The Wandering Plume of Filth: A Randomized, Empirical Assessment of Visible Wall Contamination Radiating from Commercial Hand Dryers Versus Paper Towel Dispensers in Functioning Public Restrooms

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Abstract

A visual audit examined contamination patterns beneath hand drying equipment across 120 devices in 95 functioning public restrooms covering three intervention types: hand dryers (n=51), brown paper towels (n=30), and white paper towels (n=39). Hand dryers were further classified as dispersal-type (n=50), which blow air outward onto walls and users, or capture-type (n=1), which collect water in internal reservoirs. Visual metrics included plume of filth presence, dimensional measurements, mold assessment (0-3 scale), and dirt assessment (0-3 scale). Paired microbiological sampling (CFU enumeration) was conducted at 109 out of 120 locations. Dispersal-type hand dryers exhibited visible wall plumes in 100% of installations (50/50) and visible wall mold in 100% (50/50). Plumes averaged 10 square feet, originating narrow at the device (median 1.0 ft) and fanning outward toward the floor (median 3.0 ft). Capture-type dryers showed no wall plumes but produced comparable or higher CFU output, including the study maximum of 5,431 CFU. No visual metric predicted microbiological output. Correlations between CFU and visual mold score (r=0.20, p=0.18), plume area (r=0.07, p=0.64), and plume darkness (r=-0.03, p=0.86) were uniformly non-significant. The visually cleanest installation in the study—zero visible mold, zero visible dirt, no detectable plume—was a capture-type dryer that produced 5,431 colony-forming units, the highest output recorded. The plume is a cumulative record of dryer emissions modulated by cleaning frequency. Visual inspection cannot identify hazardous installations. Brown paper towel dispensers showed 40% mold rates; white paper towel dispensers showed 13%—an 8-fold difference compared to dispersal dryers. Independent laboratory analysis (Hayes Microbial Consulting, EPA Laboratory ID: VA01419) confirmed fungal presence in 70% of plume tape samples, including 100% of dryer plumes tested, identifying Aspergillus/Penicillium, Alternaria, Cladosporium, Chaetomium, and other species documented to cause allergic reactions, hypersensitivity pneumonitis, and mycotoxin production. Every person entering a

restroom with a dispersal-type hand dryer enters a space with confirmed mold colonization—contamination created by the dryer regardless of whether that person chooses to use it.

This paper is part of an eleven-study series examining hand hygiene practices in public restrooms. The papers were written in chronological order as testing evolved. Earlier papers are left largely as they were written at the time for detail, historicity, and clarity. Studies in this series may be referenced in each document by series number (Paper 1-11) or by citation number in the reference list:

Transmission of Bacteria and Fungus via Dyson and Xlerator Hand Dryers in Starbucks, Home Depot and Whole Foods Restrooms: A Comparative Analysis; Blouch, R. A. Jr. (2025) MAIN STUDY [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.15504115 PAPER [1]

Testing the Validity of Hand Dryer Drying Time Specifications: A Quantitative Study of Residual Water on Dyson and Xlerator Dryers in Retail Store Environments; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.15503698 PAPER [2]

Visual Analysis of Water Dispersion Patterns During Hand Drying: A Qualitative Comparison of High-Speed Air Dryers and Paper Towels; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.15503304 PAPER [3]

Bacterial and Fungal Contamination Assessment of Paper Towel Types: A Quantitative Analysis of White versus Brown Varieties in Retail Restrooms; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.15504144 PAPER [4]

Systematic Performance Failure in Commercial Hand Dryers: A Large-Scale Quantitative Analysis of Time-To-Dry on Hands in Dyson and Xlerator Hand Dryers in Public Restrooms; Blouch, R.A Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.17858443 PAPER [5]

Baseline Water Mass on Freshly Washed Hands: Establishing Reference Values; Blouch R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.17858834 PAPER [6]

An Empirical Refutation of Green Energy Claims for Dyson and Xlerator Hand Dryers in Use in Public Restrooms; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.17859198 PAPER [7]

Catastrophic Time-To-Dry Failures by Dyson, Excel and World Dryer Hand Dryers via the Bi-Modal Loose Water and Bound Water Mechanism: A Comprehensive Definitive Analysis; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.17869567 PAPER [8]

Validation of Hand Dryer Microbial Amplification Using Broad-Spectrum Growth Media: A Replication Study with Enhanced Detection Methodology; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.17859894 PAPER [9]

The Wandering Plume of Filth: A Randomized, Empirical Assessment of Visible Wall Contamination Radiating from Commercial Hand Dryers Versus Paper Towel Dispensers in Functioning Public Restrooms; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.17860971 PAPER [10]

Performance Failures in Commercial Hand Dryers: An Historical Synthesis and Sequential Summary Review of an Eleven-Study Research Program; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.18322481 PAPER [11]

1. Introduction

1.1 Background and Rationale

Long before initial field work for this research series began a pattern was observed. The initial views were a curiosity, happening well before its significance was understood. Black colored dirt radiates from the hand dryer output airjets on restroom walls [1]. That observation—visible contamination spreading outward from drying devices—repeated enough times became the systematic investigation that informs this eleven-paper series. This paper returns to document that phenomenon directly.

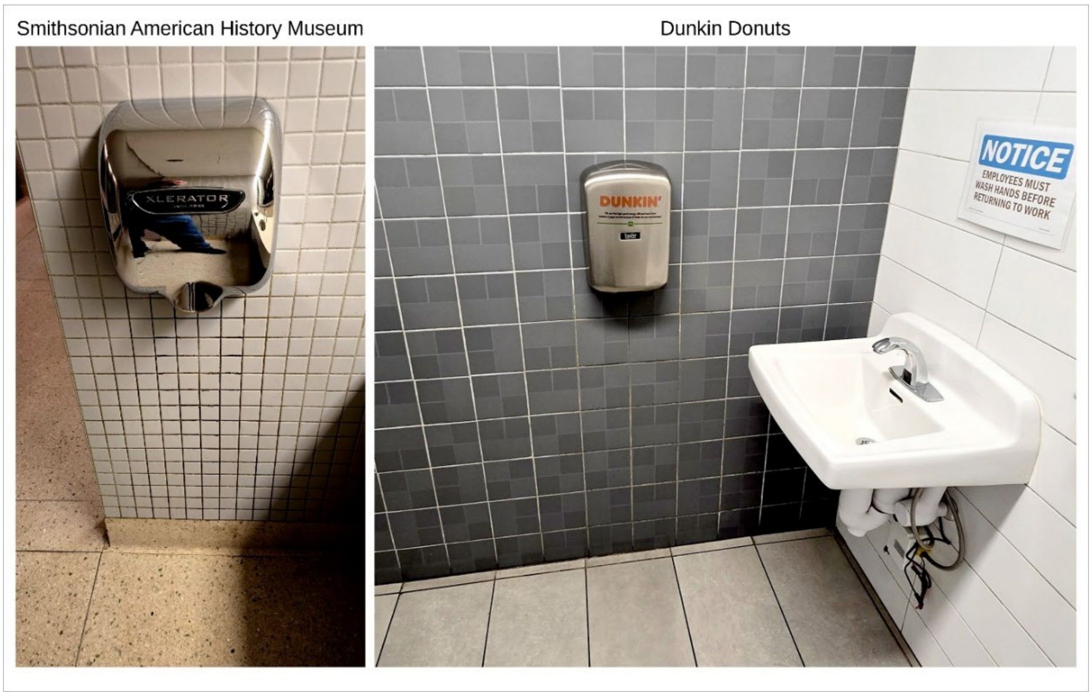


Figure A: Black mold under the hand dryer at the American History Museum in Washington DC and under a hand dryer at a Dunkin Donuts near a sign requiring employees to wash hands and providing the only means of drying. The white grout above and to the sides of the filth plume define the plume.

Companion studies in this series have established two co-occurring effects of hand dryer operation. First, hand dryers amplify bacterial and fungal contamination by 50-110× compared to ambient room air [1, 10], with this amplification occurring universally across device types and facility conditions, and dryer output containing organisms not present in the intake air. Second, high-speed videography has documented that hand dryers disperse water—and its microbial payload—onto users, walls, and floors during operation [11]. Visible droplets captured on video represent only a fraction of the aerosol burden; in high-shear environments like jet dryers, invisible aerosols (≤5 μm) outnumber visible droplets by factors of 100 to 10,000.

