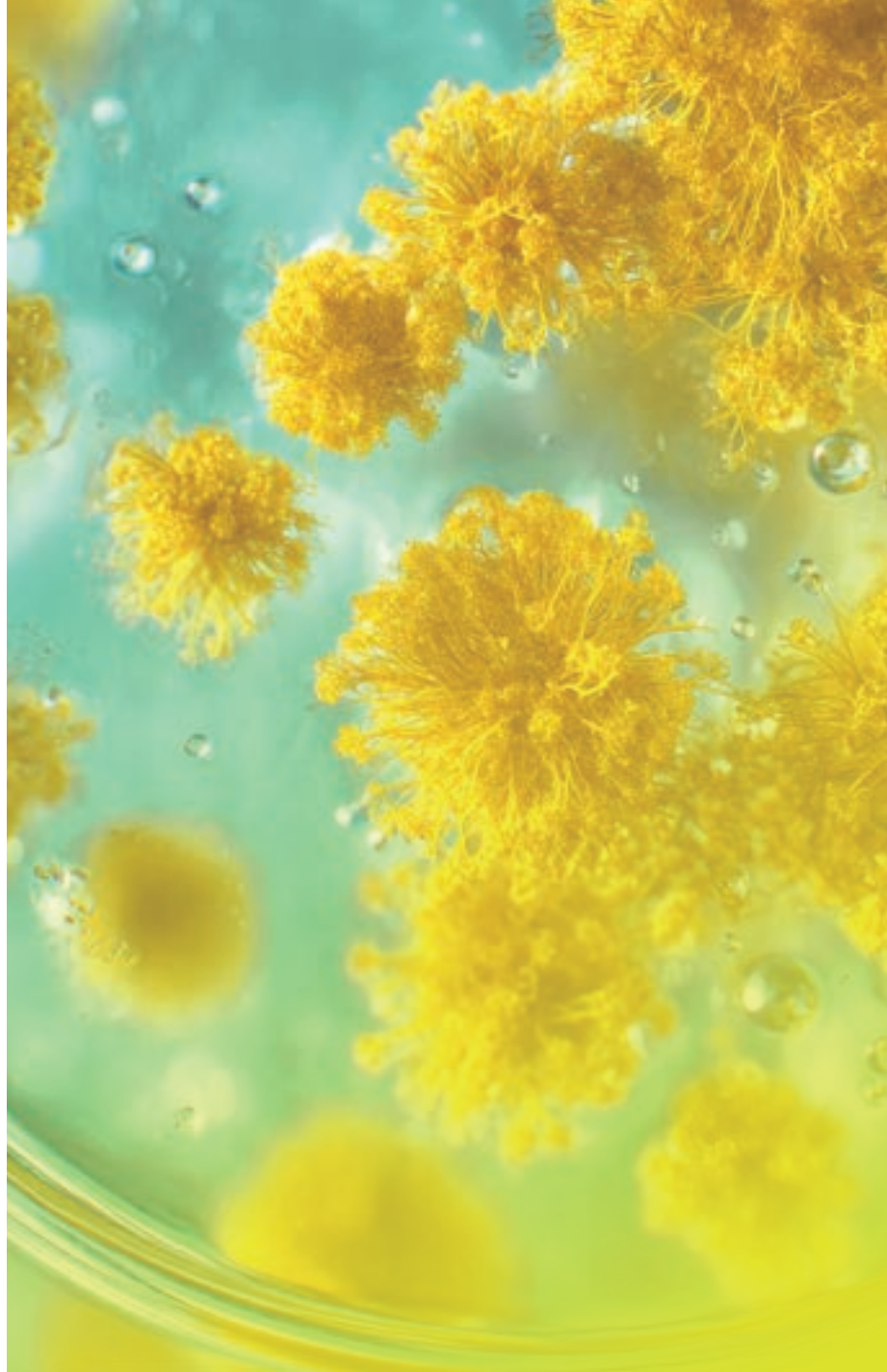
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YCM and MRC

Since its establishment in 2015, the YCM Mold Research Center has focused on scientific research in mold detection, identification, and prevention. In 2019, it obtained dual certification under ISO/IEC 17025 and ISO/IEC 17020, becoming the only mold-focused professional organization in Asia to achieve both certifications. The center has accumulated over a thousand cross-industry case experiences and established a database containing millions of mold behavior and risk data points.

As the developer of the GMPP mold prevention certification standard, the center leads the way in data-driven and precise mold control. Through this magazine, YCM hopes to disseminate the latest mold knowledge and experience to industry, government, academia, and the general public.

- 04** Temperature Driven Mold Secondary Contamination
- 11** Mushrooms As Materials For Computer Chips
- 15** Water Determine Factor of Mold Appears
- 20** Six Post-Shower Habits Keep Bathrooms Clean and Reduce Mold Risk
- 25** Climate Change The Emerging Risk of Mold Diversity

Temperature Driven

Mold Secondary Contamination

Why does indoor air quality sometimes deteriorate suddenly without visible mold growth?

In environments where moisture or temperature–humidity balance is disrupted, attention often focuses on visible mold growth. However, the greater risks to health, materials, and indoor air quality usually come later. When mold colonies dry out, experience temperature changes, or are physically disturbed, mature spores, hyphal fragments, and mycotoxins can quickly become airborne. At that point, contamination is no longer confined to surfaces. It becomes inhalable, spreads through the air, and expands into previously unaffected areas.



This kind of secondary contamination does not occur randomly. It depends on three closely linked factors: how mature the spores are, how fragile the mold colony structure has become, and whether airflow or vibration is present. Temperature plays a central role in all three. It controls how quickly spores mature, affects moisture loss and material cracking within the substrate, and even influences how efficiently spores can germinate after release. When temperatures fluctuate, mold risk can shift suddenly from seeming stability to large-scale spore release, creating exposure conditions that are far more harmful than visible growth alone.

OPTIMAL MOLD GROWTH

24-28°C, 60-75% RH

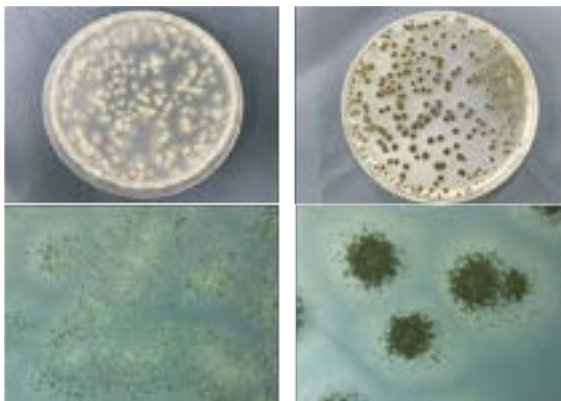


Temperature Governs Metabolic Rate and Sporulation Dynamics

Most indoor molds are mesophilic organisms that grow within a moderate temperature range, roughly between 5 and 35 °C, with optimal activity around 24–28 °C. (Zhan et al., 2021; Pasanen et al., 1991). Within this window, enzymatic reactions and respiratory metabolism operate efficiently, allowing spores to germinate more quickly and hyphae to extend at their fastest rates. Under stable conditions combining these temperatures with moderate humidity, mold colonies can expand rapidly and establish dense biomass. (Zhan et al., 2021).

