Spray Coating in Health Environment

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Abstract

The effective use of disinfectants on surfaces, therefore, within the health care environment constitutes an important factor in preventing Hospital Acquired Infections (HAIs). For surface disinfection processes in hospitals the open bucket and closed bucket systems are commonly used, these systems involves the use of wipers to deliver the disinfectant agents to the target surface. Wipers (cotton rags, cellulose- based wipers) however, have proven to be inefficient in the delivery of disinfectant agents as they are incompatible with some disinfectant agents or have a high possibility of contaminating the disinfectant solution or other surfaces they come in contact with.

A mobile fine spray unit, utilising a novel Spill-Return Atomiser (SRA) has been developed for the purpose of disinfection within healthcare environments. The developed system produces droplet sizes 15µm< D_{32} < 25µm for flow rates as low as 0.1 l/min with liquid supply pressure of up to 12MPa. This is achieved by providing an effective and efficient delivery system for specified disinfectant agents. Furthermore, the unit is able to spray uniformly on to any given surface, providing, mist-like coverage. Any streaking patterns, caused by excessively large droplets, left on the surface during or after spray application would jeopardize the efficiency of delivering the decontaminant.

A coating performance test was carried out with the aim of determining the coating performance of the SRA on four different surfaces that are commonly found within the healthcare environment; they are steel, acrylic, glass and laminated wood. The SRA was used to spray water on these surfaces at different pressures, flow rates, spraying angles and spraying distances. Images of the surfaces were also taken after each application for further analysis.

The effect of atomiser application distance and angle upon the impacted droplet size of droplets distributed on each of the three test surfaces was studied (laminated plywood, brushed steel and glass). A *sweeping* method of application was also utilised at all test distances in order to assess the comparative coating quantity performance of *sweeping* and fixed/stationary atomiser application positions. Streaking, as illustrated in the tests, is a function of, mainly, spray duration, distance, water supply pressure and material properties.

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Introduction Surfaces within the healthcare environment contribute to the transmission of epidemiologically important microbes such as Methicillin Resistant Staphylococcus Aureus (MRSA), Vancomycin- Resistant Enterococcus (VRE), Clostridium difficile, and viruses (ie, norovirus, rotavirus, and rhinovirus) thereby causing Hospital Acquired Infections (HAIs); the fact that personnel may contaminate their gloves (or hands in the absence of gloves) by touching such surfaces suggests that contaminated surfaces may serve as a reservoir or source of MRSA and VRE in hospitals. Therefore, the effective use of disinfectants on surfaces within the health care environment constitutes an important factor in preventing HAIs [1].

A potable fine spray unit, utilising a novel Spill-Return Atomiser (SRA) [2] has been developed for the purpose of disinfection within healthcare environments. The unit must be able to spray uniformly on to any given surface, providing, "mist-like" coverage. Any streaking patterns, caused by excessively large droplets, left on the surface during or after spray application would jeopardise the efficiency of delivering the decontaminant.

This paper presents the effect of atomiser application distance and angle upon the impacted droplet size of droplets distributed on each of the three test surfaces were studied (laminated plywood, brushed steel and glass). A *sweeping* method of application was also utilised at all test distances in order to assess the comparative coating quantity performance of *sweeping* and fixed/stationary atomiser application positions. Streaking, as illustrated in the tests, is a function of, mainly, spray duration, distance, water supply pressure and material properties.

Apparatus and Procedures

The test rig as shown in Figure 1, reported previously [3-4] comprises of a basic four-wheeled trolley onto which a portable 10 litre tank, Spill-return Atomiser (SRA) and a spill return pipe which bleeds liquid from the atomiser back into the tank for recirculation. Water was used as a simulated disinfection liquid solution as it has similar physical properties as most solutions likely to be used. Series of tests were carried to ascertain the coating performance of the SRA on different surfaces. Typical surfaces found in the healthcare environment were used as the test surfaces as commonly found in bedside cabinets, windows and medical equipments. The apparatus setup within the simulated hospital chamber [3] used for coating performance test is shown in Figure 2. The apparatus includes the test rig described in Figure 1 and the Spill-Return Atomiser (SRA). A tray and a sponge for measuring the liquid collection prior to the coating test, at the required time intervals, and then subsequently weighed and recorded. The Spill-return Atomiser (SRA) as shown in Figure 3 and previously reported in [6 and 7] has been designed for the purpose of disinfection in healthcare environments. It consists of a long swirl chamber which is the distinctive feature which differentiates it from other SR's. The swirl chamber refers to the distance between the tangential inlets and the exit orifice as shown Figure 3. One jet is discharged to the outside at high speed and atomised, producing conical sprays and the other jet is spilled via low pressure pipe to the liquid reservoir.