These two factors operate as co-equal contributors to the contamination patterns documented in this study. The amplified microbial load provides the organisms. The dispersed water provides both the transport mechanism and the moisture conditions hospitable to colonization. Neither factor alone explains persistent mold growth; together, they create the conditions observed beneath virtually every hand dryer in commercial service.

Prior research has documented deposition of bacteria and bacterial spores onto surfaces following hand dryer use [12], dispersal of microbes to multiple surfaces beyond the immediate drying area [13], and environmental contamination patterns that vary by drying method [9, 14]. What has not been systematically documented is the cumulative, visible result of this deposition over time.

This study asks a different question than its companions: What happens to the room itself when a hand dryer operates in it repeatedly, over months and years? Is there physical evidence of the microbiological burden these devices produce? And if so, what does that evidence tell us about the exposure risk for everyone who enters the space—not just those who use the dryer?

The answer is visible beneath virtually every hand dryer in commercial service. A pattern of contamination—dark staining, visible mold growth, accumulated grime—radiates outward from the device onto adjacent wall and floor surfaces. We call this the plume of filth.

The plume raises three questions this study addresses:

First, is the plume causally related to the dryer? Or is it simply characteristic of any high-traffic wall area in a restroom? The intervention comparison provides the answer: 100% of dispersal-type hand dryer installations show visible wall mold; 13% of white paper towel installations show visible mold. Same facility types, same cleaning variability, vastly different outcomes.

Second, can visual inspection identify hazardous installations? If plume severity correlates with microbiological output, visual assessment could serve as a proxy for exposure risk. It cannot. No visual metric predicted CFU output. The cleanest-looking installation produced the highest colony count in the study.

Third, what determines plume severity? If not dryer output—which is constant—then what? The answer is cleaning. Plume severity reflects the cumulative history of dryer emissions minus the cumulative history of wall cleaning. The dryer is a constant. The plume is a variable. The variable is janitorial, not mechanical.

One installation in the study, a grocery store restroom (Karns), illustrated the equilibrium state that all hand dryer installations have already reached. Mold had spread from the drying zone to tile and grout surfaces throughout the room. The widest plume base in the study. Room-wide colonization. Yet the facility was otherwise maintained—toilets clean, mirrors clean, floors swept. The dryer had simply been winning longer than the cleaning.

Every dispersal-type hand dryer installation has mold. The only variable is how visible the mold is at the moment of inspection—a function of cleaning history, not dryer behavior.

2. Materials and Methods

2.1 Study Design

A comparative observational study assessed visible contamination patterns associated with hand drying equipment in functioning public restrooms in 95 stores in Central Pennsylvania in September and October of 2025. Sampling was randomized by convenience: the investigator traveled to the next available public restroom without predetermined selection criteria. 120 devices and the walls and floors near where they are placed were examined/analyzed using modified NIOSH and FDA mold analysis standardized testing.

Three drying intervention categories were assessed:

- Hand dryers (n=51)
- Brown/recycled paper towels (n=30)
- White/ paper towels (n=39)

Most observations included paired visual and microbiological assessment.

2.2 Hand Dryer Type Classification

Hand dryers were classified by air dispersal mechanism, a novel conceptualization formulated in Paper 5 [22] of this series:

Dispersal-type (n=50): Devices that project air outward onto the user's hands and surrounding surfaces. Includes Xlerator, Dyson Airblade, World Dryer, Excel, and similar designs. Water and aerosolized organisms are dispersed into the room environment and onto adjacent wall surfaces.

Capture-type (n=1): Devices into which users insert their hands, with water collected in internal reservoirs or drains. Includes Aike and Toyo models. Water is captured rather than dispersed, eliminating wall contamination but not microbiological output.

This classification emerged as significant during analysis: capture-type dryers showed fundamentally different contamination patterns than dispersal-type dryers while producing comparable or higher microbiological output.

2.3 Visual Assessment Protocol

Visual metrics were recorded following NIOSH-informed documentation practices for mold and contamination assessment [8].

Binary Assessments:

- Plume presence (present/absent): Any visible contamination pattern beneath the drying device
- Mold presence (present/absent): Visual identification of fungal growth characteristics

Dimensional Measurements:

- Width at device (top of plume): Measured in feet at dryer exhaust height
- Width at floor (bottom of plume): Measured in feet at floor level
- Height: Vertical extent of visible contamination

Calculated Metric:

- Contamination area (square feet): ½(width_top + width_bottom) × height

Severity Scales:

- Visual mold assessment (0-3): 0=none, 1=size of a piece of paper, 2=size of a door, 3=larger than a door
- Visual dirt assessment (0-3): 0=none, 1=size of a piece of paper, 2=size of a door, 3=larger than a door
- Plume darkness (0-10): Intensity of discoloration
- Plume area score (0-10): Normalized area assessment

2.4 Microbiological Sampling

109 of 120 plume tests were paired with microbiological sampling using Tryptic soy agar (TSA) plates.

Dryers:

- Ambient room air (90-second exposure in front of the dryer with gentle hand wave)
- Dryer output air (90-second powered exposure at outlet as if hands were being dried)

Paper Towels:

- Ambient room air (30-second exposure in front of the towel dispenser with gentle hand wave)

- Dryer output air (30-second contact exposure with fresh towel surface)

Colony-forming units (CFU) were hand enumerated after a 72 hour two stage incubation at 97 degrees F, then 80 degrees F. Full methodology is detailed in the companion microbiological study (Paper 9) [10].

2.5 Laboratory Tape Sampling

Tape samples (1.0 cm^2) were collected from visible plume contamination at a subset of locations (n=10) and submitted to Hayes Microbial Consulting (EPA Laboratory ID: VA01419, Midlothian, VA) for direct fungal analysis. A contact plate was also submitted for fungal and bacterial culture. Samples were collected October 3, 2025, received October 7, 2025, and analyzed October 8, 2025. Analysis followed laboratory SOPs HMC#102 (direct analysis), HMC#103, HMC#104, and HMC#105 (culture).

2.6 Supplementary Video Review

Video recordings made during field sampling were reviewed post-hoc to assess device housing condition. This review focused on installations with minimal wall mold (score = 1, trace), examining the underside of dryer housings and wall-device junctions for mold colonization patterns.

Findings from video review were documented separately from field observations, with date of review and source notation. Original field data sheets were preserved unmodified; supplementary observations were recorded on separate documentation sheets stapled to originals.

2.7 Statistical Analysis

Spearman rank correlations assessed relationships between visual metrics and CFU output. Chi-square tests compared mold prevalence across intervention types. Paired t-tests assessed dimensional differences (width at top vs. bottom). Statistical significance was set at $\alpha = 0.05$.

3. Results

3.1 Dryer Type Distribution

Of 51 hand dryer installations assessed, 50 (98%) were dispersal-type and 1 (2%) were capture-type. Unless otherwise specified, results below refer to dispersal-type dryers only.

3.2 Plume Prevalence (Dispersal Dryers)

Dispersal-type hand dryers showed universal plume presence and mold colonization:

Metric	n	Rate
Wall plume present	50/50	100%
Visible wall mold	50/50	100%

3.3 Comparison to Paper Towels

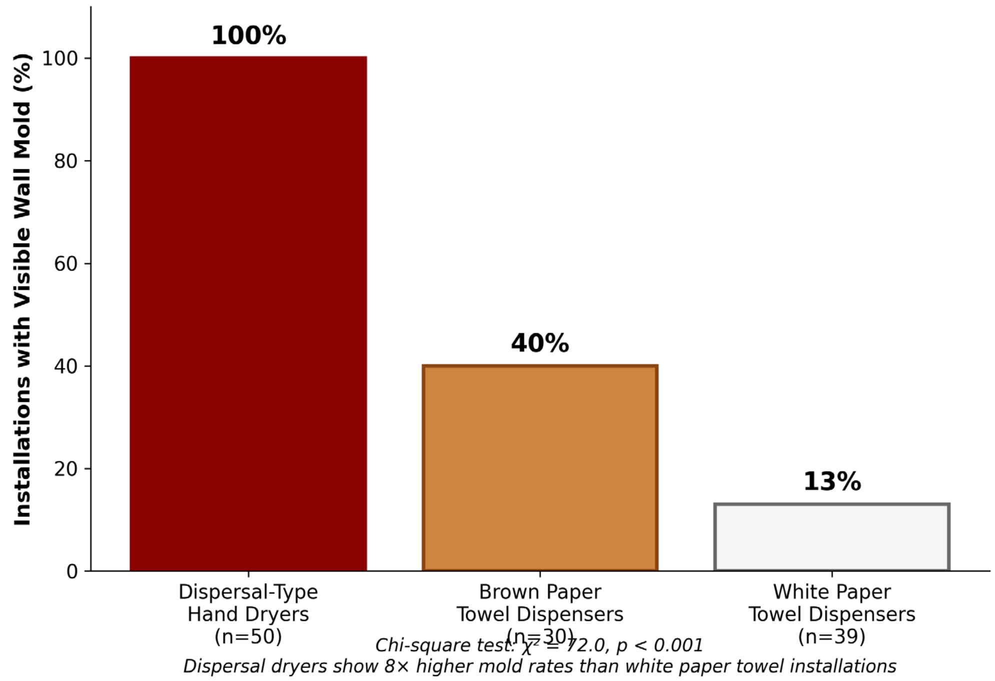
Mold rates varied dramatically by intervention type:

Intervention	n	Mold Rate
Dispersal hand dryers	50	100%
Brown paper towels	30	40%
White paper towels	39	13%

Chi-square test: $\chi^2 = 72.0$, $p < 0.001$

Dispersal-type hand dryers showed 8× higher mold rates than white paper towel installations in comparable facility types. The differential contamination between paper towel types is consistent with prior findings that brown/recycled towels carry higher microbial loads than white/virgin towels [15].