As temperatures drop, growth slows noticeably. When conditions shift from around 25 °C down to the mid-teens, spore germination takes longer and hyphal extension becomes sluggish. This slowdown reflects basic physiological limits: enzyme activity decreases, and cell membranes become less flexible, making growth energetically less efficient even if moisture remains available (Pasanen et al., 1991).

Importantly, the temperature that favors growth is not always the same temperature that favors sporulation. Many mold species prioritize vegetative expansion under warm, humid conditions, investing energy in building biomass rather than producing spores. As temperatures decline but remain within a viable range, this strategy can shift. Cooling conditions often trigger increased sporulation, allowing the colony to convert accumulated biomass into large numbers of mature spores. For example, a seasonal temperature drop from around 28 °C to 20–22 °C under sufficient humidity can initiate widespread sporulation, setting the stage for significant spore release once drying or disturbance occurs.



YCM Mold Research Center
Day 4 growth morphology: 25°C incubation (left) vs. 40°C incubation (right)

Left panels: Widespread hyphal growth on PDA medium (upper); 75× magnification reveals sparse colony architecture (lower).

Right panels: Comprehensive sporulation across all colonies on PDA medium (upper); 75× magnification reveals dense colony architecture with intensive spore production (lower).



YCM Mold Research Center
Day 10 fungal colonization on cotton substrate at varying temperatures

Left: 25°C; Center: 35°C; Right: 40°C

These patterns were clearly demonstrated in thermal cycling experiments conducted by the YCM Mold Research Center. During warming phases between 25 and 40 °C, extensive hyphal networks developed at lower temperatures, while spore maturation accelerated markedly at higher temperatures. During cooling cycles from 40 back to 25 °C, abundant sporulation occurred at elevated temperatures, and mature spores persisted through cooling without a corresponding increase in vegetative growth. Together, these observations show that elevated temperature primarily speeds up reproductive maturation, rather than simply increasing surface growth.

Similar trends were observed across different material substrates. In YCM tests on cotton, leather, and polyester, cultures maintained at 40 °C formed dense colonies within four days and reached advanced spore maturity well before those grown at 25 °C. Lower-temperature cultures showed slower growth, sparse colonization, and delayed sporulation. Although the materials differed in moisture retention and surface properties, their thermal response patterns were consistent: higher temperatures pushed colonies more quickly toward maturity and early accumulation of large, release-ready spore reservoirs.

Taken together, these findings highlight temperature as more than a general growth modifier. By controlling the transition from vegetative expansion to

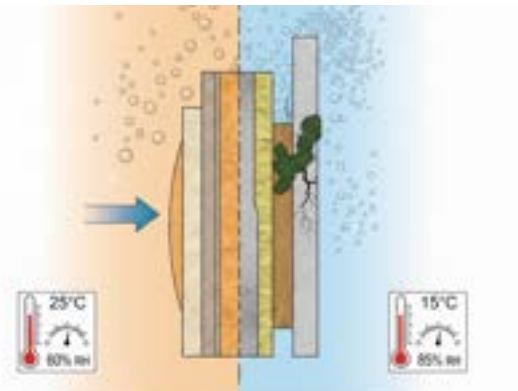
reproductive maturity, temperature sets the conditions that determine whether a mold colony remains surface-bound or becomes a potential source of airborne contamination. In this way, temperature acts as a primary driver in the early stages of secondary contamination cascades.

Temperature-Driven Spore Dispersal via Hygrothermal Cycling

Temperature influences mold dispersal not only by shaping fungal physiology, but also by controlling how moisture moves in and out of building materials. In many cases, spores are not released simply because humidity is high, but because temperature changes drive repeated wet-dry cycles and sudden microclimate shifts that weaken colony attachment.

● Condensation on Cold Surfaces

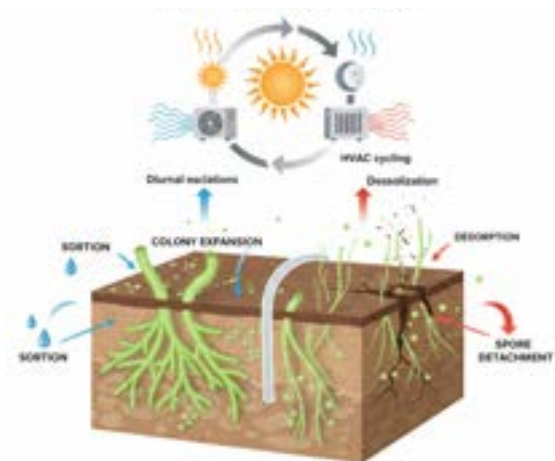
Warm humid air contacting cold surfaces (exterior walls, glazing, refrigerant lines) undergoes cooling below dew point, precipitating immediate condensation that elevates local humidity to saturation. Even at 60% ambient RH, these thermal bridges sustain prolonged condensation, generating localized hypersaturation that promotes colony hydration and expansion.



● Temperature-Dependent Humidity Gradients

Constant absolute humidity yields divergent relative humidity across thermal zones—60% RH at 25 °C may reach 85% in 15 °C microclimates. This establishes discrete hygric zones within building envelopes, causing selective surfaces to approach critical thresholds for fungal development or structural transition.

● Thermal Fluctuations Driving Hygric Cycles



Diurnal oscillations, seasonal transitions, and HVAC cycling impose iterative sorption-desorption on substrates. Hydration phases enable colony expansion with continued vegetative growth and sporulation; subsequent desiccation induces substrate moisture loss, hyphal network

contraction, and matrix fracturing, diminishing adhesive forces and priming spore detachment. This hygrothermal cycling constitutes the dominant physical mechanism underlying secondary aerosolization.

Different types of mold respond very differently to environmental change, largely because of their inherent biological traits. Sudden shifts in temperature or humidity can therefore trigger very different spore-release behaviors depending on the mold type.



