Do warm air dryers in public bathrooms need regular disinfection?

By Kelvin Du
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Abstract:

**Aims:** To evaluate hygiene of warm air dryers (WADs) as a potential source of contamination to users and environment in a bathroom.

**Methods:** This project was comprised of 3 independent experiments on number of microbial colonies on users’ hands and in the bathroom environment in relation to WAD use, namely, i) Pilot Test with samples collected on WAD user’s hand and other body areas before and after hand washing without soap; ii) Investigation of WAD with samples collected on the edge, 2cm and 4cm inside a randomly selected WAD at 8 time points, which were 9:00, 11:00, 13:00, and 15:00 on each of 2 separate days; and iii) Investigation of Washed Hands with samples collected on 24 participants’ pairs of hands after washing with soap then one dried by WAD and the other by naturally shaking. After 48 hours of 30°C incubation, number of microbial colonies from all samples was counted. Additional visual readings took place at 24, 72, and 96 hours after incubation where appropriate. Standardised hand washing method and randomization process were used. Wilcoxon Signed Rank Test was used to evaluate the difference of microbial counts on washed hands between two drying methods.

**Results:** The Pilot Test confirmed that much less microbes were observed on the hand palm and more microbes for all the other sampled body areas after hand washing with water only and immediately drying with a warm air dryer than before hand washing. The Investigation of WAD demonstrated approximately three times more microbes on the edge than the other sample sections inside the WAD, and an increase of microbes from inside out as the day passed. The Investigation of Washed Hands identified average number of microbial colonies on WAD aired hands was more than twice as much as that on control hands (23 vs 10). WAD use was associated with significant increase of microbes on users’ hands after washing with antibacterial soap (W-value: 46, P-value: 0.048).

**Conclusion:** This project demonstrates that microbes inside WADs are likely to be blown out during WAD use. Regular disinfection of WADs in the bathrooms should be encouraged to achieve better results of hand hygiene.
Background Research

In our current society, many bathrooms in public areas are equipped with warm air dryers (WADs) as the primary method of drying users' hands after washing. Existing studies reported that WAD use would reduce microbes on poorly washed hands.\textsuperscript{1-3} Compared to other drying methods such as use of paper towels, there have been experiments reporting that WAD use is associated with less microbial removal on hands after washing;\textsuperscript{1,2,4} increased microbial cross contamination via airborne dissemination to the environment, bystanders and the users;\textsuperscript{5,6} and a larger spread of airborne microbes.\textsuperscript{6}

While most studies agreed that WAD use did remove microbes from the poorly washed hands,\textsuperscript{1-3} Yamamoto et al. pointed out different hand areas were affected differently.\textsuperscript{1} The latter finding implied the impact of different hand washing methods on microbial counts, which however was rarely controlled in previous experiments on WAD use.

With regard to the findings of increased microbes in the environment after WAD use,\textsuperscript{5-7} it is possible that the microbes might be blown away from poorly washed hands to the environment.\textsuperscript{8,9} The findings of less microbe removal on washed hands compared with other drying methods,\textsuperscript{1,2} may reflect the possibility that WADs blew additional microbes from inside onto the hands. However, none of the reports have investigated the possibility that WADs themselves might be another source of microbe increase to users' hands and the environment.

Furthermore, many of these reports focused on the comparison of microbial reduction before and after washing hands with non-antibacterial soap to simulate poorly washed hand scenarios,\textsuperscript{1,3,5,6} and therefore their findings are not of much relevance to the routine practice of using antibacterial soap. The interpretation to hand hygiene is also limited because using antibacterial soap is another important component for hand hygiene in addition to properly drying methods. However, whether WAD in combination with the use of antibacterial soap will have an impact on microbial counts on washed hands remains unknown.

Aims

1) To investigate if WAD use is associated with less microbes on hands and more microbes in the environment;
2) To investigate microbial counts over time inside different sections of a WAD;
3) To investigate how WAD use affects microbial counts on hands after using antibacterial soap.