Figure 1: Mold Prevalence by Drying Method



3.4 Plume Dimensions (Dispersal Dryers)

Plumes originated narrow at the device and fanned outward toward the floor:

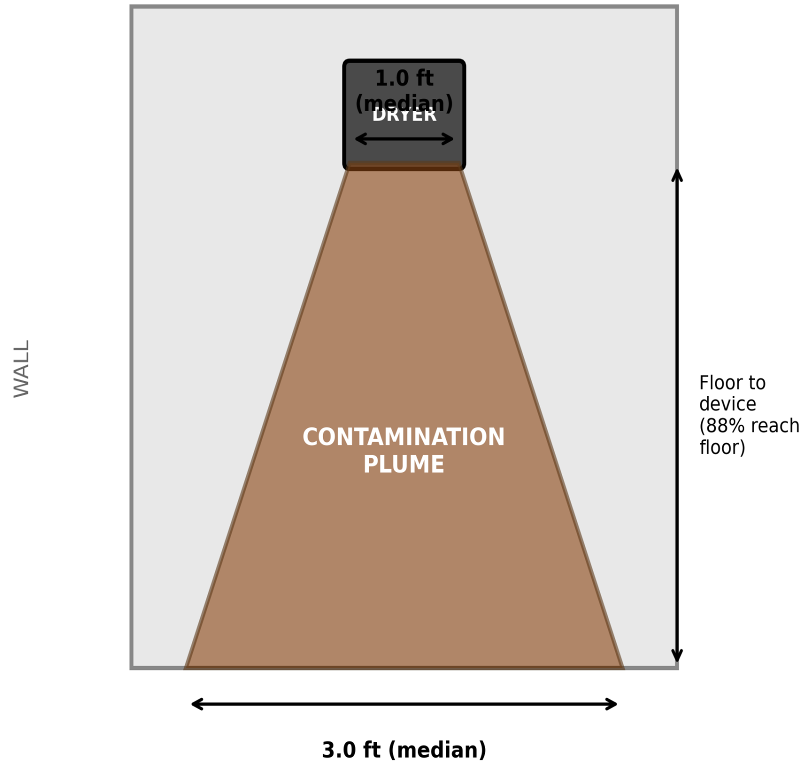
Dimension	Mean	Median	Range
Width at top (ft)	1.4	1.0	0.5–3.0
Width at bottom (ft)	3.6	3.0	1.0–8.0
Area (sq ft)	10.5	10.0	0.4–20.0

The bottom-to-top width ratio demonstrated significant spread: mean difference 2.2 ft (paired t-test: t=10.01, p<0.0001). Of installations with measurable plumes:

- 86% (42/49) showed wider bottom than top
- 0% showed wider top than bottom
- 14% showed equal width (predominantly small plumes)

Vertical extent reached floor level in 88% of installations (44/50).

Figure 2: Plume Geometry



Plumes originate narrow at the device exhaust and fan outward toward the floor. Mean area: 10.5 sq ft. Pattern consistent with aerosol dispersion physics.

3.5 Mold Severity Distribution (Dispersal Dryers)

Among dispersal-type installations with valid mold assessments (n=50):

Mold Score	Description	Count	Percentage
0	None	0	0%
1	Trace	12	24%
2	Moderate	30	60%
3	Heavy	8	16%

The majority (76%) showed moderate to heavy wall mold colonization.

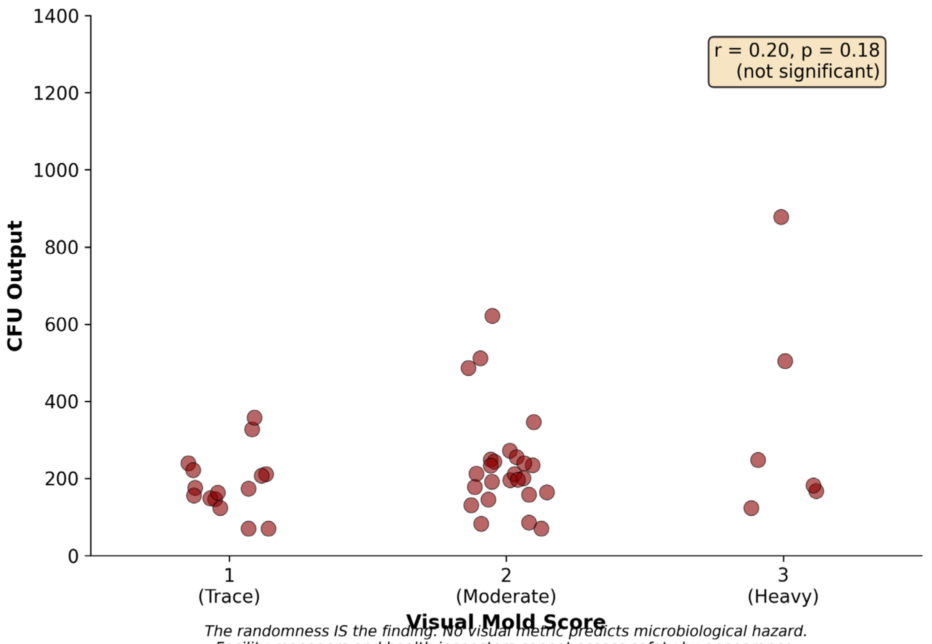
3.6 Correlation Between Visual Metrics and CFU Output

No visual metric predicted microbiological output (dispersal dryers, n=46 with valid CFU):

Visual Metric	vs CFU (Spearman r)	p-value	Significant?
Visual mold score	0.20	0.18	No
Visual dirt score	0.01	0.93	No
Plume area	0.07	0.64	No
Plume darkness	-0.03	0.86	No

All correlations were weak (|r| < 0.21) and non-significant (all p > 0.17).

Figure 3: Visual Appearance Does Not Predict Microbiological Output



The randomness IS the finding. No visual metric predicts microbiological hazard.
Facility managers and health inspectors cannot assess safety by appearance.

3.7 The Failure of Visual Inspection

The three visually cleanest dispersal dryer installations (mold score = 1, trace) produced substantial CFU output:

Store	Visual Mold	Visual Dirt	CFU Output
Raymore and Flanigan	1	1	407
Firehouse Subs	1	0	172
Christmas Tree Hill	1	1	n/a

Even installations with minimal visible wall contamination produced CFU counts consistent with the broader population.

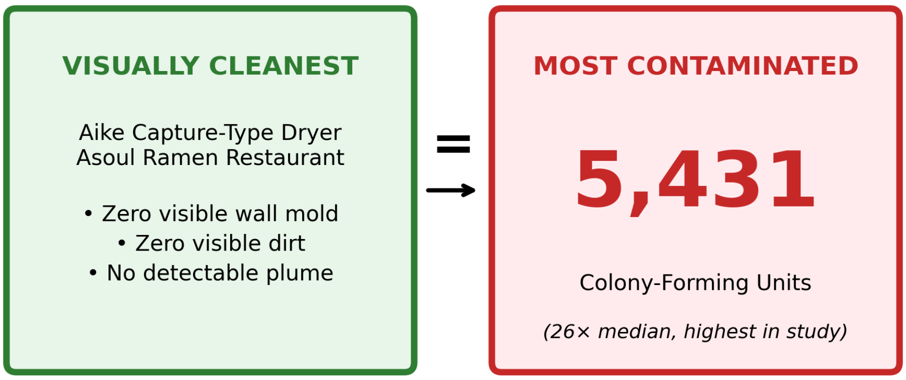
3.8 Capture-Type Dryers

The capture-type dryers (Aike) showed a fundamentally different contamination pattern:

Store	Dryer	Wall Plume	Wall Mold	CFU Output
Asoul Ramen	Aike	None	0	5,431

With no wall plume and no visible surface contamination in a visually clean restroom the Aike produced 5,431 CFU—the highest output in the entire study, 26× the median dispersal dryer output.