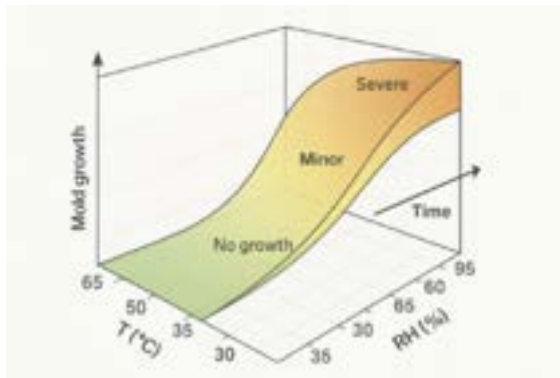
Xerophilic molds, such as *Aspergillus*, *Penicillium*, and *Cladosporium*, are especially sensitive to rapid drying. When indoor conditions are warm and humid and dehumidification, heating, or air conditioning is suddenly activated, temperature or relative humidity can change quickly. This causes mold colonies to lose water almost instantly and contract. As dehydration progresses, the extracellular materials that normally bind chains of spores begin to break down, allowing spores to detach easily. Under these conditions, even minimal airflow or light vibration can release large numbers of spores into the air (O'Gorman & Fuller, 2008; Górný et al., 2002). Because these spores are typically small (around 2–10 μm), they can remain suspended for long periods and are among the most common contributors to indoor air quality degradation.

Hydrophilic molds, such as *Stachybotrys chartarum* and *Chaetomium*, behave quite differently. Their spores are embedded in thick, moisture-loving matrices that strongly adhere to surfaces under high humidity, making spontaneous dispersal unlikely. However, when these molds experience rapid drying, sudden temperature increases, or strong mechanical disturbance such as demolition or renovation, the colony structure can fail abruptly. This can lead to short-duration but intense release events, ejecting spores, hyphal fragments, and toxin-associated particles into the air (Tucker et al., 2007; Dyląg et al., 2022). These explosive release episodes are generally considered to pose higher health risks than the gradual spore dispersal typical of xerophilic molds.

An important and often overlooked factor is the positive feedback between temperature and release risk. Elevated temperatures accelerate mold growth and spore production, leading to denser, more mature colonies. These mature structures, while biologically robust, are mechanically fragile when exposed to sudden drying or cooling, making them more prone to rupture and mass aerosolization. Field observations frequently show this cascading pattern: temperature-driven maturation followed by thermal or humidity shock, resulting in a sharp increase in airborne contamination.



T–RH–Time Integrated Model



Three-dimensional risk framework for fungal colonization as a function of temperature, relative humidity, and exposure duration.

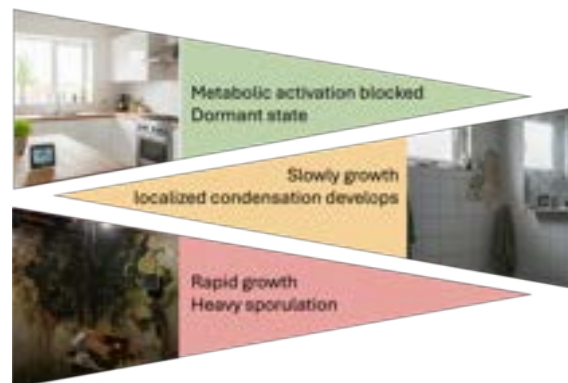
Color gradient from green to orange denotes risk progression from negligible growth to severe proliferation. Conceptual model synthesizes empirical data from Pasanen et al. (1991), Zhan et al. (2021), Kuka et al. (2022), and Wu & Wong (2022).

Temperature (T), relative humidity (RH), and exposure duration are the three main environmental factors that shape indoor fungal risk. Looking at any one of these on its own rarely tells the full story. Mold growth, maturation, and eventual release into the air become much easier to understand and predict when temperature, humidity, and time are considered together.

Relative humidity is the primary trigger for fungal activity. It functions as the biological “on–off switch” for growth. Most indoor molds require water activity above a_w 0.80 to initiate metabolism (Mannaa & Kim, 2017), and sustained RH above 80% allows growth across a broad temperature range (approximately 10–30 °C). In contrast, maintaining RH near 60% strongly suppresses growth even when temperatures are otherwise favorable. As a result, RH is widely recognized as the dominant environmental control in indoor fungal risk.

Temperature regulates the speed of fungal development. Warmer conditions accelerate enzymatic activity, hyphal growth, and spore production, allowing colonies to reach maturity more quickly. Temperature fluctuations can also amplify moisture cycling, weakening colony structure and increasing the likelihood of spore release. In this sense, temperature determines how fast risk escalates once humidity thresholds are exceeded.

Time defines whether risk can fully develop. Fungal growth and maturation require sustained exposure, not brief excursions. Materials exposed to elevated RH for multiple days are far more likely to support colonization, and higher temperatures shorten the time needed to reach hazardous, spore-rich stages.



Germination tests conducted by the YCM Mold Research Center provide clear, practical evidence of how temperature influences a mold’s ability to recolonize after dispersal. Under the same starting spore concentrations, spores that had developed under higher temperatures showed a 50% germination rate, compared with only 10% for those formed at lower temperatures. This fivefold difference means that once spores become airborne, those conditioned by warmer environments are far more effective at establishing new growth, even under barely permissive moisture conditions near the minimum water activity threshold.

Taken together, these findings show that the T–RH–Time framework goes beyond simply predicting whether mold will grow or not. It helps explain when colonies are likely to mature, how temperature and moisture cycles can trigger spore release, and why recolonization can happen so efficiently after dispersal. By looking at temperature, humidity, and time as a connected system, risk assessment shifts from static snapshots to a more realistic, dynamic picture of how mold behaves and persists in real indoor environments.

C Conclusion

Fungal risk does not come from a single factor acting alone, but from a chain of environmental changes working together over time. Humidity determines whether mold can start growing, but the shift from surface contamination to airborne spread is largely driven by

temperature. As temperatures rise, mold matures faster and builds up large numbers of spores. When this is combined with moisture and temperature cycling, colonies become unstable and more likely to break apart. As a result, sudden indoor air quality problems are usually caused not by rapid new growth, but by temperature changes that push already mature colonies past their release threshold.

From a practical risk management perspective, controlling mold is less about reacting to individual readings and more about understanding how temperature, humidity, and time move together. Keeping materials from staying damp for long periods, avoiding sharp heating or drying after mold has formed, and reducing airflow or physical disturbance can greatly lower the chance of spores becoming airborne. In this way, effective mold control goes beyond simply lowering humidity and focuses on managing temperature-driven progression across the entire contamination process, helping prevent secondary spread before it occur

Mushrooms

As Materials For Computer Chips

Can living fungal networks store information in way that challenge how we define memory and computing?