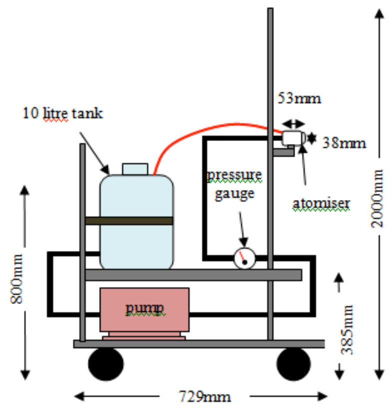


Figure 1. The test apparatus

Coating Analysis

The assessment of coating quantity involved the analysis of the amount (weight) of liquid deposited by the SRA upon various surfaces from a range of distances and angles. By adding a specialist dye to the liquid in the reservoir of the test rig, drops became more visible to both the human eye and the camera lens, therefore upon the image analysis, droplet sizes and formations could be easily identified. The dye used in this case was 'hydra-aqua', a specialist blue water dye. This particular dye was chosen as it did not affect the viscosity of the liquid, which would in turn affect the drop size and various other spray characteristics. Each test in this particular series of trials, utilised an exit orifice diameter of 0.3mm, a spill diameter of 0.5mm (swirl chamber length-diameter ratio, 6:1) and a delivery pressure of 9MPa [4]. Six different downstream locations were used in this study; 0.8, 1, 1.2, 1.4, 1.6 and 1.8m. At each distance five angles of application were used; 0 (front-on), 20, 40, 60 and 80^{o} as shown in Figure 5.20. In addition to the five stationary angles of application a sweeping (side-to-side) method of application was used at each of the six predetermined distances. Although a sweeping method of application is difficult to replicate manually during tests, each right-to-left and left-to-right sweep took approximately 1 second. At each of the chosen application distances and angles, the atomiser was aimed at the centre of a clearly marked 0.25m^2 target area, as shown in Figure 4.

Target area dimensions were limited by the test chamber. The atomiser was set in line with centre of the target area in all tests, at a height of 1.2m. Three target surfaces (laminated plywood, brushed steel and glass) were used in order to assess the coating quantity and performance of the SRA across a range of surfaces An operating pressure of 9MPa was used in all tests as preliminary testing showed that this was the optimum pressure for a range of performance characteristics, such as flow rate and drop size.

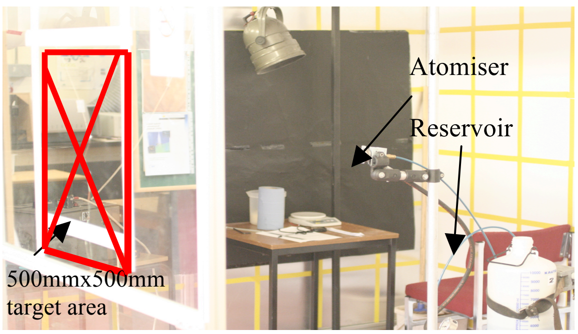


Figure 2. The apparatus set up within the test chamber

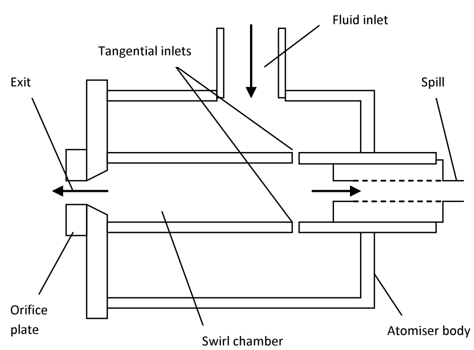


Figure 3. Schematic diagram of SRA

An application period of 5 seconds was chosen for each test as this was stated as the maximum application time used within the NHS for the application of disinfection fluid. Before each individual test, a $0.25m^2$ piece of sponge was placed inside a specially constructed steel housing tray, which was then subsequently weighed using a set of digital scales and recorded. Once the spraying operation had completed over the period of 5 seconds [1] using a stopwatch, the tray containing the sponge was carefully placed over the $0.25m^2$ target area and held there for a period of 30 seconds, in order to allow the sponge to absorb the liquid deposited on the target surface. The steel tray served two purposes in this particular series of test procedures; (i) to allow for even pressure to be exerted onto the sponge during the process of liquid absorption, and (ii) to prevent liquid escaping the target area during the liquid absorption process. Once the liquid had been absorbed from the surface the tray containing the sponge was removed from the target surface area and weighed for a second time, the weight again being accurately recorded.