Figure 4: The Paradox of Visual Inspection



The same installation. Visual cleanliness provides zero indication of microbiological hazard. Capture-type dryers redirect contamination rather than eliminating it.

3.9 Laboratory Confirmation of Plume Contamination

Independent laboratory analysis of tape samples collected from drying zone plumes confirmed fungal presence in 70% of samples (7/10). Species identified included:

Organism	Spore Estimate	Documented Health Effects
Aspergillus/Penicillium	Light	Allergen, hypersensitivity pneumonitis, opportunistic pathogen, mycotoxin production
Chaetomium	Rare	Allergen, potential toxin producer

Organism	Spore Estimate	Documented Health Effects
Alternaria	Rare	Allergen, hypersensitivity pneumonitis, toxic metabolite production
Cladosporium	Rare	10+ allergenic antigens, hypersensitivity pneumonitis
Curvularia	Rare	Allergen, allergic fungal sinusitis
Bipolaris/Drechslera	Rare	Allergen, allergic fungal sinusitis, opportunistic infections
Basidiospores	Rare	Allergen, hypersensitivity pneumonitis
Epicoccum	Rare	Allergen
Pithomyces	Rare	Poorly studied
Ascospores	Rare	Likely allergenic

Contact plate culture identified Alternaria (4 CFU), Cladosporium (1 CFU), Penicillium (1 CFU), Micrococcus (1 CFU), and Staphylococcus sp. coagulase negative (1 CFU).

Three samples (30%) showed no fungi detected.

Due to loss of chain of custody documentation, attribution of individual samples to intervention type was not possible. The complete laboratory report is provided in Appendix D.

3.10 Video Review Findings

Post-hoc video review of installations with minimal wall contamination (mold score = 1) confirmed mold colonization at the device housing in all cases examined:

Store	Wall Mold	Device Mold (Video)	Notes
Raymore and Flanigan	1 (trace)	Present	Junction between wall and device housing
Firehouse Subs	1 (trace)	Present	Underside of Xlerator housing
Christmas Tree Hill	1 (trace)	Present	Perforated outlet plate, wall-device junction

In all three cases, the wall surface showed only trace contamination while the device housing showed clear mold colonization. This pattern is consistent with prior findings of bacterial contamination on dryer hardware [16] and suggests the plume originates at the device itself, with wall contamination representing spread from that origin point.

4. Discussion

4.1 Two Independent Phenomena

This study reveals that hand dryer contamination operates through two independent channels that are likely intrinsically bound:

Channel 1: Instantaneous output. What the dryer emits during operation. Measured in CFU. Documented in companion studies at 50-110× ambient air [1, 10]. Constant across installations. Unaffected by facility condition or visible cleanliness.

Channel 2: Cumulative deposition. What accumulates on surfaces over time, somehow enhanced by the presence of the dryer. Measured by visual metrics. Variable across installations as it it subject to variations in facility cleanliness. The intensity and extent of the plume must be determined by dryer emissions minus cleaning since the rest of the room does not have it.

These channels are statistically independent. The zero correlations between visual metrics and CFU output are not null findings—they are the finding. The plume tells you what the dryer has done, creating a persistent record of the individual drying cycle by each user. The output airjet CFU count tells you what the dryer is doing. Neither predicts the other.

Prior research has documented that hand dryer contamination affects not only the user but also the environment and bystanders [17, 18]. The present findings extend this observation: the plume represents accumulated contamination that persists in the room for all subsequent occupants regardless of their hand-drying choices.

4.2 The Co-Factor Mechanism

The plume results from two co-occurring processes documented in companion studies:

Microbial amplification (Papers 1, 8 [1, 23]): Hand dryers emit 50-110× the microbial load of ambient air, including organisms not present in the intake air. This provides the biological material.

Water dispersion (Paper 2 [21]): High-speed videography documents that dryers disperse water onto walls, floors, and users. Visible droplets represent only a fraction of total aerosol production; invisible aerosols outnumber visible droplets by factors of 100-10,000 in high-shear environments.

Neither factor alone explains persistent mold colonization. Dry microbes deposited on walls might not establish colonies. Water without microbial payload would not produce mold growth. The dryer delivers both simultaneously to the same surfaces, creating conditions for colonization.

The plume is the cumulative fossil record of this dual deposition—the visible result of months or years of dryer operation.

4.3 Why Visual Inspection Fails

The intuition that dirty-looking installations are more dangerous is wrong. Visual contamination reflects cleaning history, not emission rate. A recently cleaned installation with heavy dryer output looks cleaner than a neglected installation with moderate output.

This has practical implications. Facility managers cannot assess hand dryer safety by visual inspection. Health inspectors cannot identify hazardous installations by looking at them. The hazard is invisible because it originates at the device itself, not from accumulated surface deposits—and even when surface deposits are cleaned, the device remains colonized.

4.4 The Certainty of Mold

Every dispersal-type hand dryer in this study showed mold colonization—100% (50/50). This is not a probability. It is a certainty. Every dispersal-type hand dryer installation has mold. The only variable is severity at the moment of inspection—trace, moderate, or heavy—and this depends entirely on when the wall was last cleaned.

The Karns case is not an outlier. It is the equilibrium state. Every installation exists at some point on the trajectory toward Karns, pulled back temporarily by cleaning, pushed forward continuously by the dryer.

4.5 Dispersal vs. Capture: Different Patterns, Same Hazard

Capture-type dryers (Aike, Toyo) eliminate wall contamination by collecting water in reservoirs rather than dispersing it into the room. No plumes. No wall mold. Visually pristine.

Yet the Aike produced 5,431 CFU—26× the median dispersal dryer output and the highest in the study. The organisms are still emitted; they simply land elsewhere—on hands, on the user, in the reservoir, in the air column above the device.

Capture-type dryers redirect the contamination rather than eliminating it. The absence of a visible plume does not indicate the absence of a microbiological hazard. Visual inspection fails for both dryer types, but for different reasons: dispersal dryers show contamination that doesn't predict output; capture dryers hide contamination entirely.

4.6 Impact on Room Ambient Air

Our companion microbiological analysis (Paper 9 [10]) confirms that ambient air in dryer restrooms shows significantly elevated contamination compared to paper towel restrooms ($p=0.018$, 2.2× difference), providing independent quantitative evidence that dryer emissions affect room-level air quality and raising the question if the persistent mold on the walls is aerosolizing into the room. Further testing is needed.

4.7 Causation

The intervention comparison supports a causal relationship between dispersal-type hand dryers and plume formation:

1. Differential rates: 100% wall mold for dispersal dryers vs. 13% for white paper towels in comparable facilities—an 8-fold difference

2. Spatial correspondence: Plumes originate at dryer output and radiate in the direction of airflow

3. Dimensional pattern: Narrow at device, wide at floor—consistent with aerosol dispersion

4. Mechanism established: Companion studies document that dryers emit amplified microbial loads [1, 10] while simultaneously dispersing water onto surrounding surfaces [11]; the plume is where both land

5. Origin confirmed: Video review shows mold colonization at the device itself, with wall contamination spreading outward from that origin

The aerosol deposition mechanism appears to parallel that documented for toilet plume in Paper 1 [19]: aerosolized material settles on surfaces in proximity to the source, accumulating over time to produce visible contamination patterns and likely impacted by the dryer mechanics as well.

4.7 Health Implications

Visible mold in occupied spaces represents a documented health hazard.

Laboratory analysis of plume samples (Appendix D) confirmed the presence of Aspergillus/Penicillium, Alternaria, Cladosporium, Chaetomium, Curvularia, and Bipolaris/Drechslera—organisms documented by the analyzing laboratory to cause allergic reactions, hypersensitivity pneumonitis, allergic fungal sinusitis, and in some cases produce mycotoxins. Prior research has specifically noted that both bacteria and fungi spread from hand dryers in public restrooms [20].