Scientists have successfully transformed mushrooms into a form of computer memory, revealing a novel intersection between biology and computing technology. The research shows that fungal structures, long studied for their ecological importance, can also perform information storage functions traditionally reserved for electronic materials.

The findings add to a growing body of work exploring biological systems as computing substrates and raise new possibilities for sustainable, adaptive, and energy-efficient information technologies.

From Forest Floor to Data Storage

Mushrooms are the visible fruiting bodies of fungi, but the real functional structure lies underground in vast networks of mycelium. These thread-like filaments form complex, interconnected systems capable of responding to environmental stimuli such as light, nutrients, pressure, and electrical signals.



Researchers have now demonstrated that these same properties can be harnessed to encode, store, and retrieve information. By interfacing fungal material with electronic components, they showed that mushrooms can function as memory units capable of retaining states over time. This challenges conventional assumptions that biological materials are too unstable or imprecise for computing applications.



How Fungal Memory Works

The memory function relies on the electrical behavior of fungal mycelium. When exposed to electrical stimulation, fungal networks exhibit measurable changes in conductivity and electrical resistance. These changes can persist, effectively allowing the system to “remember” past inputs. In practical terms, these electrical states can be interpreted as binary information, similar to the ones and zeros used in digital computing. Unlike silicon-based memory, however, fungal memory does not require rigid architectures or complex fabrication processes. Instead, the living structure itself adapts and reorganizes, enabling information storage through biological processes rather than fixed circuitry.

Sustainability and Material Advantages



One of the most significant implications of the research lies in sustainability. Traditional computing hardware relies on rare minerals, energy-intensive manufacturing, and generates large amounts of electronic waste. Fungal materials, by contrast, are biodegradable, renewable, and can be grown using agricultural byproducts. Mycelium-based materials require far less energy to produce and can be composted at the end of their lifecycle.

Why Fungi Are Suitable for Bio-Computing

Fungi possess several traits that make them attractive candidates for unconventional computing:

- highly interconnected network structures
- natural signal transmission capabilities
- resilience to environmental stress
- ability to grow and self-repair
- low energy requirements

These characteristics allow fungal systems to process information in parallel rather than sequential ways. Researchers emphasize that this approach does not aim to replace conventional computers, but rather to complement them in specific applications where adaptability and sustainability are priorities.



Change Over Time

Unlike static electronic components, fungal systems are alive. This introduces both opportunities and challenges. On the positive side, living materials can adapt to changing conditions, heal minor damage, and reorganize themselves. This could enable computing systems that respond dynamically to their environment or recover from partial failure.

However, biological variability complicates predictability and control. Researchers note that stabilizing memory states and ensuring reproducibility will be key challenges before practical deployment.

Potential Applications Beyond Computing

The implications of fungal-based memory extend beyond traditional computing. Researchers suggest potential applications in:

- biosensors that record environmental changes
- smart materials that respond to stimuli
- adaptive architecture
- low-power data storage for remote environments

In these contexts, the ability of fungi to integrate sensing, processing, and memory within a single material could offer advantages over conventional electronic systems.

Relation to Other Bio-Computing Research

This work builds on earlier studies showing that fungi can transmit electrical signals similar to neural impulses. Some researchers have likened mycelial networks to primitive information-processing systems.

It also complements research into bacterial computing, DNA-based data storage, and neuromorphic systems inspired by biological brains.



Common Fungal Species Used in the Research Context

While multiple fungi exhibit suitable properties, species commonly explored for mycelium-based electronics include:

- *Pleurotus ostreatus*
- *Ganoderma lucidum*
- *Trametes versicolor*

Conclusion

The successful transformation of mushrooms into functional computer memory highlights the untapped technological potential of fungi. By leveraging the natural electrical and structural properties of mycelium, researchers have demonstrated a new form of bio-based memory that challenges traditional computing paradigms.

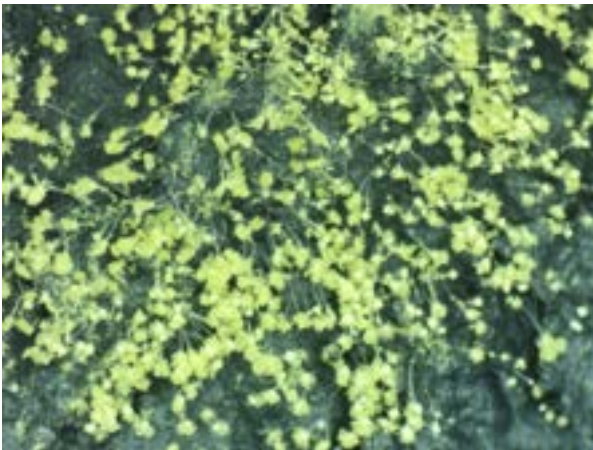
While practical applications remain in early stages, the work underscores a broader shift toward integrating living systems into technology design. As computing seeks sustainable and adaptive alternatives, fungi may play an unexpected but significant role in shaping the future of information storage.

Water

Determine Factor of Mold Appears

If you could choose only one strategy to prevent mold, what would be the defining factor?

Within our daily environment, mold spores act like tiny "time capsules," drifting through the air or sitting on surfaces in a deep, silent sleep. For researchers and homeowners alike, the million-dollar question has always been: what exactly triggers these dormant spores to suddenly "wake up" and start growing?



Maybe it's the warmth of the room that coaxed them out?

Perhaps they finally found a source of nutrients to feast on?

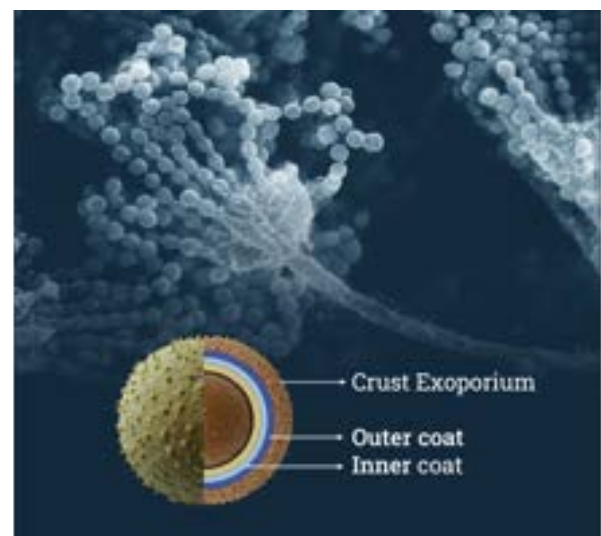
Or maybe it was the presence of oxygen that gave them a breath of life?