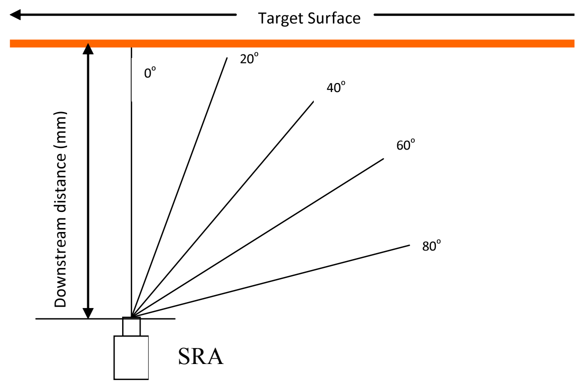


Figure 4. Schematic representation of application angles used in coating tests

By subtracting the original ‘dry’ weight of the sponge and tray from the secondary reading recorded by weighing the tray and sponge with the addition of the liquid deposited on the target test surface area, the amount of liquid deposited onto a $0.25m^2$ target surface area of each material (laminated plywood, brushed steel and glass) could be estimated. In order to ensure that the sponge used in each individual test procedure was dry, several pieces of sponge, each measuring $0.25m^2$, were used in a rotation system in order to complete this particular series of tests. Each piece of sponge was left to dry for a minimum period of two hours, before being used again in any test.

Results and Discussion

Through the processing of data obtained from the streaking trials [3], a comparison of the acrylic and glass surface showed that the use of the latter was more appropriate to consider for testing coating. Furthermore, the surface texture of both were similarly smooth, thus resulting in the choice to continue the testing of glass alone to accompany the other previously used test materials; laminated plywood and brushed steel. Figures 5-7 show the effect of application distance and angle upon the quantity of liquid deposited upon the $0.25m^2$ target areas on each of the three test surface materials (laminated plywood, brushed steel and glass). A sweeping method of application was also utilised at all test distances (800-1800mm) in order to assess the comparative coating quantity performance of sweeping and fixed/stationary atomiser application positions.

Figure 5 shows that, of the distances tested, the distance at which the most liquid is uniformly deposited, without the onset of streaking using the laminated plywood test surface was 1400mm. It was also noted that at all fixed application angles, streaking occurred up to and including an application distance of 1000mm. However, none of the application distances tested when employing a sweeping method of application resulted in streaking of the liquid deposited on the target surface.

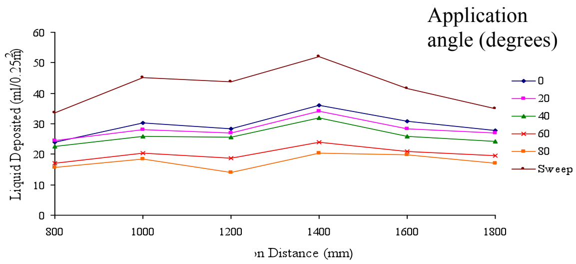


Figure 5. Effect of application distance and angle upon liquid quantity (ml) deposited on $0.25m^2$ laminated plywood test surface (supply pressure - 9MPa)

Figure 6 shows that, of the distances tested, the distance at which the most liquid is uniformly deposited, without the onset of streaking using the brushed steel test surface was also 1400mm. Moreover, at all fixed application angles, streaking occurred up to and including an application distance of 1200mm. However, only the application distances of 800 and 1000mm when employing a sweeping method of application resulted in streaking of the liquid deposited on the target surface.

