A microbiological and hygiene assessment of vertical hand-dryer cleanliness in food manufacturing facilities

Emma J. Samuel[1*], Ellen W. Evans[1] and Rowena E. Jenkins[2] and Elizabeth C. Redmond[1]

[1]ZERO2FIVE Food Industry Centre Food and Drink Research Unit, Cardiff Metropolitan University, Cardiff, United Kingdom.

[2]Swansea University Medical School, Swansea University, Swansea, United Kingdom.

*Corresponding author: emsamuel@cardiffmet.ac.uk

Introduction

Wet hands can transfer contamination to hand contact surfaces more readily than dry[1-2] and so effective hand-drying in the food handler hand hygiene regimen is an essential step[3]. Indeed, thorough drying following a compliant handwashing attempt offers additional opportunity to further reduce remaining hand contamination[4] or soil prior to the application of hand sanitiser (often required in food production environments)[5].

Consensus as to whether or not hand-dryers potentially decrease or increase hand contamination during the drying process remains unclear[2,6,7] with investigations conducted in real-world[2] conditions in food manufacturing and processing sectors lacking. While prior hand-dryer research suggests that elevated bacterial levels have been associated with grocery store environments[8], other studies indicate little variation between bacterial levels and situational factors (being grocery stores, fast-food restaurants and retail)[9].

Likewise, whether microbiological deposition found on skin/hands[6], clothes[11] and surrounding surfaces[12] while drying hands using vertical hand dryers are as a result of microbial accumulation in internal hand-dryer mechanism/components, or, are drawn into the hand-dryer air outlets from the external environment during operation, is also unclear[8,9]. The continued use of hand-dryers in environments where containing cross-contamination is paramount (i.e. healthcare and food handling environments) has previously been questioned[11,12] with enhanced cleaning protocols and regular maintenance possibly inadequate to mitigate all potential hand re-contamination risks[9].

Purpose

This study aimed to determine microbiological contamination and organic residue of vertical hand-drying units (under real-world conditions) installed at a multi-site food manufacturing and processing business with reference to situational factors and hand-dryer condition and cleanliness.

Methods

Sampling locations: The internal and external surfaces of vertical hand-dryers located in changing rooms (*n*=6) and a production department *(n*=1) in food manufacturing and processing facilities, as well as adjacent wall surfaces and hand-dryer air samples, were gathered on two separate occasions post-cleaning and post-production.

Method: Dipslides (incubated at 35˚c for 48 hours) assessed total viable count bacteria (TVC) (*n*=74) and presumptive *Enterobacteriaceae* (*n*=73) together with adenosine trisphosphate (ATP) bioluminescence swabs (*n*=74) to determine cleanliness standards. Visual assessments according to a pre-defined audit grading index recorded hand-dryer condition, surface appearance (e.g. wet or dry, visible food/soil) and inspection of hand-dryer high efficiency particulate air-filter inspection (HEPA). Data were inputted and analysed using SPSS (Version 28, IBM, USA).

Ethical Approval: Granted by Cardiff Metropolitan University School of Sport and Health Sciences (Ref PGR-4829).

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Results

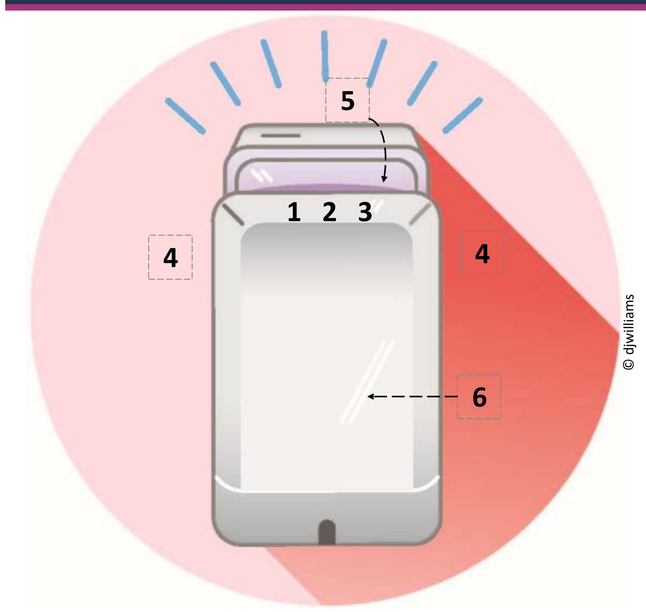

Figure 1: Hand-dryer surface sampling points (1, 2, 3 = outer edge), (4 = wall surfaces), (5 = air sample at air outlets) and (6 = internal trough surfaces)

Sampling method and facility characteristics

- To avoid sampling over the same surfaces, ATP swabs and dipslides were recovered adjacent to each other from hand-dryer outer edges over which hands/arms are dipped while using the unit (points 1, 2 and 3, Figure 1), from wall surfaces either side of the unit dependent on situational factors (point 4) and from the internal trough, from hand-dryer wall surfaces (point 6). To mimic hand motions triggering air circulation, dipslides were dipped into the hand-dryer for 30 seconds to gather air samples (point 5).
- Table 1 indicates hand-dryer location together with the approximate number of users having repeated access to the units throughout the working day.