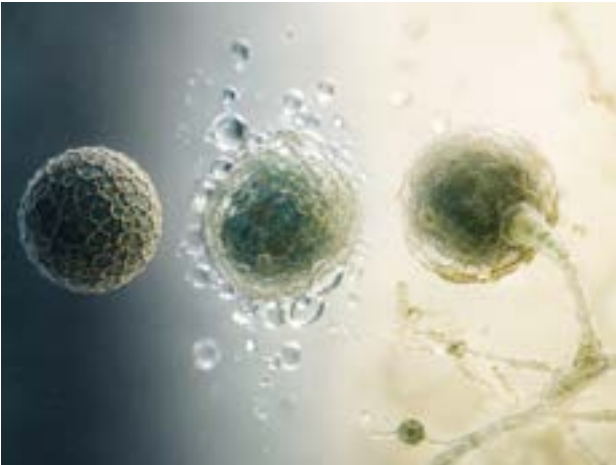
While it is true that temperature, food sources, and oxygen levels determine how fast or how thick the mold grows, none of them hold the ultimate power. After countless experiments, researchers discovered a striking reality: even with the perfect temperature and a feast of nutrients, a mold spore will never hit the "start" button without one vital ingredient—Moisture.

Fundamental Concepts of Spore Germination

Mold spores can be thought of as the "seeds" of the fungal world, but they travel much lighter than the seeds of a sunflower or a bean. While a plant seed packs a heavy suitcase full of starches, fats, and proteins to fuel its early growth, a mold spore is a minimalist. It carries only the bare essentials—just enough energy and a few protective molecules to survive in harsh, dry environments. This "travel light" strategy allows spores to remain dormant for years, waiting patiently for the perfect moment to strike.

Behind their tough, multi-layered walls, these dormant spores are masters of survival. They are shielded by specialized water-repellent coatings and pigments that guard against drought, UV rays, and environmental stress. Inside, everything is at a standstill: metabolism drops to near zero, and the cell's internal machinery is locked in a deep freeze to save every drop of energy. It is a state of perfect, suspended animation.





The arrival of moisture, however, changes everything in an instant. The moment water becomes available, the spore begins to soak it up like a sponge, swelling in size as its protective armor softens. This "hydration" is the spark that reignites the engine of life. Within just 6 to 12 hours, a tiny germ tube—the first sign of a new mold colony—bursts through the spore wall. In less than two days, what started as a microscopic speck can grow into a visible colony. In some aggressive species, like the common black bread mold, this entire transformation happens even faster, turning a "silent seed" into a growing organism before we even realize it's there.

The Necessity and Sufficiency of Water in Spore Germination

Water is the ultimate "on-off" switch for mold; without it, the machinery of life simply stays frozen. Even if a spore is surrounded by oxygen and sitting on a feast of nutrients, it will remain in a deep sleep as long as the environment is dry. But the moment moisture hits a critical threshold, the transformation is electric. The cell walls swell, dormant enzymes wake up, and the first germ tubes punch through their protective armor. In the

world of mold, moisture isn't just a helpful neighbor—it is the landlord that decides when the doors open.

Mold species, however, don't all agree on how much water they need to "wake up." Scientists have spent decades measuring these requirements using a scale called water activity. For instance, the common black mold *Aspergillus niger* usually waits until moisture levels reach about 0.83, while the *Penicillium* we often find on damp walls and cardboard can start growing at 0.79. These numbers might seem like technical jargon, but they reveal a hidden truth: mold is much more resourceful than we imagine, and its "thirst" is often much easier to quench than we'd like to believe.



But the most striking discovery challenges our very definition of "dry." While we might think mold only grows in soggy basements or during humid summers, a specialized mold called *Aspergillus penicillioides* can germinate at a water activity as low as 0.58. To put that into perspective, that is roughly 58% relative humidity—the exact level most of us consider "perfectly comfortable" in our homes. This "xerophilic" (dry-loving) mold serves as a powerful reminder: the danger zone isn't just a damp, dripping corner. Sometimes, the spores are waking up in the very air we think is safe.

Factors Shaping Hyphal Growth Rate and Persistence

Moisture stands as the undisputed gatekeeper of the microbial world. It is the primary condition that determines whether a spore can initiate its life cycle. Without moisture, spores remain entirely static—frozen in a dormant state—regardless of how favorable other environmental factors might be. Only after moisture levels cross the critical threshold do temperature and nutrients begin to exert their secondary influence on the mold's development.



Temperature acts as the "metabolic accelerator," primarily dictating the duration of the lag period and the subsequent growth rate. Extensive experiments, such as those conducted by Ayerst (1969), demonstrate that even with adequate moisture, low temperatures can significantly stall the germination process. However, this is often just a temporary pause; once temperatures return to a suitable range, the biological clock resumes. In essence, temperature controls the "tempo" of the invasion, governing how quickly a microscopic spore transforms into a visible problem.



Nutrients serve as the essential fuel for sustaining growth rather than the initial spark. A spore's internal energy is remarkably limited; relying solely on its own reserves, a germ tube can typically extend no more than 0.1 micrometers in length. Research indicates that in environments of pure water, about 40% of *Aspergillus nidulans* spores can achieve germination, while only 5% of *Aspergillus niger* spores manage to do so. While they may "wake up," they cannot build a lasting colony without external help. However, when the environment provides even basic glucose or inorganic salts—often found in household dust, skin flakes, or food residues—germination rates skyrocket, allowing those tiny tubes to extend into the mature, sprawling networks we recognize as mold.

Moisture in Industrial Reality

Moisture in industrial settings rarely appears as an obvious "splash of water." Instead, it creeps in through subtle environmental shifts that quietly push surface water activity past the danger zone. These hidden culprits include short-term spikes in humidity, micro-condensation from temperature swings, the natural "thirst" (hygroscopicity) of certain materials, and stagnant microclimates caused by poor ventilation. In many cases, a surface that looks perfectly dry to the naked eye is already moist enough for a spore to begin its journey.



Cardboard, textiles, leather, and foam act like sponges in a warehouse, absorbing moisture within hours when nighttime temperatures drop and relative humidity climbs to 75–85%. During container transport, "cargo sweat" can rapidly saturate packaging and wood without ever leaving a visible puddle. Even in manufacturing, processes like applying adhesives or cooling after hot-pressing can create transient moisture films. When these materials—whether fabrics or sponges—are stacked tightly or pushed against cold walls, they create "cold spots" and trapped air, leading to latent moisture absorption

that is nearly impossible to detect through casual inspection.