Hypotheses

This project was comprised of three independent experiments to address each project aim, namely, i) Pilot Test, ii) Investigation of WAD, and iii) Investigation of Washed Hands.
Pilot Test
Hypothesis: WAD use will remove microbes on hands and will spread microbes into the environment

Investigation of Warm Air Dryers (WAD)
Hypothesis: Microbes will shift from deep inside the WAD to the edge after use and microbial counts on the WAD edge will increase over time

Investigation of Washed Hands
a) Null Hypothesis: The amount of microbes on the palm of the hands will not differ between the use of a WAD and naturally drying method after washing hands with anti-bacterial soap.
b) Alternative Hypothesis: The amount of microbes on the palm of the hands will differ between the use of a WAD and naturally drying method after washing hands with anti-bacterial soap.

Methods and Procedures

The Pilot Test, Investigation of WAD, and Investigation of Washed Hands, were conducted at Newington College during the period of June 17th to 27th in 2016.

Experiment Materials
- 21 x Sterilised Agar Plates
- 82 x Clean Cotton Buds
- 1 x Masking Tape
- 1 x Fine Tipped Permanent Marker
- 1 x Coin
- 1 x Ruler

Due to limited number of agar plates available, each agar plate was divided into equal sized sections where appropriate.

Warm Air Dryer (WAD)
All men’s bathrooms have been checked for different WAD types. There is only one type of WAD in use. It is a JD McDonalds Autobeam, which has a white and Silverglass Nozzle (Figure 1). The WAD investigated in this project was randomly selected, which was located on the second floor of the N Block.

Figure 1. WAD Picture and Specifications

<table>
<thead>
<tr>
<th>Picture</th>
<th>Specifications</th>
</tr>
</thead>
</table>
| ![Picture](image1.jpg) | Dry Time: Under 25 seconds  
Dimensions: 300 x 251 x 219mm  
Heater: 2200 Watt  
Air Velocity: 21 m/s (75.6 km/h)  
Height from Ground: 125 cm |
Measure of Microbial Growth
All samples from each experiment were collected using clean cotton buds to swab selected sampling areas before swabbed onto the corresponding sections of agar plates. These agar plates were then placed in the incubator oven in room P21 on the 3rd floor of the Science block. After 48 hours of 30°C incubation, the agar plates were taken out for a visual reading and the number of microbial colonies per section of each plate was counted. If agar plates were not available before Wednesday afternoon, number of microbial colonies was counted on Friday (24 hours of incubation) and Monday (96 hours of incubation) for samples collected on Thursday. Additional visual readings were also done after 72 hours of incubation where appropriate.

Pilot Test
For Project Aim 1 (To investigate if WAD use is associated with more microbe spread in the environment and less microbes on hands), this experiment was conducted using a before/after design similar to previous studies,1,3,5,6 that saw a comparison of microbial counts before and after use of the warm air dryer. The participant for this experiment was the researcher himself. Because there have been ample studies which repeatedly reported that WAD use would spread more microbes and reduce number of microbial colonies on washed hands,1,2,5 this experiment was not replicated with a larger sample size. Similar to previous studies, water was used without any antibacterial soap to wash the participant’s left hand so as to simulate a poorly washed hand scenario. Based on the findings of a recently published study,1 a total of 5 sampling sections were considered, i.e., Hand Palm, Hand Back, Upper Body, Middle Body and Lower Body. The Upper Body consists of areas between the collarbone and the belly button, the Middle Body consists of areas between the belly button and the thighs, and the Lower Body consists of the area between the thighs and the knees. The centre surface area of the participant’s uniform was purposively selected to sample correspondingly to each body area.