The Institute of Medicine (2004) found sufficient evidence linking indoor mold exposure to upper respiratory symptoms, cough, and wheeze in healthy people; asthma symptoms in asthmatics; and hypersensitivity pneumonitis in susceptible individuals [2]. The CDC reports that people in damp buildings experience respiratory infections, developing or worsening asthma, allergic rhinitis, and eczema [3]. Extended exposure has been linked to cognitive effects, immune system changes, and increased anxiety and depression [4, 5, 6].

Every person entering a restroom with a dispersal-type hand dryer enters a space with confirmed mold colonization. This exposure occurs regardless of whether that person uses the dryer or not. The contamination was created by previous users and persists for subsequent occupants.

Hand dryers do not create a user-specific risk. They create a room-level contamination state affecting everyone who enters.

4.8 Limitations

Cleaning frequency was not directly measured. The survival of mold presence as a useful metric (binary: is mold growing?) partially addresses this confound—mold either colonized or it did not—but plume dimensions remain confounded by cleaning history.

Device housing inspection was not conducted systematically from study outset. The video review confirming device mold in wall-clean installations was performed post-hoc. Future studies should include systematic device housing assessment.

Capture-type dryers were underrepresented (n=1), reflecting their low market penetration (approximately 2% of installations encountered). The finding that capture dryers eliminate wall plumes while retaining microbiological hazard requires validation with larger samples.

Sample sizes for paper towel subgroups are modest (n=30 brown, n=39 white), though adequate for detecting the large effects observed.

5. Conclusion

This study examined visible contamination patterns beneath 120 hand drying installations across 95 commercial restrooms, comparing dispersal-type hand dryers (n=50), capture-type hand dryers (n=1), brown paper towel dispensers (n=30), and white paper towel dispensers (n=39).

Dispersal-type hand dryers produced visible wall contamination—"plumes of filth"—in 100% of installations (50/50), with confirmed mold colonization in 100% (50/50). Plumes averaged 10 square feet, originating narrow at the device and fanning outward toward the floor. Independent laboratory analysis confirmed fungal presence in 100% of dryer plume samples tested, identifying species associated with respiratory illness including Aspergillus, Cladosporium, and Chaetomium. Brown paper towel dispensers showed 40% mold rates; white paper towel dispensers showed 13%—an 8-fold difference compared to dispersal dryers.

Our findings support three conclusions:

First, dispersal-type hand dryers cause persistent room contamination. Every dispersal dryer in the study showed mold colonization—100% (50/50). The 8-fold difference in mold rates between dispersal dryers and white paper towel installations (100% vs. 13%), combined with spatial patterns showing contamination originating at and radiating from dryer devices, establishes a causal relationship.

Second, visual inspection cannot identify hazardous installations. No visual metric predicts microbiological output. The cleanest-looking installation produced the highest CFU count. Facility managers, health inspectors, and users cannot assess hand dryer safety by appearance.

Third, the plume represents a health hazard independent of dryer use. Visible mold affects everyone who enters the room, not just dryer users. Per CDC and Institute of Medicine findings, indoor mold exposure causes respiratory symptoms, asthma exacerbation, and hypersensitivity pneumonitis in susceptible individuals.

The visual pattern documented here—contamination radiating outward from drying devices—was the first observation that prompted this research series beginning in September of 2023. We close the work with a complete, experimentally based explanation of how it gets there, doing harm at every step of the process. If increased levels of bacteria and fungus are correlated with increased disease and death these machines are making people sick and killing them at untold rates. As we asked in our first paper, “what happens if you remove the dryer from the room?” The answer is now inescapably clear. Hand dryers convert restrooms into spaces where mold colonization is not a risk but a certainty, where cleaning cannot keep pace with contamination, and where every occupant—user or not—shares the exposure. The plume is not separate from the dryer's microbiological effects. It is the physical manifestation, persisting in the room long after the device stops running, affecting everyone who enters.

Acknowledgments

The author acknowledges Elizabeth Dettry for substantial assistance with colony enumeration. Additional thanks to family members who assisted with field sampling and to friends who assisted with related studies in this series.

Analysis was conducted in collaboration with AI assistants (Claude, GPT, Grok), which served as synthesis and computation tools. All underlying observations, measurements, and colony counts represent primary data collection by human researchers.

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Appendix A: Video Review Documentation

Supplementary video review conducted December 2, 2025.

Purpose:

Assessment of device housing condition for installations with minimal wall contamination (mold score = 1, trace).

Installations reviewed:

1. Raymore and Flanigan — Xlerator

2. Firehouse Subs — Xlerator older standard

3. Christmas Tree Hill — Xlerator older standard

Findings:

Mold colonization confirmed at device housing in all three installations. See Section 3.11 for details.

Documentation:

Video recordings archived with original field materials. Supplementary observation sheets stapled to original field data sheets.

Appendix B: Complete Statistical Analysis

B.1 Sample Sizes

Category	n
Total plume evaluations	120
Hand dryers (total)	51
— Dispersal type	50
— Capture type	1
Brown paper towels	30
White paper towels	39

B.2 Plume Prevalence (Dispersal Dryers)

Wall plume present: 50/50 = 100.0%

B.3 Mold Prevalence by Intervention

Intervention	Mold Present	Total	Rate
Dispersal dryers	50	50	100.0%
Brown paper towels	12	30	40.0%
White paper towels	5	39	12.8%

Chi-square test: $\chi^2 = 72.0$, df = 2, $p < 0.001$

Ratio (dispersal vs white): 7.8× (100% / 12.8%)

B.4 Mold Severity Distribution (Dispersal Dryers)

Score	Description	n	Percentage
0	None	0	0.0%
1	Trace	12	24.0%
2	Moderate	30	60.0%
3	Heavy	8	16.0%

B.5 Plume Dimensions (Dispersal Dryers)

Width at top (ft): n = 49, Mean = 1.45, Median = 1.00, SD = 0.71, Range = 0.0 – 3.0

Width at bottom (ft): n = 50, Mean = 3.64, Median = 3.00, SD = 1.86, Range = 0.0 – 8.0

Area (sq ft): n = 47, Mean = 10.54, Median = 10.00, SD = 4.52, Range = 0.4 – 20.0

Paired t-test (bottom vs top width): n pairs = 49, Mean difference = 2.20 ft, SD of difference = 1.54, $t = 10.01$, $p = 2.43 \times 10^{-13}$

Spread direction: Wider at bottom: 42/49 = 86%, Wider at top: 0/49 = 0%, Same width: 7/49 = 14%

B.6 Correlations: Visual Metrics vs CFU (Dispersal Dryers)

Visual Metric	n	Spearman r	p-value	Significant?
Visual mold score	46	0.203	0.1762	No
Visual dirt score	42	0.014	0.9305	No
Plume area score	46	0.071	0.6374	No
Plume darkness score	46	-0.026	0.8623	No

Interpretation: No visual metric significantly predicted CFU output. All correlations were weak ($|r| < 0.21$) and non-significant (all $p > 0.17$).

B.7 CFU Output by Dryer Type

Dispersal dryers: n = 46, Median = 208 CFU, Mean = 272.4 CFU, SD = 209.3, Range = 70 – 1,209

Capture dryer: n = 1, Value = 5,431 CFU (highest in study)

B.8 Laboratory Analysis Summary

Tape samples (direct analysis): Samples analyzed: 10, Fungal positive: 7/10 (70%), No fungi detected: 3/10 (30%)

Species identified: Aspergillus/Penicillium (Light), Chaetomium (Rare), Alternaria (Rare), Cladosporium (Rare), Curvularia (Rare), Bipolaris/Drechslera (Rare), Basidiospores (Rare), Epicoccum (Rare), Pithomyces (Rare), Ascospores (Rare), Myxomycetes (Rare)

Contact plate culture (sample #11): Alternaria: 4 CFU, Cladosporium: 1 CFU, Penicillium: 1 CFU, Micrococcus: 1 CFU, Staphylococcus sp.: 1 CFU. Total fungi: 6 CFU, Total bacteria: 2 CFU

B.9 Statistical Software

All analyses conducted using Python 3.12 with SciPy 1.11 statistical library. Chi-square tests used scipy.stats.chi2_contingency. Spearman correlations used scipy.stats.spearmanr. Paired t-tests used scipy.stats.ttest_rel.