Although these humidity events are often brief, they are more than enough to open the "risk window" for mold germination. This explains the frustrating mystery many factory managers face: why mold suddenly appears "out of nowhere" in environments that seem perfectly dry. It isn't a miracle; it's a microscopic response to a series of minor, yet sufficient, moisture events that we often overlook in our daily operations.

Conclusion

Moisture is the true starting point of mold growth. Temperature and nutrients may influence how fast mold develops, but without sufficient water availability, spores remain dormant. Therefore, mold prevention should focus first on moisture control, especially by monitoring environmental relative humidity as a practical field indicator.

When relative humidity stays elevated for several days, even surfaces that appear dry may provide enough moisture for spores to germinate. For factories, warehouses, packaging, textiles, leather, and logistics environments, this means that short periods of humidity control failure can already create mold risk.

In the future, mold prevention should move from simple humidity control toward predictive risk management by linking relative humidity, material water activity, and spore germination behavior. Controlling moisture means controlling the very beginning of mold problem.

Six Post-Shower Habits

Keep Bathrooms Clean and Reduce Mold Risk

Bathrooms are among the most challenging spaces to keep consistently clean. Frequent water use, steam, and limited airflow create ideal conditions for grime, limescale, and mold to develop rapidly.

While deep cleaning is often treated as the solution, cleaning professionals emphasize that daily habits immediately after showering are far more effective in maintaining long-term bathroom hygiene.

Experts agree that people with consistently tidy bathrooms do not rely on constant scrubbing. Instead, they follow a small set of routine behaviors after every shower that reduce moisture, prevent buildup, and stop mold before it becomes established.



Why Post-Shower Habits Matter

Mold, bacteria, and mineral deposits thrive in warm, damp environments. After a hot shower, moisture condenses on glass, tiles, grout, floors, and soft furnishings. If left unmanaged, this moisture lingers long enough for fungal spores—already present in indoor air—to settle and grow.

Professional cleaners emphasize that most bathroom mold problems begin not with neglect, but with everyday moisture that is never fully removed. Addressing dampness immediately after showering interrupts the conditions that allow mold and bacteria to spread.

1. Using a Squeegee on Surfaces

One of the most consistently recommended habits is using a squeegee immediately after finishing a shower. This practice involves wiping down glass screens, tiled walls, shelves, and even the shower floor.

Removing excess water reduces the formation of limescale, soap residue, and moisture films that support microbial growth. Experts note that this step takes less than a minute but significantly reduces the need for intensive cleaning later.

By clearing water before it evaporates, surfaces dry faster and remain less hospitable to fungi and bacteria. Using a squeegee on the shower floor also prevents towels from absorbing excessive moisture during drying.



2. Removing Empty or Unused Bottles

Clutter inside the shower is more than a visual issue. Bottles and containers trap water beneath them, creating small damp zones where mold can develop unnoticed.

Professionals recommend removing empty bottles immediately and regularly reassessing which products are actually used. Reducing the number of items in the shower improves airflow, allows surfaces to dry evenly, and simplifies cleaning.

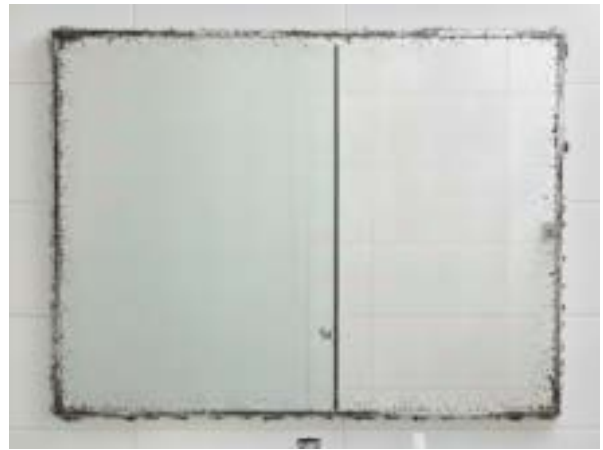
Crowded showers not only dry more slowly, but also encourage soap residue and moisture to accumulate in hard-to-reach areas, increasing the likelihood of mold forming beneath products.



3. Avoiding Touching Mirrors While Steamy

Wiping mirrors with hands or towels while they are steamy often leads to streaking, fiber residue, and fingerprints. These marks attract dust and moisture once the mirror dries, increasing cleaning frequency.

Experts advise leaving mirrors untouched until condensation clears naturally or using a squeegee for an even, streak-free result. When mirrors are cleaned, using lint-free cloths and minimal product reduces residue buildup that can attract moisture later.



Although mirrors are not typical mold sites, damp residues around edges and frames can contribute to broader bathroom humidity issues.

4. Clearing Hair From Drains

Hair combined with soap residue is one of the most common causes of slow drains and blockages. From a hygiene perspective, accumulated organic material in drains creates favorable conditions for bacterial growth and unpleasant odors.

Removing visible hair from the drain after each shower prevents buildup before it becomes problematic. Professionals note that this small habit reduces the need for chemical drain cleaners and lowers the risk of standing water—an important factor in controlling bathroom moisture.

Weekly flushing of drains with hot water, followed by mild household treatments, supports long-term drain hygiene.

5. Ventilating Immediately After Showering

Ventilation is consistently identified as the most critical factor in preventing bathroom mold. Steam left trapped in a closed bathroom condenses on surfaces, raising humidity and encouraging fungal growth.

Experts recommend opening windows or running extractor fans immediately after showering, continuing ventilation for at least 15 to 30 minutes. Even brief airflow allows moist air to escape before it settles.

Ventilation reduces condensation, protects paint and fixtures, and lowers the risk of mold spreading beyond the bathroom into adjacent rooms.



6. Hanging Towels and Bath Mats Properly

Textiles are often overlooked as moisture reservoirs. Towels and bath mats left crumpled or lying on floors dry slowly and retain moisture for extended periods.

Professionals advise hanging towels and bath mats fully spread out in a ventilated space. Proper drying prevents musty odors and limits microbial growth between washes.

Bath mats should be washed weekly, while towels should be laundered regularly according to usage. Fully dried textiles remain fresher and reduce humidity in the bathroom environment.



Health and Hygiene Implications

Persistent bathroom dampness is closely linked to mold growth and microbial contamination. While small amounts of mold may appear harmless, prolonged exposure can contribute to respiratory irritation, allergic reactions, and worsening asthma symptoms.