Procedures
1. Take 5 agar plates and divide each agar plate into two halves, labeling one of the halves ‘Before’ and the other half ‘After’ while also labeling which section will be swabbed for the agar plate on the base of the agar plate using a fine tipped permanent marker (Figure 2);
2. Use a clean cotton bud for one sampling section, and swab a 3cm² area of the centre of this section thoroughly for 5 seconds while rotating the cotton bud at a slight angle (Figure 3);
3. Gently inoculate the half of the agar plate labeled ‘Before’ with the sample while rotating the cotton bud at a slight angle without tearing the agar, before disposing of the cotton bud;
4. Repeat steps 2 and 3 for the other four sections;
5. Rinse left hand with water for 10 seconds;
6. Place hand 10 cm under the warm air dryer and hand dry for 10 seconds;
7. Use a clean cotton bud, and swab the same 3cm² area of the left palm thoroughly for 5 seconds while rotating the cotton bud slightly;
8. Gently inoculate the half of the agar plate labeled ‘After’ with the sample while rotating the cotton bud at a slight angle without tearing the agar, before disposing of the cotton bud;
9. Repeat steps 7 and 8 with the other four sections;
10. Firmly enclose the agar plate using sticky tape;
11. Place the agar plate into the incubator oven;
12. Take the agar plates out of the incubator oven 48 hours later to read number of microbial colonies then record results.

<table>
<thead>
<tr>
<th>Figure 2</th>
<th>Figure 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example of Agar Plate Labeling</td>
<td>Example of Sampling Hand Palm</td>
</tr>
</tbody>
</table>

**Investigation of WAD**

For Project Aim 2 (*To investigate microbial counts over time inside different sections of a WAD*), this experiment was conducted using a time series design. A total of 8 sampling time points were selected for this investigation as at 9:00, 11:00, 13:00 and 15:00 on 2 separate days (i.e., 20/06/16 and 23/06/16). Equipment and materials necessary for this investigation were gathered before going to the bathroom. All agar plates were labeled for the different periods of time and what WAD section was being investigated. Three sampling sections were selected as the edge, 2cm, and 4cm inside the WAD, which were swabbed with clean cotton buds at one sampling time point. Such sampling was repeated at the other sample collection time of the same day. Inoculation of the agar plates would occur before placing the agar plates into the incubator for future assessment on microbe growth. This process was repeated on another day (23/06/16).

**Procedures**

1. Gather all necessary equipment and materials for this investigation;
2. Go to the bathroom on the second floor of the N Block at 9:00;
3. Label all agar plates with the time tested and section investigated (Figure 4);
4. Use a clean cotton bud to swab the edge of WAD thoroughly for 5 seconds while rotating the cotton bud at a slight angle;
5. Gently inoculate the correctly labeled agar plate with the sample while rotating the cotton bud at a slight angle, before disposing of the cotton bud;
6. Repeat step 4 to 5 for samples from 2cms inside WAD and 4cms inside WAD, respectively;
7. Firmly enclose the agar plate using sticky tape;
8. Store the agar plates in locker (approved by the teacher);
9. Repeat the process from step 1 to step 8 at 11:00, 13:00 and 15:00, respectively;
10. Place all the plates collected on this day into the incubator oven after the last collection at 15:00;
11. Read number of microbial colonies from all samples after 24 hours incubation;
12. Take the first set of agar plates out of the incubator oven 48 hours later and the second set of agar plates 96 hours later to read number of microbial colonies then record results.