Appendix C: Laboratory Analysis Report

Hayes Microbial Consulting, LLC

EPA Laboratory ID: VA01419

Lab ID: #188863

DPH License: #PH-0198

Report #25049698

Collected: October 3, 2025

Received: October 7, 2025

Reported: October 8, 2025

[Full PDF report embedded]

#25049698

Analysis Report prepared for

Ron Blouch Company

103 E Locust St.
Mechanicsburg, PA 17055

Phone: **(717) 319-2550**

Dreyer's + Towels Plume

Collected: **October 3, 2025**
Received: **October 7, 2025**
Reported: **October 8, 2025**

We would like to thank you for trusting Hayes Microbial for your analytical needs!
We received 11 samples by FedEx in good condition for this project on October 7th, 2025.

The results in this analysis pertain only to this job, collected on the stated date, and should not be used in the interpretation of any other job. Information supplied by the customer can affect the validity of results. These results apply only to the samples as received. This report may not be duplicated, except in full, without the written consent of Hayes Microbial Consulting, LLC.

All information provided to Hayes Microbial is confidential information relating to our customers and their clients. We will not disclose, copy, or distribute any information verbally or written, except to those designated by the customer(s). We take confidentiality very seriously. No changes to the distribution list will be made without the express consent of the customer.

This laboratory bears no responsibility for sample collection activities, analytical method limitations, or your use of the test results. Interpretation and use of test results are your responsibility. Any reference to health effects or interpretation of mold levels is strictly the opinion of Hayes Microbial. In no event, shall Hayes Microbial or any of its employees be liable for lost profits or any special, incidental or consequential damages arising out of the use of these test results.

Stephen N. Hayes

Steve Hayes, BSMT(ASCP)
Laboratory Director
Hayes Microbial Consulting, LLC.

EPA Laboratory ID: VA01419

Lab ID: #188863

DPH License: #PH-0198

Ron Blouch
Ron Blouch Company
103 E Locust St.
Mechanicsburg, PA 17055

Dreyer's + Towels

#25049698

Di

#1	Tape (1.00	Organis	Spore	Mycelial
1 - Slide		Aspergillus|Penicillium	Light	ND
		Chaetomium	Rare	ND

#2	Tape (1.00	Organis	Spore	Mycelial
2 - Slide		Alternaria	Rare	ND

#3	Tape (1.00	Organis	Spore	Mycelial
3 - Slide		No Fungi Detected		

#4	Tape (1.00	Organis	Spore	Mycelial
4 - Slide		Basidiospores	Rare	ND
		Curvularia	Rare	ND

#5	Tape (1.00	Organis	Spore	Mycelial
5 - Slide		No Fungi Detected		

#6	Tape (1.00	Organis	Spore	Mycelial
6 - Slide		Aspergillus|Penicillium	Light	ND

#7	Tape (1.00	Organis	Spore	Mycelial
7 - Slide		No Fungi Detected		

* indicates data provided by the customer

Ron Blouch
Ron Blouch Company
103 E Locust St.
Mechanicsburg, PA 17055

Dreyer's + Towels

#25049698

Direct

#8	Tape (1.00	Organis	Spore	Mycelial
8 - Slide		Pithomyces	Rare	ND
		Cladosporium	Rare	ND
		Myxomycetes	Rare	ND
		Bipolaris|Drechslera	Rare	ND

#9	Tape (1.00	Organis	Spore	Mycelial
9 - Slide		Epicoccum	Rare	ND

#10	Tape (1.00	Organis	Spore	Mycelial
10 - Slide		Aspergillus|Penicillium	Rare	ND
		Ascospores	Rare	ND

* indicates data provided by the customer

Ron Blouch
Ron Blouch Company
Mechanicsburg, PA
17055
(717) 319-2550

Dreyer's + Towels

#2504969

Culture Fungi and Bacteria

SOP - HMC#103, HMC#104, HMC#105

#11	Contact Plate (1.00 plate)
	D268 - D/SA 268

Fungal Reporting Limit: 1 cfu/plate
Bacterial Reporting Limit: 1 cfu/plate

Organism	Type	Raw Count	cfu/plate	% Total
Alternaria	Fungi	4	4	66.7%
Cladosporium	Fungi	1	1	16.7%
Penicillium	Fungi	1	1	16.7%
Total	Fungi	6	6	100%
Micrococcus	Bacteria	1	1	50%
Staphylococcus sp., coagulase negative	Bacteria	1	1	50%
Total	Bacteria	2	2	100%

Spore Estimate		Percentages
ND	None Detected	0%
Rare	Less than 10 spores	< 1%
Light	10 - 99 spores	1-10%
Moderate	100 - 999 spores	11-25%
Heavy	1000 - 9999 spores	26-50%
Very Heavy	10000 or greater spores	51-100%

Mycelial Estimate	
ND	None Detected No active growth at site.
Trace	Very small amount of Mycelium Probably no active growth at site.
Few	Some Mycelium Possible active growth at site.
Many	Large amount of Mycelium Probable active growth at site.

Alternaria	**Habitat:**	Commonly found outdoors in soil and decaying plants. Indoors, it is commonly found on window sills and other horizontal surfaces.
Health Effects:		A common allergen and has been associated with hypersensitivity pneumonitis. Alternaria is capable of producing toxic metabolites which may be associated with disease in humans or animals. Occasionally an agent of onychomycosis, ulcerated cutaneous infection and chronic sinusitis, principally in the immunocompromised patient.
Ascospores	**Habitat:**	A large group consisting of more than 3000 species of fungi. Common plant pathogens and outdoor numbers become very high following rain. Most of the genera are indistinguishable by spore trap analysis and are combined on the report.
Health Effects:		Health affects are poorly studied, but many are likely to be allergenic.
Aspergillus|Penicillium	**Habitat:**	The most common fungi isolated from the environment. Very common in soil and on decaying plant material. Are able to grow well indoors on a wide variety of substrates.
Health Effects:		This group contains common allergens and many can cause hypersensitivity pneumonitis. They may cause extrinsic asthma, and many are opportunistic pathogens. Many species produce mycotoxins which may be associated with disease in humans and other animals. Toxin production is dependent on the species, the food source, competition with other organisms, and other environmental conditions.
Basidiospores	**Habitat:**	A common group of Fungi that includes the mushrooms and bracket fungi. They are saprophytes and plant pathogens. In wet conditions they can cause structural damage to buildings.
Health Effects:		Common allergens and are also associated with hypersensitivity pneumonitis.
Bipolaris|Drechslera	**Habitat:**	They are found in soil and as plant pathogens. Can grow indoors on a variety of substrates.
Health Effects:		They may be allergenic and are very commonly involved in allergic fungal sinusitis. They are opportunistic pathogens but occasionally infect healthy individuals, causing keratitis, sinusitis and osteomyelitis.
Chaetomium	**Habitat:**	Ascomycete fungus, commonly isolated from soil and decaying plant materials. It is cellulolytic and grows well indoors on damp sheetrock and other paper substrates. It is often found growing with Stachybotrys.

Health Effects:

It is reported to be allergenic and may produce toxins.

Cladosporium	**Habitat:**	One of the most common genera worldwide. Found in soil and plant debris and on the leaf surfaces of living plants. The outdoor numbers are lower in the winter and often relatively high in the summer, especially in high humidity. The outdoor numbers often spike in the late afternoon and evening. Indoors, it can be found growing on textiles, wood, sheetrock, moist window sills and in HVAC supply ducts.
Health Effects:		A common allergen, producing more than 10 allergenic antigens and a common cause of hypersensitivity pneumonitis.
Curvularia	**Habitat:**	They exist in soil and plant debris, and are plant pathogens.
Health Effects:		They are allergenic and a common cause of allergic fungal sinusitis. An occasional cause of human infection, including keratitis, sinusitis, onychomycosis, mycetoma, pneumonia, endocarditis and desseminated infection, primarily in the immunocompromised.
Epicoccum	**Habitat:**	It is found in soil and plant litter and is a plant pathogen. It can grow indoors on a variety of substrates, including paper and textiles and is commonly found on wet drywall.
Health Effects:		It is a common allergen. No cases of infection have been reported in humans.
Micrococcus	**Habitat:**	Gram Positive cocci. Normal skin flora and mucous membrane inhabitant.
Health Effects:		Mostly nonpathogenic, but may cause infections in immunocomprozed people.
Myxomycetes	**Habitat:**	Found on decaying plant material and as a plant pathogen.
Health Effects:		Some allergenic properties reported, but generally pose no health concerns to humans.