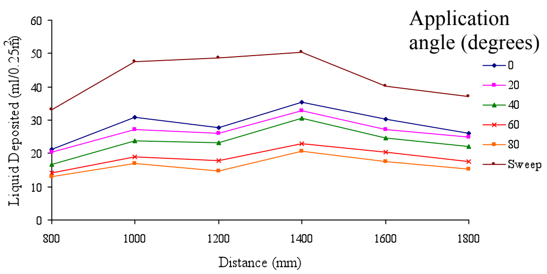


Figure 6. Effect of application distance and angle upon liquid quantity deposited on $0.25m^2$ brushed steel test surface (supply pressure - 9MPa)

Figure 7 shows the most liquid is uniformly deposited, without the onset of streaking using the glass test surface was 1400mm. Also, at all fixed application angles, streaking occurred up to and including an application distance of 1200mm. Furthermore, at the application distance of 1400mm, it was found that streaking occurred once the application angle exceeded 20^o. However, only the application distances of 800 and 1000mm when employing a sweeping method of application resulted in streaking of the liquid deposited on the target surface. Figures 5-7 display several trends relating to the relationship between atomiser application distance and angle. To exemplify, a significantly larger amount of liquid was uniformly deposited on all three test surfaces when employing a sweeping method of application as opposed to a fixed/stationary atomiser application position. Thus, the most efficient method of application of the disinfectant in practice would be a sweeping motion.

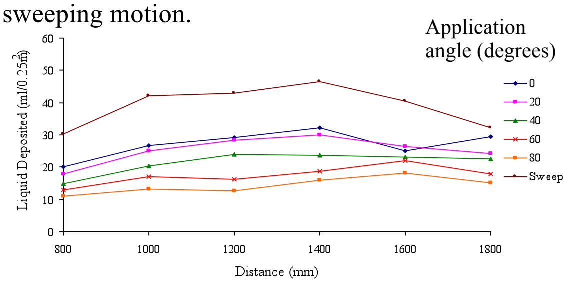


Figure7. Effect of application distance and angle upon liquid quantity deposited on $0.25m^2$ glass test surface (supply pressure - 9MPa)

Figures 5-7 have also showed that as the angle of the atomiser in relation to the target surface is increased, the amount of liquid subsequently deposited on the target surface is decreased. The optimum application distance for both fixed and sweeping atomiser application methods was 1400mm. At this distance, the highest amount of uniformly deposited liquid was collected from each of the three test surfaces (laminated plywood, brushed steel and glass) and streaking was not detected in any case.

Of the three materials tested, the laminated plywood and brushed steel surfaces lent themselves most to the application of liquid in a uniform fashion using the SRA as they both produced very similar results in terms of liquid deposition at all application distances and angles used in this series of tests (see also Figure 5 and 6). The reason for the comparatively high liquid deposition on both the laminated plywood and brushed steel surfaces in relation to the glass surface is thought to be a result of higher surface tension, caused by small imperfections on each material. Higher surface tension in this case means that droplets must be of a greater size or carry greater momentum in order to overcome the surface tension and subsequently either deflects off the surface or cause streaking. As the comparatively smooth glass surface had little or no imperfections it therefore has less surface tension.

Droplet Image Analysis

Figure 8 (a, b and c) shows the effect of atomiser application distance and angle upon the impacted droplet size of droplets distributed on each of the three test surfaces (laminated plywood, brushed steel and glass) using digital camera for image analysis. A *sweeping* method of application, identical that detailed in the previous Section was also utilised at all test distances in order to assess the comparative coating quantity performance of *sweeping* and fixed/stationary atomiser application positions. It must be noted that the average impacted droplet sizes shown in Figure 8 are in fact the amalgamation of numerous smaller droplets originally produced by the SRA, known as the Lamella effect caused by the buildup of liquid on the surface over the 5 second application period. The droplets estimated using image analysis.

Figure 8(a) shows that, of the distances tested, the distance at which the most liquid is uniformly deposited, *without the onset of streaking* using the laminated plywood test surface, at which the average drop size was smallest (≥1.4mm) was 1400mm, utilising application angles of 0-60^o or a sweeping technique. It is advisable to apply liquid to a laminated surface from a distance of 1400mm wherever possible when using a fixed atomiser position. It was again noted that at all fixed application angles (0-90^o), streaking occurred up to and including an application distance of 1000mm.

Figure 8(b) shows the brushed steel test surface, at which the average droplet size was smallest (≥1.25mm) was 1400mm, utilising application angles of 0-60^o or a sweeping technique. As in the case of the laminated plywood test surface at all fixed application angles (0-90^o), streaking occurred up to and including an application distance of 1000mm. Of the three material surfaces tested, the brushed steel surface produced the smallest overall impacted droplet size over the range of application distances, angles and methods featured in this series of tests.