<table>
<thead>
<tr>
<th>Figure 4 Example of Agar Plate Labeling</th>
<th>Code of Labeling</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Agar Plate Labeling" /></td>
<td></td>
</tr>
<tr>
<td>1.1.1</td>
<td>1.X.X= 20/06/16</td>
</tr>
<tr>
<td>1.1.2</td>
<td>2.X.X= 23/06/16</td>
</tr>
<tr>
<td>1.1.3</td>
<td>X.1.X= 9:00</td>
</tr>
<tr>
<td></td>
<td>X.2.X= 11:00</td>
</tr>
<tr>
<td></td>
<td>X.3.X= 13:00</td>
</tr>
<tr>
<td></td>
<td>X.4.X= 15:00</td>
</tr>
<tr>
<td></td>
<td>XX.1= Edge</td>
</tr>
<tr>
<td></td>
<td>XX.2= 2cm</td>
</tr>
<tr>
<td></td>
<td>XX.3= 4cm</td>
</tr>
<tr>
<td>Example:</td>
<td>1.3.2= 20/06/16, 13:00, 2cm</td>
</tr>
</tbody>
</table>

**Investigation of Washed Hands**

For Project Aim 3 (*To investigate how WAD use affects microbial counts on hands after using anti-bacterial soap*), this experiment was conducted using a matched pair design to control for variation between individual participants that might affect the microbial counts. Consent was sought from 24 male students who agreed to participate in this experiment. The hand washing method was standardised for every participant and encouraged to strictly follow during the experiment. For practical reasons, the experiment was separated into two parts, which were conducted for two sets of twelve participants on two separate days (22/06/16 and 24/06/16), respectively. Two groups of six participants from the first set and four groups of three from the second set were taken to the bathroom during the science classes. Each time samples were collected from a participant, all others were to remain outside the bathroom to avoid contamination of results. No other teachers and students used the bathroom during the sampling process. Samples were obtained from randomly selected sampling sections of the palm from each hand of a participant after drying each hand with different methods. The agar plates would then be sealed and placed in the incubator for future assessment on microbial growth.

**Sample Size**

The matched pair sample size formula was used to calculate minimum number of participants required for two-sided statistical tests of the hypotheses in this experiment,\(^{12}\) i.e., \(N = \left(\frac{Z_{\alpha} + Z_{\beta}}{\delta}\right)^2 SD\), where \(Z_{\alpha}\) was 1.96 and \(Z_{\beta}\) was 1.282 with \(\alpha = 0.05\) and \(\beta = 0.10.\(^{13}\) The standard deviation (SD) of the experiment was assumed to be 1.45 (log SD = 0.37)\(^1\) and \(\delta\) was set to 1 as the minimum meaningful difference of microbial counts. After substituting these values into the equation, the minimum sample size was 23 participants. Based on the widely acceptable
assumption of 5% probability when the null hypothesis is incorrectly rejected, alpha (\(\alpha\)) as 0.05 was decided to be used; and beta (\(\beta\)) as 0.10 to have a power of 90% probability to correctly reject the null hypothesis.\(^{14}\) Because sufficient sample size is very important to make generalisable inferences, a total of 24 volunteers were invited for participation to increase the statistical power.

**Participants**
Participants for this investigation were 24 healthy young male volunteers aged between 14 and 16, with no signs of any skin diseases or lesions. All volunteers were asked for their permission to be sampled with their washed hands for this experiment. Each volunteer’s hands underwent separate hand drying methods, as one hand was dried using a warm air dryer while the other hand was dried by naturally shaking.

**Coin Toss Randomisation**
To better reduce unknown variation and bias,\(^{15}\) for example the difference in cleanliness of different hand, a coin toss was performed for each participant to decide which of the his hand would be WAD air-dried and which would be treated as matched control. Heads indicated that the left hand would be air dried while tails indicated that the right hand would be air-dried. Similar randomisation process was used to select sampling sections of hands (Figure 5).

<table>
<thead>
<tr>
<th>Coin toss randomisation*</th>
<th>Sampling areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample section A: TH;</td>
<td>A</td>
</tr>
<tr>
<td>Sample section B: HH;</td>
<td>B</td>
</tr>
<tr>
<td>Sample section C: TT;</td>
<td>C</td>
</tr>
<tr>
<td>Sample section D: HT;</td>
<td>D</td>
</tr>
<tr>
<td>*Coin tossed two times</td>
<td></td>
</tr>
<tr>
<td>(T = Tail; H = Head)</td>
<td></td>
</tr>
</tbody>
</table>

**Washing Hands**
Hand washing was completed with antibacterial soap. All volunteers underwent the same predefined hand washing procedure. Participants began by wetting their hands with water and then applying the amount of soap from two presses. They then rubbed their hands together for 5 seconds before intersecting their fingers and rubbing all surfaces for another 10 seconds before rinsing their hands with water for 15 seconds.