Penicillium	**Habitat:**	Often the most common type of fungi isolated from the environment. They are common indoors as well, and are found in house dust, water-damaged papers, fabrics, behind or on paint, and in fiberglass duct insulation. They are also found in a variety

APPENDIX D: PLUME OF FILTH IMAGES


HAND DRYER


dyson


Step 'n Wash under the sink/counter.
Padres, para ayudar a lavar las manos de sus niños, este baño tiene un "Step 'n Wash" debajo del lavabo.
step n wash
XLERATOR
EXCEL DRYER


WORLD DRYER
HEPA


XLERATOR
EXCEL DRYER
FEEL THE POWER

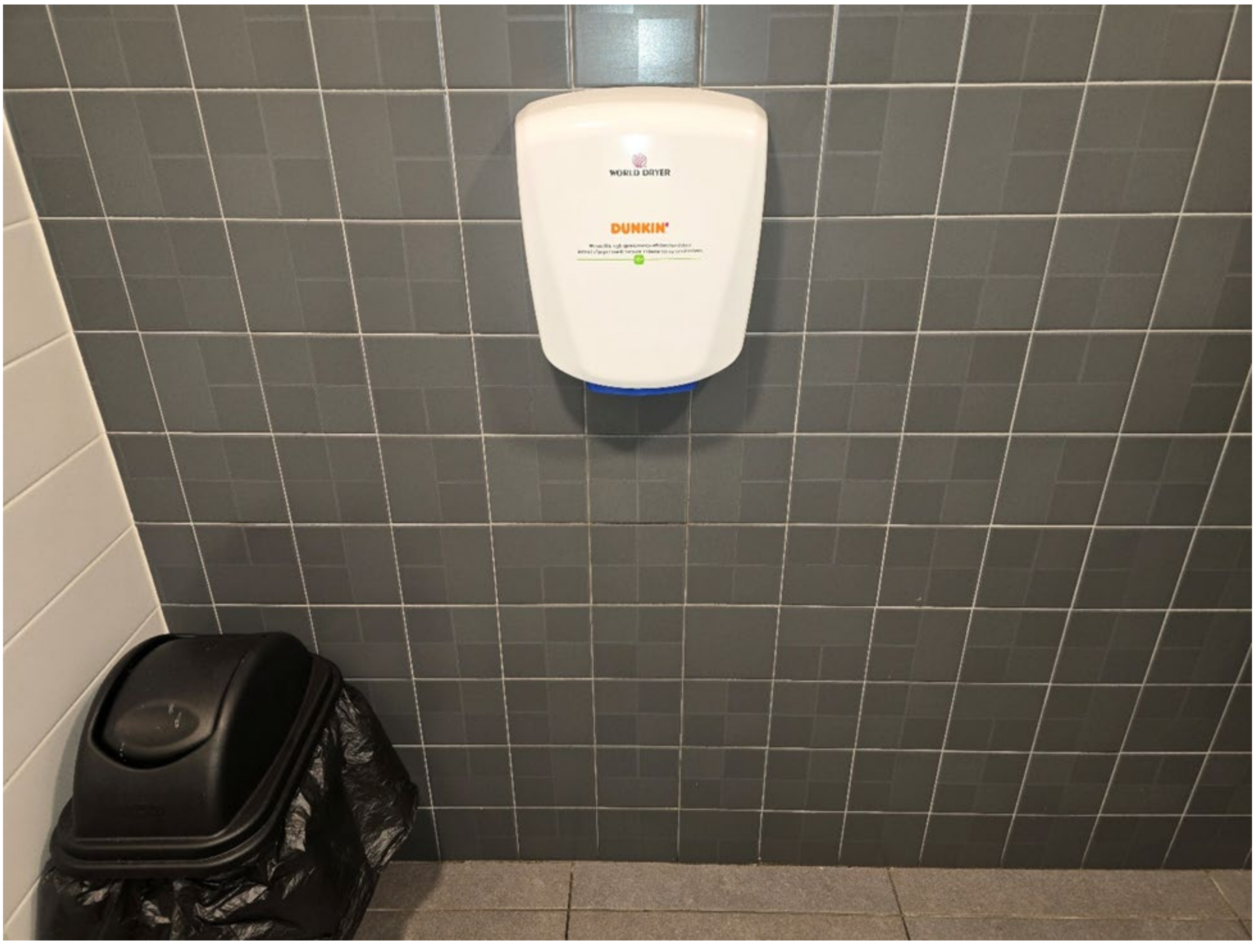

XLERATOR

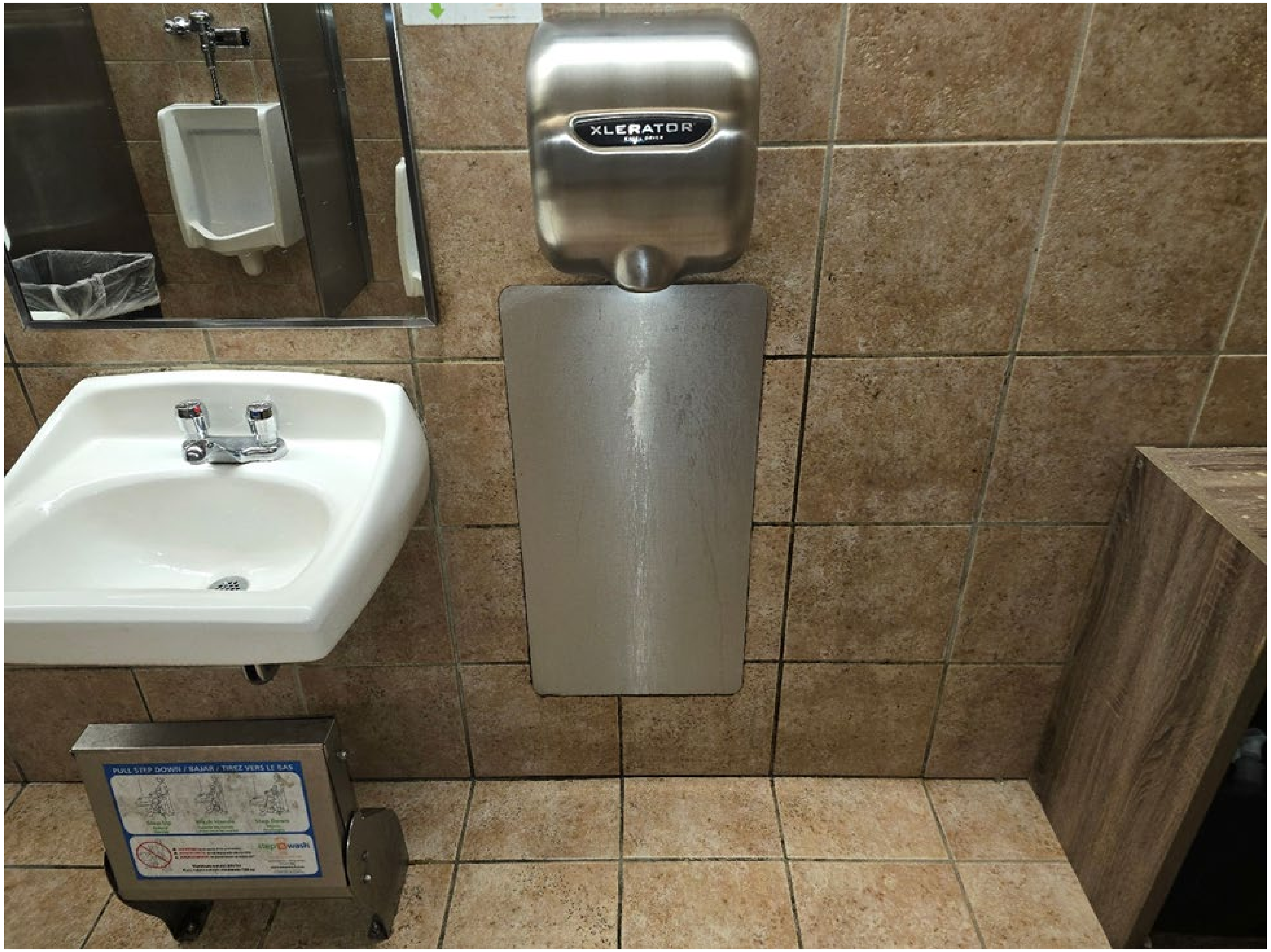

XLERATOR


Employees Must
Wash Hands
Before Returning
to Work
dyson


THANK YOU
for visiting our environmentally friendly restroom. High speed energy efficient hand dryers are now being used instead of paper towels.
One ton of paper towels consumes 17 trees, 3 cubic yards of landfill space and pollutes 20,000 gallons of water.
XLERATOR eco
EXCEL DRYER