Figure 8(c) also shows the glass test surface, at which the average droplet size was smallest (≥1.75mm) was 1400mm, utilising application angles of 0-40^o or a sweeping technique. At all fixed application angles (0-90^o), streaking occurred up to and including an application distance of 1200mm. However, only the application distance of 800mm when employing a sweeping method of application resulted in streaking of the liquid deposited on the target surface. Of the three material surfaces tested, the glass surface produced the largest overall impacted droplet size over the range of application distances, angles and methods featured in this series of tests. The reason for this is thought to be related to the comparatively low surface tension of the smooth glass test surface.

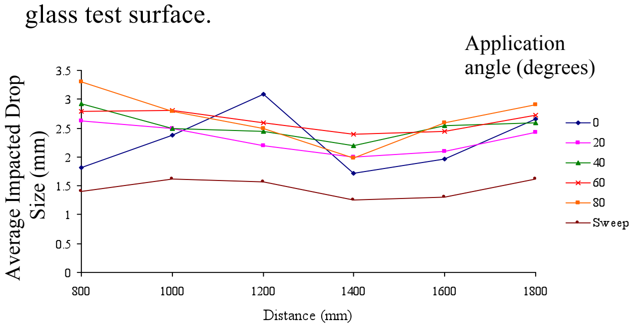


Figure 8 (a). the laminated plywood

Figures 9-11 show spray deposition upon each of the three test materials. It is evident from the data obtained and presented in Figure 8 that the individual droplets upon impaction range from 2-2.5mm in diameter.

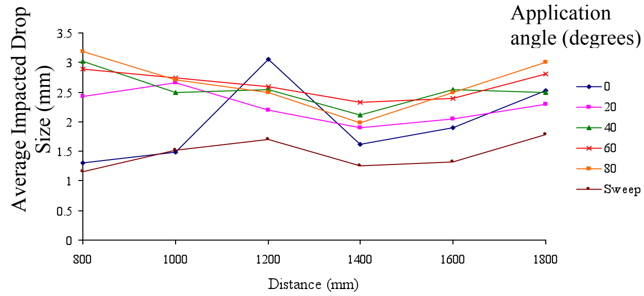


Figure 8 (b). brushed steel

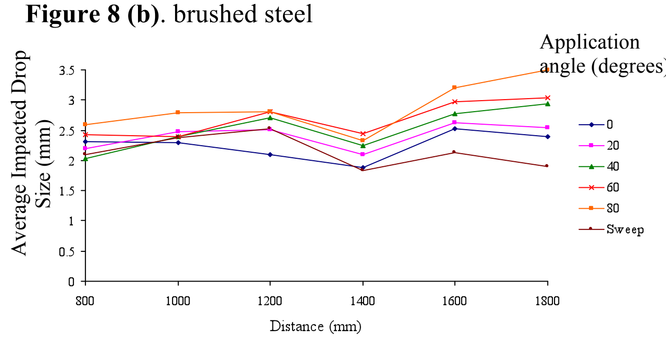


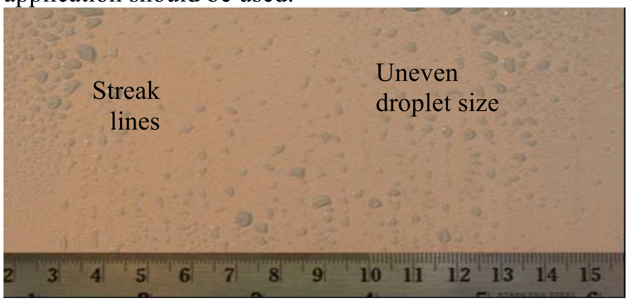
Figure 8 (c). glass

Effect of atomiser application distance, angle and method upon the impacted droplet size of droplets distributed on various test surfaces (supply pressure - 9MPa)

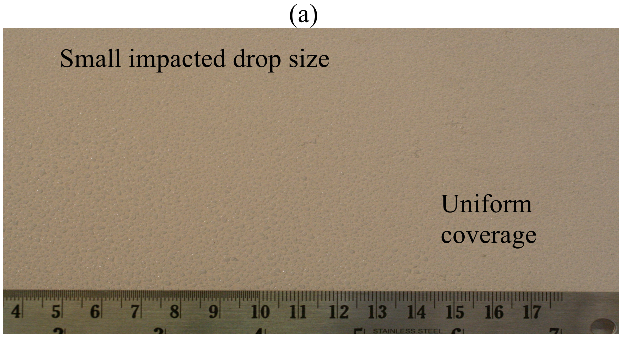
However, with the effect of coalescence and the subsequent lamella, this figure was greatly increased to a diameter of 1-3.5mm. It is the latter of the two data ranges which is featured in Figures 8-11. Future investigation should include the mathematical modelling of such important phenomena, which would also be applicable to other coating processes, such as paint coating.