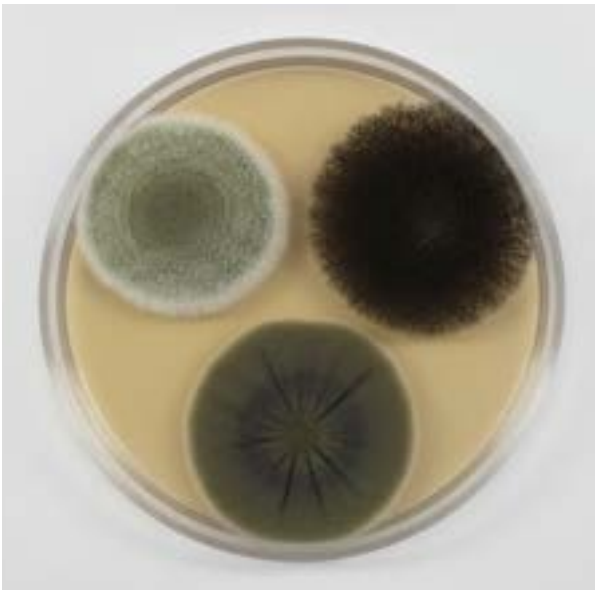
Individuals with respiratory conditions, weakened immune systems, children, and older adults are particularly vulnerable to mold-related health effects. Preventive habits reduce both visible mold and invisible airborne spores.

Common Fungi Found in Bathrooms

Bathrooms commonly host molds from genera that thrive in damp indoor environments

- *Cladosporium* spp. – frequently found on painted walls, window frames, and sealants
- *Aspergillus* spp. – capable of growing on tiles, grout, and dust-coated surfaces
- *Penicillium* spp. – often present on porous materials such as grout and silicone

These fungi are widespread in indoor air and typically become problematic only when moisture remains uncontrolled.



Prevention Over Remediation

Cleaning professionals emphasize that preventing mold is far easier and more cost-effective than removing it once established. Replacing sealant, grout, or damaged surfaces can be expensive and disruptive.

Consistent post-shower habits focus on moisture control rather than chemical treatments. By drying surfaces, ventilating effectively, and managing textiles, households reduce the conditions mold needs to survive.

Seasonal Considerations

Bathroom mold risk increases during colder months when homes are sealed to retain heat. Reduced window opening and slower evaporation make post-shower routines even more important during winter.

Conclusion

A tidy bathroom is less about constant cleaning and more about consistent habits. Small actions taken immediately after every shower—such as removing water, improving airflow, and drying textiles—play a decisive role in preventing mold, reducing bacteria, and maintaining hygiene.

Cleaning professionals stress that these habits require minimal time but deliver long-term benefits, keeping bathrooms cleaner, healthier, and easier to maintain without excessive effort.

EXPERT INSIGHT & RISK

Climate Change

The Emerging Risk of Mold Diversity

How is climate change changing the rules of
mold risk?

BY Mold Research Center
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Climate change is no longer just a story of extreme weather or melting glaciers; it has permeated every layer of the microscopic world. Rising temperatures, altered humidity cycles, and the increasing frequency of extreme weather events are redefining the survival boundaries of molds and other fungi. These organisms, invisible to the naked eye, were long regarded as localized issues of buildings, food, and health. Today, however, they have become some of the most active ecological responders to climate change.



The distribution and activity of fungi are extremely sensitive to climatic variations: global warming drives them to migrate toward higher latitudes, while changes in humidity and material composition reshape both indoor and outdoor fungal communities. Meanwhile, extreme rainfall and flooding act as catalysts for massive mold outbreaks. Yet, compared with studies on plants, insects, or marine ecosystems, research on fungal responses to climate change remains fragmented and insufficient. The expansion and reorganization of molds not only alter the flow of energy within ecosystems but also threaten building durability, indoor air quality, and human health.



Mold Migration Toward Higher Latitudes

Under the influence of climate change, molds and other fungi are no longer confined to the geographic patterns we once considered stable. As global temperatures rise and cold seasons become shorter, many fungal groups are showing a clear poleward shift—expanding toward higher latitudes where conditions were previously less favorable for growth and survival. This trend has been reported not only in medicine and public health, but also in studies of plant pathogenic fungi and broader ecosystem-level fungal change (Waheed et al., 2023).

Long-term ecological records provide one of the clearest signs of this shift. Over a 56-year period, many large fruiting-body fungi have been observed fruiting earlier, ending later, and in some cases producing two fruiting periods within a single year. These changes suggest that warming is extending the active season for fungi, giving them more time to grow, reproduce, release spores, and establish themselves in new regions (Gange et al., 2007).



The implications are especially important for mold-risk assessment. According to projections reported by Financial Times (2023), if current warming trends continue, the habitable range of *Aspergillus fumigatus* in Europe could expand by approximately 77% by 2100, spreading from southern Europe into higher-latitude temperate regions. A similar warning can be seen in the case of *Cryptococcus gattii*, a fungus once associated mainly with tropical and subtropical zones, which began causing outbreaks in the temperate Pacific Northwest of North America in the late 1990s. This has become one of the most widely cited examples of fungal expansion into cooler regions (Ngamskulrungraj et al., 2024).

This movement is more than a change on the map. When fungi enter new regions, they also enter new buildings, forests, crops, stored materials, and microbial communities. Local ecosystems and industries may face species they have not historically monitored or controlled. As temperature barriers weaken, fungi can compete and coexist with local plants, wood, soil microorganisms, and building materials in new ways, gradually forming unfamiliar ecological relationships.

At the same time, climate stress can make hosts and materials more vulnerable. Warming, drought, and

unstable humidity can reduce the defensive capacity of plants and organic materials, creating “windows of opportunity” for fungal invasion, colonization, and symbiosis. Some fungi may also adapt rapidly, developing greater tolerance to heat, cold, or moisture stress. Together, these changes suggest that mold migration is not simply a biological curiosity. It is an early warning that old assumptions about geography, seasonality, and material risk may no longer be reliable.

A region once considered low-risk because of its colder climate may not remain low-risk in the future. Warehouses, retail environments, packaging systems, wood products, textiles, leather, paper, and indoor spaces may all need to be evaluated under a changing climate baseline. Mold prevention can no longer rely only on historical regional experience; it must account for a future in which fungi are moving, adapting, and becoming active in places where they were once less expected.



Reorganization of Mold Diversity Under Climate Change

Climate change does not simply create “more mold.” It changes which molds become dominant, where they appear, and how strongly they influence the surrounding environment. As humidity patterns, material moisture, airflow, and indoor temperature stability shift, fungal communities begin to reorganize. Some species decline, while others become more competitive under warmer, wetter, or poorly ventilated conditions.