**Hand Drying**
After washing their hands, participants were asked to shake their control hands to get rid of excess water while the other hand was dried using the WAD for 15 seconds. The WAD aired-hand would be stationary 10 cm away from the edge of the hand dryer, while the control hand palm faced opposite the WAD. One out of four sampling sections of the palm of both hands was then be swabbed immediately after drying. The whole process was repeated 23 more times.
Procedures
1. Gathering all necessary equipment and materials for investigation on the second floor of the N Block;
2. Ask participants for their consent before gathering them to go to the bathroom;
3. Label all agar plates by dividing each one into 6 sections, 2 sections for two hands of one participant;
4. Do coin toss first time to decide which hand is chosen to have hand drying with WAD;
5. Do coin toss the 2nd time and the 3rd time to decide which section of the palm of both hands will be swabbed for testing;
6. Ask participants to wash both hands with anti-bacterial soap using the same hand washing method for 15 seconds;
7. Dry the randomly selected hand with WAD, 10cm away from the hand dryer for 15 seconds, with the other hand dried naturally by shaking;
8. Using a clean cotton bud to swab the randomly selected sampling section thoroughly for 5 seconds while rotating the cotton bud at a slight angle;
9. Gently inoculate the labeled agar plate with the sample while rotating the cotton bud at a slight angle, before disposing of the cotton bud;
10. Firmly enclose the agar plate using sticky tape;
11. Repeat from step 4 to step 10 for the other participants;
12. Place all the agar plates into the incubator;
13. Read number of microbial colonies from all samples after 24 hours incubation;
14. Take the first set of agar plates out of the incubator oven 48 hours later and the second set of agar plates 72 hours later to read number of microbial colonies then record results.

Statistical analysis

Numbers of microbial colonies were counted from all samples in each experiment. Minimum, average, median, and maximum microbial counts were calculated for WAD dried and naturally dried hands respectively. The Wilcoxon Signed Rank Test was used, which is a nonparametric-statistical hypothesis test that determines the rank of each paired sample. This test was used in another WAD experiments on microbial counts. The W-statistics was manually calculated and further confirmed by use of an online calculator. P Value ≤0.05 was set as statistically significant in this experiment.

Risk Assessments

It is possible that the bathroom selected and WAD selected may contain airborne bacteria and viruses that may affect one's health (Table 1). The project comprised washing hands activities as normal as routine practice and therefore it can be considered to be low risk. Nevertheless, each participant for the final investigation was asked verbally for consent to participate in this project and explained potential risks. Another main risk should be the threat that bacteria growing on the agar plate can be spread through contact and it can result in possibly major health issues. Similarly, when the bacteria would grow to a larger
amount after incubation and if the agar plate is opened, it can become airborne, thus contaminating the environment. That's why standard sampling procedures as instructed in the classes were adopted and strictly complied with.