Conclusions

A difficulty is to define when a surface has reached an ideal fully coated situation. It is found that for low viscosity liquids such as water, and which do not "dry" in the manner of paint coatings, there is tendency for impacted droplets to coalesce into isolated larger flattened "lamella", this particularly being the case for polished waxed or varnished surfaces. A comprehensive analysis of the coating performance of the Spill-Return Atomiser (SRA) has showed that application distance, angle and technique have a significant effect upon the coating process. The most effective application distance, height and application angle for a single stationary SRA, as demonstrated by the data featured through the analysis are 1.4 - 1.8m, 1.2 - 1.6m and 0-20^o respectively. However, by using a 'sweeping' method of application, the application distance (and time period) at which uniform coverage is obtained can be decreased. Thus when working in confined areas or within strict time constraints, a sweeping method of application should be used.

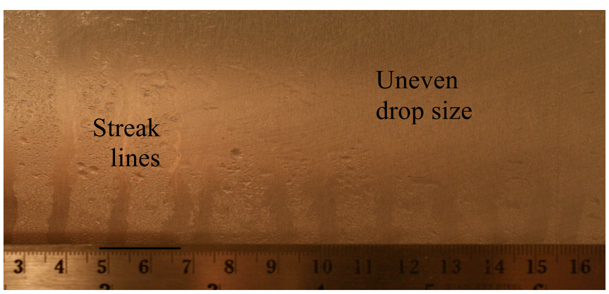


(a)

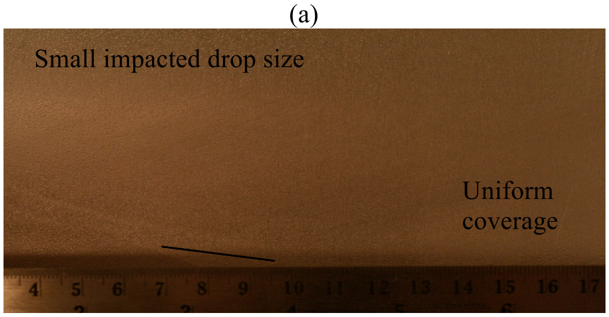


(b)

Figure 9. Impacted droplet deposition on; laminated plywood test surface, application angle of 0^o and distance of 800mm (a), and application angle of 0^o and distance of 1800mm (supply pressure - 9MPa) (b)



(a)

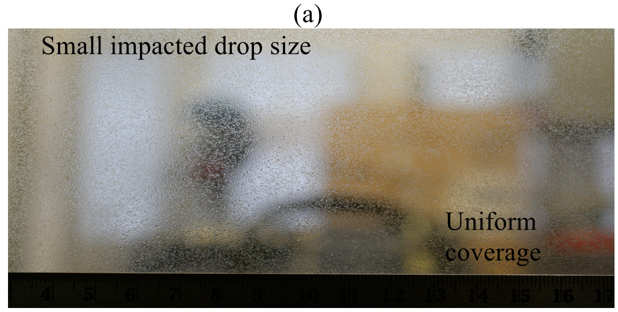


(b)

Figure 10. Impacted droplet deposition on; brushed steel test surface, application angle of 40^o and distance of 1000mm (a), a sweeping and distance of 1400mm (supply pressure - 9MPa) (b)

Future publication includes obstacles, ceilings and

(a)



(b)

Figure 11. Impacted droplet deposition on; glass test surface, application angle of 0^o and distance of 1200mm (a), and a sweeping method and distance of 1600mm (supply pressure - 9MPa) (b)

prototype system will also include trials for disinfection in actual healthcare environments (i.e. hospitals).

Mathematical mapping of the droplet impaction phenomena will also formulated, which could be used to predict the coating performance of a range of sprays. This mathematical mapping could also be utilised in the study of other spray coating applications, such as paint coating and combustion processes.

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