Table 1: Hand-dryer (*n*=7) location and approximate employee numbers

Hand-Dryer Locations	*n*	Employee numbers (approx.)
High risk changing room	2	15
High care changing room	1	6
Low risk changing room	3	75
Low risk production	1	60

Surface ATP measurements and visual assessments (*n*=74)

Following company environmental ATP protocols, an RLU ≥300 was considered unacceptable in relation to surface cleanliness. As indicated by Table 2, both post-cleaning and post-production internal hand dryer surfaces exceeded RLU 300 on 88% and 94% of occasions respectively, while wall surfaces adjacent to hand dryers exhibited the lowest ATP measurement range (mean 754 PC to 939 PP).

Table 2: ATP RLU measurements (minimum, maximum and mean) by time gathered (post-cleaning *n* =37, post-production *n*=37)

Equipment surface	*n*	Time	RLU Min	RLU Max	RLU Mean	≥300 RLU %
Hand dryer (internal)	17	Post cleaning	148	167816	21112.24	88
Hand dryer (external)	12		46	24891	2747.58	67
Adjacent wall surface	8		69	1578	754.25	63
Hand dryer (internal)	17	Post production	252	381127	88737.53	94
Hand dryer (external)	12		69	129373	14040.25	92
Adjacent wall surface	8		12	2877	939.13	75

92% of surfaces sampled were dry

89% of hand-dryers appeared in good condition

- Overall, hand-dryers located in low risk locations (*Md* = 3176, *n*=42) in comparison to high risk/care areas (*Md*= 504, *n*=32) had higher, statistically significant, RLU measurements (*U* = 283, *z* = -4.244 *p* < .001, *r* = 0.24) suggesting that food products handled (e.g. raw meat), together with a higher number of hand-dryer users, may have greater impact on hand-dryer cleanliness.
- RLU measurements recovered from hand-dryers troughs (point 6, Figure 1) (*Md* = 4946, *n* = 34) in comparison to outer edges (*Md* = 1043, *n* =24) were also found to be statistically significant (*U* = 237, *z* = -2.692 *p* = .007, *r* = 0.13).

Dipslide results relating to surface (*n*=74) and air samples (*n*=17)

- Statistically significant differences (*U* = 463, *z* = -2.405 *p* = .016, *r* = .07) were identified between TVC dipslides recovered from hand-dryers situated in low risk locations (*Md* = 12-40 CFU/cm^2, *n* = 40) compared to high risk/care (*Md* = 2.5 CFU/cm^2, *n* = 34) but no differences were detected for *Enterobacteriaceae.*
- TVC samples recovered from inside hand-dryer units (*Md* = 100 CFU/cm^2, *n* = 28) in comparison to hand-dryer outer edges (*Md* = 2.5 CFU/ cm^2, *n* = 23) were also statistically significant *(U* = 139, *z* = -3.525 *p* < .001, *r* = 0.24*).*

Table 3: Percentage TVC and *Enterobacteriaceae* dipslides ≥12 CFU/cm^2 together with maximum CFU/cm^2 post-cleaning and post-production for sampled surfaces

Equipment surface	*n*	Post Cleaning levels ≥ 12 CFU/cm^2		Post Production levels ≥ 12 CFU/cm^2		Post Cleaning Maximum CFU/cm^2		Post Production Maximum CFU/cm^2	
		TVC	*Ent.**	TVC	*Ent.**	TVC	*Ent.**	TVC	*Ent.**
Hand-dryer (internal)	17	86%	29%	79%	29%	250	250	250	100
Hand-dryer (external)	12	45%	36%	50%	8%	100	40	100	40
Adjacent wall	8	38%	13%	12%	12%	40	12	100	12

* = *Enterobacteriaceae*

- As distance away from the hand-dryer increased, positive TVC and *Enterobacteriaceae* ≥12 CFU/cm^2 diminished (Table 3), however, the maximum microbial counts recovered from equipment surfaces post-cleaning and post-production were similar regardless of sampled location. No statistically significant differences were found between dipslides collected post-cleaning or post-production, from wet or dry surfaces or according to surface condition or visible cleanliness.
- Air sample results (*n*=17) indicated microbial counts ranging from 2.5 CFU/cm^2 to 40 CFU/cm^2 for TVC with no *Enterobacteriaceae* (0 CFU/cm^2) found on any occasion.
- Notably, TVC colony morphology recovered from inside hand-dryers (Figure 2a) and air samples (Figure 2b) were found to be distinctly different regardless of location or time gathered (i.e. post-cleaning or post-production).

Figure 2a: Inside hand-dryer colony morphology – pinpoint, punctiform, opaque/cream. Graded TVC 250 CFU/cm^2

Figure 2b: Air sample colony morphology – circular, raised, shiny, opaque white and deep yellow. Graded TVC 12 CFU/cm^2

HEPA filters (Figure 3) were found in various condition but did not appear to affect the microbial (TVC) counts recovered from air samples (all colony morphology remaining consistent).

3a. 3b. 3c. 3d.

Figure 3: HEPA filters in various condition (a) heavy soil, (b) moderate (black mould evident), (c) fair (black mould spores on tray) and (d) poor condition (worn)

Significance of study

- Vertical hand-dryers may potentially act as a hand contamination vector particularly in relation to associated food product risk category (i.e. low risk having greater impact on cleanliness) and user numbers.
- Regular inspection and maintenance of all hand-dryer components (including HEPA filters) together with environmental monitoring (to validate cleaning processes) may be essential to mitigate potential risks.
- However, and as indicated in prior research[9,12], uncertainty as to microbial source and circulation (e.g. from inaccessible operational components) may warrant discontinuation of hand-dryers in food manufacturing environments and further investigation in real-world conditions are required.