Table 1 Assessment of Potential Risks

<table>
<thead>
<tr>
<th>Risks</th>
<th>Risk Reduction</th>
<th>Accident Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bathroom and WAD may contain airborne bacteria and viruses that affect health</td>
<td>Notifying participants of potential risks, monitor their hands washed with antibacterial soap, and collect and dispose of used cotton buds to a rubbish bin</td>
<td>Record any incidents, isolate the affected area and person, and seek immediate help from the school nurse and teachers</td>
</tr>
<tr>
<td>Microbes may spread into the environment in case of dropping agar plates on the ground during the delivery</td>
<td>Safely carry all agar plates with caution, and be mindful of steps and any other slip and trip hazards</td>
<td>Record any incidents, isolate the affected area and person, and seek immediate help from the cleaners and teachers</td>
</tr>
<tr>
<td>After incubation microbes levels grow to a larger amount which can be hazardous to humans</td>
<td>Collect samples after application of antibacterial soap and check the microbial growth regularly</td>
<td>Record any incidents, isolate the affected area and person, and seek immediate help from the teachers</td>
</tr>
<tr>
<td>Microbes that grow on the agar plate can spread upon contact</td>
<td>Safely seal the agar plates, ensure they remain sealed until completing incubation, and open them with caution</td>
<td>Record any incidents, isolate the affected area and person, and seek immediate help from the teachers</td>
</tr>
</tbody>
</table>

Results

Pilot Test

Figure 6 details microbial counts for the 5 sample areas before and after using the warm air dryer. More microbial counts were observed for all sample areas except the hand palm after washing without soap and immediately air-drying the hand than before hand washing. Upper/Middle Body areas almost had twice as many microbes after using the WAD. However, microbial count on the palm of the hand was nearly 3 times higher before WAD use than immediately after.

Figure 6 Number of Microbial Colonies Before and After Air-drying
Investigation of WAD

Figures 7-11 compare microbial counts at different time points and also compare microbial counts from different sections of the warm air dryer.

**Edge**

Figure 7 shows a monotonically increasing trend pattern on different days, since the number of microbial colonies increased from 10 to 26 on the first day (June 20, 2016), and from 12 to 17 on the second day (June 23, 2016). An increasing trend was also observed between days except the count at the end of June 23, 2016.

**Figure 7 Number of Microbial Colonies from the Edge of WAD**

2cm inside the WAD

Figure 8 shows a general decreasing trend, since the number of microbial colonies decreased from 6 to 2 on the first day, and from 3 to 1 on the second day. This decreasing trend was also observed between days, as days passed.
4cm inside the WAD

Figure 9 shows a lack of distinct trend pattern when comparing the two days, although on the second day there might be an increase in number of microbial growth over the course of the day from 1 to 4 colonies. However, this trend was not shown on the first day.

Results on the first day

Figure 10 shows that WAD use may have different effects on the number of microbial colonies at different sections. While there appears to be more colonies growing on the edge as day passed, number of microbial colonies from the sampling sections deeper inside seems to decrease over time. Microbial count was almost 2 times higher on the edge than the other sections at the beginning of the day; and as much as 13 times higher by the end of the day.
Results on the second day
Figure 11 also shows a very similar pattern to the first day when comparing different WAD sections, as number of microbial colonies on the edge is continually increasing. The microbial count was also increasingly higher on the edge than the other two sections, which was much like the first day.

Investigation of Washed Hands
The results obtained for three pairs of samples were inconclusive because the colonies could not be counted. Therefore, they were not included for the analysis. The majority of results from 21 pairs of effective samples indicate that WAD air-dried hands had more microbe counts compared to the control hands that were dried by naturally shaking (Figure 12).
Table 2 indicates that the average, minimum, maximum, and median microbial counts for the WAD air-dried group are all greater than those for the control group. Average microbial counts were rounded up from 22.05 and 9.90 for Aired and Control groups respectively.

Table 2 Descriptive Statistics of Microbial Counts for Aired and Control Groups

<table>
<thead>
<tr>
<th></th>
<th>WAD Air-dried</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>23</td>
<td>10</td>
</tr>
<tr>
<td>Minimum</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Maximum</td>
<td>100</td>
<td>43</td>
</tr>
<tr>
<td>Median</td>
<td>16</td>
<td>7</td>
</tr>
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</table>

Wilcoxon Signed Rank Test
The Wilcoxon test indicates that number of microbial colonies on aired hands was significantly higher than that on the control hands. Table 3 presents the manual calculation, which was confirmed by the online calculator (W-value: 46, Sum of positive ranks: 144, Sum of negative ranks: 46, P-value is 0.048).