This reorganization is especially important in built environments. When building materials remain damp for extended periods, the surface is no longer just a passive background for microbial growth. It becomes an active ecological niche. Studies have shown that prolonged high-humidity conditions can increase fungal diversity and favor material-associated molds such as *Aspergillus*, *Penicillium*, and *Stachybotrys*. These genera are well adapted to moisture-rich substrates and can produce enzymes that help them break down organic materials, release spores, and increase overall microbial biomass (Lax et al., 2019).

Recent research confirms that climate-related factors are already changing fungal community structure. Elevated CO₂ levels and rising temperatures have been shown to alter the composition of arbuscular mycorrhizal fungi associated with maize and wheat roots. Although total diversity did not change significantly, the dominant species shifted, suggesting that climate pressure may reorganize fungal hierarchies even when the total number of species appears stable (Liu et al., 2023).

A similar pattern can be seen indoors. A two-year monitoring study across nine museum storage facilities found strong links between microclimate fluctuations—especially changes in temperature and relative humidity—and shifts in fungal abundance and community composition. These findings show that indoor fungal communities are highly sensitive to climate variability. They do not respond only by increasing or decreasing in number; they also change through species turnover, dominance shifts, and structural reorganization (Derksen et al., 2025).



However, climate change does not always increase fungal diversity. In urban heat islands, sealed buildings, or poorly ventilated environments, increased rainfall combined with reduced airflow may limit the movement of outdoor microorganisms into indoor spaces. In such cases, overall diversity may decline. Yet this does not necessarily mean lower risk. Instead, a smaller number of mold species may become more concentrated, more resilient, and better adapted to specific damp corners, wall cavities, storage zones, or material crevices.

This distinction is critical for risk management. A space with lower fungal diversity can still be dangerous if the dominant species are highly moisture-tolerant, heat-tolerant, or capable of forming stable biofilms. Some molds can also produce sticky extracellular substances that help them attach to surfaces and persist within microenvironments, making them harder to remove and more likely to return after cleaning (Aguilar-Marcelino et al., 2021).



In extremely humid or water-damaged environments, fungal communities often shift in favor of mold species that can rapidly colonize materials and exploit moisture. In enclosed settings without visible water intrusion, diversity may decrease, but the functional strength of specific mold communities may increase. In other words, climate change is not only changing how much mold exists. It is changing the identity, behavior, and persistence of mold communities.

This changes how mold risk should be evaluated. Visible growth and total microbial counts tell only part of the story. The more important question is which species are becoming dominant, under what material conditions, and how their functions affect product quality, indoor air, storage stability, and long-term material durability. As climate change blurs the boundary between outdoor and indoor microbiomes, mold diversity becomes a practical signal of environmental instability and emerging material risk.

Extreme Rainfall and Flooding as Accelerators of Mold Outbreaks

Extreme rainfall and flooding do not only damage buildings. They can reset the microbial environment inside them.

As climate change increases the frequency and intensity of extreme weather events, buildings are being exposed to longer and more severe moisture stress. According to the IPCC Sixth Assessment Report, every 0.5 °C rise in global average temperature is associated with a significant increase in both the occurrence and severity of extreme rainfall events, with high confidence. For indoor environments, this

means more frequent heavy rain, leaks, water intrusion, and prolonged dampness. These conditions raise the moisture content of walls, floors, insulation, wood, paper, textiles, and stored materials, allowing fungi to grow not only on surfaces but also deep within building structures.

The consequences can appear quickly after a disaster. Following Hurricane Katrina in 2005, visible mold contamination was found in 46% of surveyed residential buildings in New Orleans. In some affected areas, airborne spore concentrations rose from 82,000 spores/m³ to 630,000 spores/m³, showing how rapidly flooding can turn localized water damage into a community-scale indoor air quality crisis (Chew et al., 2006).



A similar warning emerged after Hurricane Harvey in 2017, when the U.S. Centers for Disease Control and Prevention reported cases of invasive mold infections among immunocompromised individuals. These cases underline a critical point: post-flood mold exposure is not only a building maintenance issue. For vulnerable populations, it can become a serious health risk. Together, these events reveal a clear causal chain: more extreme rainfall leads to more indoor moisture, deeper material dampness, and faster mold proliferation.

Environmental monitoring and clinical studies continue to support this pattern. Post-disaster research has shown strong positive relationships between flood depth, building dampness, and indoor mold concentrations. When buildings remain above 75% relative humidity or when material moisture content stays above 15% for extended periods, mold growth can accelerate dramatically. Under these conditions, high-moisture indicator species such as *Stachybotrys chartarum*, *Aspergillus niger*, and *Cladosporium cladosporioides* are frequently detected. These molds can colonize damaged surfaces, persist in porous materials, and reactivate when residual moisture becomes available again.

This is why flood-related mold risk does not end when the floor looks dry. Porous materials can continue to hold moisture long after visible water has been removed. Wall cavities, insulation, wood panels, cardboard, leather, textiles, and stored goods may remain damp enough to support hidden fungal growth. Once colonies mature, later drying, airflow, renovation, or physical disturbance can release spores and fragments into indoor air.



Extreme rainfall and flooding also reshape local fungal communities. Species that were once rare or limited to wet microenvironments may become dominant after prolonged water intrusion. Moisture-loving molds can gain a temporary but powerful advantage, colonizing materials faster than normal indoor competitors. As these events become more frequent, “climate-driven mold outbreaks” are likely to become less exceptional and more routine.

This changes the logic of flood recovery and prevention. Surface cleaning and short-term drying are no longer enough. Buildings, storage areas, and material inventories require longer moisture monitoring, material assessment, ventilation control, and post-remediation verification. In a climate of heavier rainfall and more frequent flooding, mold prevention must move from emergency response to climate adaptation.



Conclusion

Molds reveal a hidden biological dimension of climate risk. As temperatures rise, humidity patterns become less predictable, and extreme rainfall becomes more frequent, mold risk is moving beyond damp corners and isolated building problems. It is becoming a broader signal of environmental instability, affecting materials, indoor air, public health, and long-term building resilience.

The central lesson is that mold prevention can no longer depend only on historical climate patterns or visible contamination. Fungi are expanding into new regions, reorganizing into new communities, and responding quickly to moisture shocks after extreme weather events. These changes make mold risk more chronic, systemic, and difficult to manage through short-term remediation alone.

Future strategies must shift from reactive cleanup to proactive climate adaptation. Fungal monitoring, resilient materials, moisture control, building design, and post-disaster verification need to work together. In an unstable climate, molds are not just organisms growing in the background. They are early biological signals of whether our built environments are prepared for the conditions ahead.



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