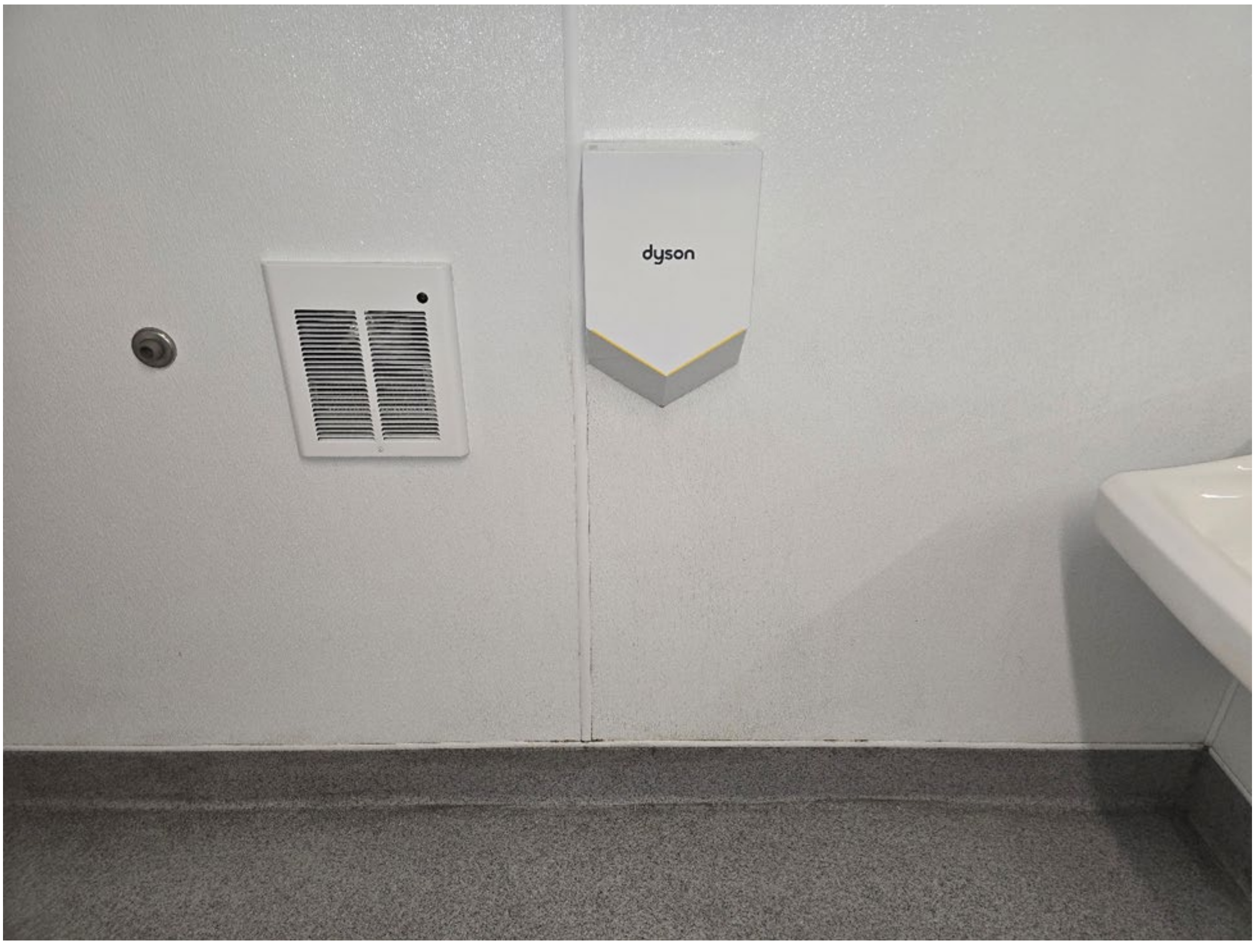

XLERATOR
EXCEL DRYER


WORLD DRYER
DUNKIN'


XLERATOR
PULL STEP DOWN / BAJAR / TIREZ VERS LE BAS


XLERATOR


THANK YOU
for visiting our environmentally friendly restroom. High speed energy efficient hand dryers are now being used instead of paper towels.
One ton of paper towels consumes 17 trees, 3 cubic yards of landfill space and pollutes 20,000 gallons of water.
XLERATOR


dyson


dyson


XLERATOR
GOJO


dyson

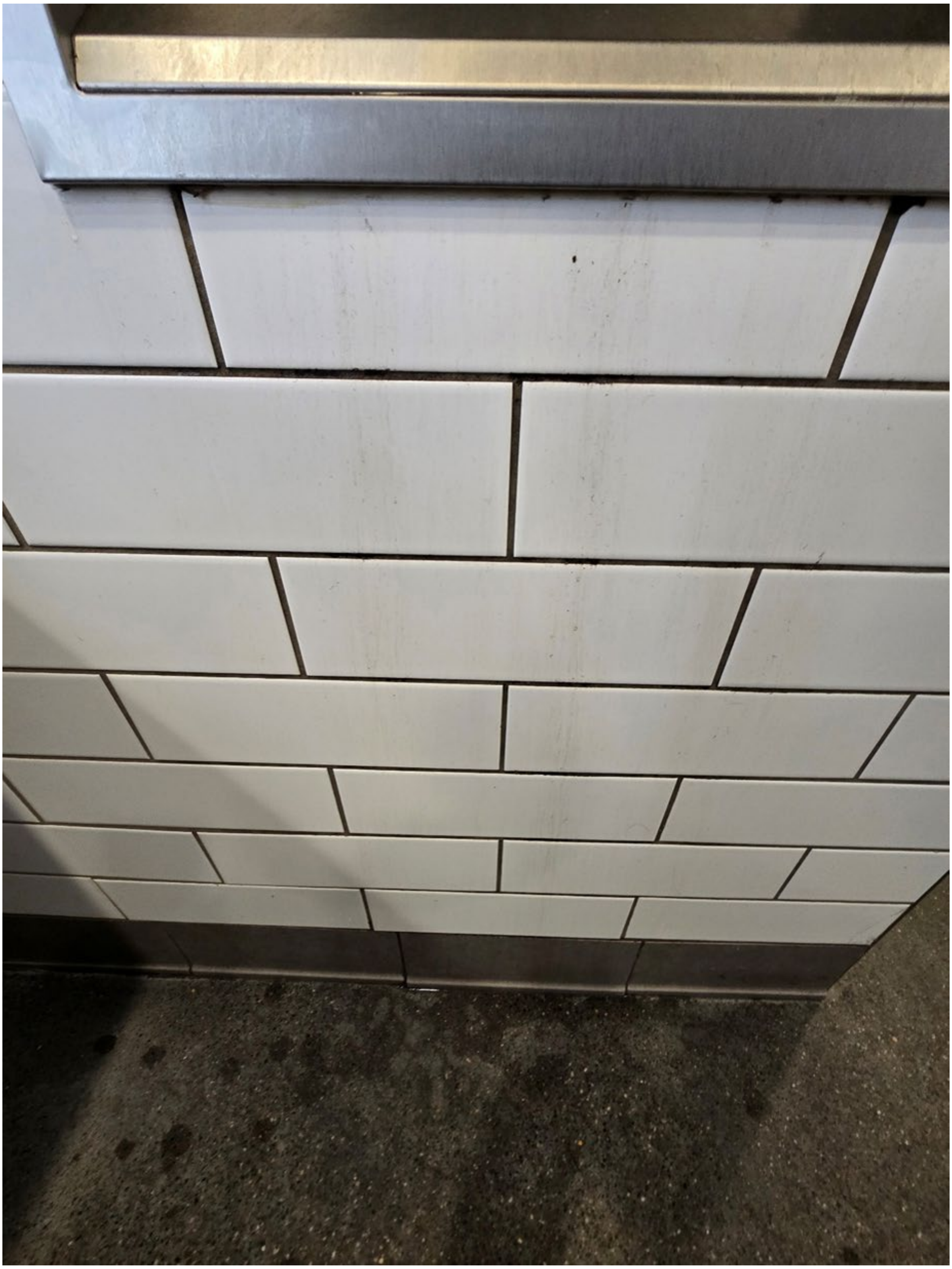

dyson

Employees Must
Wash Hands
Before Returning
to Work
dyson


Employees Must
Wash Hands
Before Returning
to Work
dyson


Employees Must Wash Hands Before Returning to Work
WATER
HAND DRYER
dyson


XLERATOR




XLERATOR
EXCEL DRYER


XLERATOR
EXCEL DRYER

Paper 10 of 11 in the Hand Dryer Hygiene Series

Supplementary materials including the complete dataset are available at www.handdryerstudy.com