Table 3 Number of Microbial Colonies and Wilcoxon Signed Rank Values

<table>
<thead>
<tr>
<th>Participants</th>
<th>Aired</th>
<th>Control</th>
<th>Sign</th>
<th>Absolute difference</th>
<th>Rank</th>
<th>Signed Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>20</td>
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<td>17</td>
<td>14</td>
<td>-14</td>
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* Comment of “n/a” represents “not applicable” in the calculation of ranks.

Discussion

Proper use of hand drying methods is an important component for hand hygiene, however WAD use is currently under dispute for its potential threat to personal and environment health.\(^1\)\(^-\)\(^6\) To the best of my knowledge, the current project was the first of its kind to replicate previous research, explore source of contamination, and examine the effects of WAD use on washed hands after application of antibacterial soap. The findings may provide avenues for intervention to improve hand hygiene practice in public bathrooms.

Comparison with Previous Studies

Consistent with previous findings,\(^4\)\(^-\)\(^6\) the Pilot Test results confirm that more microbes may be spread into the environment through WAD use. The Pilot Test also reveals a correlation between the increase of microbial counts in the environment and the decrease on hands when washing without any antibacterial soap, which demonstrates similar implications from previous studies that WAD use may shift microbes from hands to the environment.\(^7\),\(^8\) It is not surprising because WADs would blow out hot air at a very high speed so that small particles of microbes would be easily blown away into other areas of the environment.

The Investigation of WAD demonstrates a pattern of increase of microbial counts on the WAD edge and decrease from inside over time when used in a single day. It is likely that WADs will gradually blow out microbes from inside each time it is used, which may explain the observed increasing gap between microbial counts on the WAD edge and from inside as day passed. As evidenced by the current findings, the hygienic status of WAD itself might be a source of contamination to users’ hands and the environment, however, little existing research in this respect was found. School personnel were asked if they would regularly clean the insides of WADs and the “negative” response was alarming. Therefore WAD hygiene seems to have been ignored and requires further investigation.

Routine hand washing process requires the combination use of antibacterial soap and proper drying method to achieve the ideal hand hygiene level.\(^1\),\(^8\),\(^19\) Previous studies compared different hand drying methods using non-antibacterial soap,\(^1\),\(^3\),\(^5\),\(^6\) and therefore did not replicate the routine hand washing practice. The current finding shows that after washing hands with antibacterial soap, WAD use is associated with significantly more microbial counts on the palm of the hands compared with naturally shaking the hands. The combination use of antibacterial soap and WAD would potentially fail to reach the ideal hand hygiene level, because WAD use may offset the benefit of using antibacterial soap. Because WADs are designed to perform one function mainly, and that is to dry the hands, it may not take into account any possibly unhygienic consequences. This neglect of hygienic care would warrant further investigation especially when WADs may
blow out microbes from inside, which was demonstrated by the findings of current Investigation of WAD.

**Implications for Intervention**
The main reason for washing one’s hands is to reduce microbes on the hands since hand hygiene is extremely important for well-being because they touch a lot of surfaces that contain germs. However, environmental hazards will increase when dangerous microbes reside within WADs, proliferate by millions over time, and are blown to individual users’ hands, clothes, and the environment each time WADs are used, which may be carried to other private and public areas as well and potentially cause outbreaks of any “bird flu” alike. This somewhat defeats the purpose of washing hands after using a public bathroom. Learning from past outbreaks of Legionnaire Diseases, which is mainly caused by *Legionella* hiding in an air conditioning system, WAD could be a potential microbe reservoir. Regular disinfections within WADs, which is currently missing, may be mandatory to mitigate risks to public health.

**Strengths and Limitations**
Different designs were used to conduct these experiments. For example, the use of a matched pair design would effectively control for variations between individual participants. Sample size was accordingly calculated, which was bigger than some of the previous studies. Because different hand washing styles can possibly change results, only one hand washing method was standardised for all participants’ hands. The nonparametric Wilcoxon test was used to examine the hypotheses for the Investigation on Washed Hands, which accommodates the loss of unreadable 3 samples. The comparable hand drying method was selected by naturally shaking, considering readable microbial counts as a control group and to avoid the possibility that microbes might shift from paper towels to washed hands. Antibacterial soap was used for the third experiment to mimic normal practice for people washing hands in a bathroom. Sampling hands and sections were randomised to reduce bias.

However, there were some limitations. Participants came from a single class and their results may be similar between each other. The measure of microbes in relation to WAD use only considered any visual microbial growth. Therefore the results should be interpreted with caution. The Investigation of WAD was conducted in a natural setting without any interference. It is possible that a user may have touched the edge of WAD especially when the bathroom was heavily used, which might explain the inconsistent pattern of microbial counts on the edge section during 13:00 to 15:00 between two days (i.e., sharp increase from 12 to 26 on the first day, slight increase from 16 to 17 on the second day). The sampling section of 4cm inside the WAD is at the bending point, and its results indicate that the airflow direction and shapes of WAD might influence number of microbial colonies observed. Furthermore, a limited amount of agar plates was available. For practical reason, these agar plates were divided into smaller sections, which might explain the loss of 3 unreadable pairs of samples. Access to facilities was only available at certain times, which resulted in different incubation periods. Nevertheless, the results were somewhat robust as additional
visual checks took place at 24 hours of incubation and there appeared to be little difference in number of microbial colonies at different incubation periods. Agar plates were also divided very equally for each part of the project, so the microbes should have been able to grow meaningfully.

**Conclusion**

This project confirms the shift of microbes from poorly washed hands to the environment during WAD use, demonstrates an increase of microbes from inside out and over time, and identifies an increase of microbes on WAD users’ hands after washing with antibacterial soap and drying with a WAD. These results imply WADs may blow out microbes from inside and highlight the importance of regular disinfection of WADs in public bathrooms.
Acknowledgments

This project was completed at Newington College with support from Mr Fitzsimmons and Mr Potter for their advice on experimental procedures, the laboratory staff for access to facilities, and volunteers participating in this project.

References


Appendix

Figure 13: Flow chart of the Pilot experiment

1. Gather all necessary equipments
2. Go to bathroom and Label all agar plates
3. Swab 5 sections (hand palm, hand back, upper/middle/lower body areas)
4. Swab agar plates with samples
5. Wash left hand for 15 secs and WAD dry the hand stationary for 10 secs (10 cm away)
6. Swab 5 sections immediately (see above) after drying hands
7. Swab agar plate with samples
8. Place Samples in the incubator in room P21
9. Collect results after 48 hours

Bathroom
Figure 14: Flow chart of the Investigation of WAD

Gather and store necessary equipments on day 1

Go to bathroom at 9:00am with necessary equipments

Label all agar plates

Swab edge, 2cm and 4cm inside WAD

Swab agar plates for each samples (stored in locker)

Repeat process at 11:00, 13:00 and 15:00

Collect samples and place them in incubator

Read results after 24 and 48 hours of incubation

Repeat process on day 2
Figure 15: Flow chart of the Investigation of Washed Hands

Gather necessary equipments, and ask volunteers for consent to participate

Go to bathroom and label all agar plates

Do coin toss randomisation for left/right hand and sample sections

Wash hands with anti-bac soap for 15 secs using standardised hand washing method

Dry one hand stationary with WAD and dry the other hand naturally by shaking

Swab one section of palm on both hands immediately after drying onto agar plate

Repeat process with next samples on each volunteer

Collect samples and place in incubator in room P21

Read results after 24, 48, and 72 hours of incubation