Testing Effectiveness of Duct Cleaning and its Impact on Airborne Particles, Mold and Biocide Levels in Commercial Office Buildings. Evaluation Report

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Testing Effectiveness of Duct Cleaning and Its Impact on Airborne Particles, Mold and Biocide Levels in Commercial Office Buildings: Evaluation Report

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ABSTRACT

In 2008 NRC-IRC launched its Indoor Air Initiative: a multi-faceted approach to the issue of indoor air quality (IAQ), combining research, technology assessment and the development of a national forum for discussion and dissemination of IAQ information. One activity of the Initiative was a multi-year project to develop performance evaluation protocols to test and assess the effectiveness of technologies aimed at improving air quality. Under this activity, 50 technologies claiming to improve IAQ were identified. Then using a ranking process developed at NRC, three were selected for protocol development: 1) portable air cleaners (PACs); 2) commercial air duct cleaning (DC); and 3) heat/energy recovery ventilators (H/ERV). This test report deals with the application of the protocol on evaluation of DC, specifically testing its effectiveness and impact on airborne particles, mold and biocide levels in commercial office buildings. This protocol was prepared by NRC researchers under the guidance of the Technical Advisory Committee (TAC). Compliance to this protocol is voluntary until and unless a jurisdiction makes compliance mandatory through legislation.

The protocol (Zuraimi et al., 2012) includes tests for: 1) assessing DC performance via surface contaminant evaluation; and 2) assessing harmful airborne pollutant emissions associated with DC. For protocol test evaluation, a building in Ottawa, Ontario was selected. The new protocol was tested for surface cleanliness assessment using a combination of visual inspection and a vacuum test method. Using these approaches, the protocol ensures objectivity of surface cleanliness evaluation, thereby improving current industry practice to ascertain surface cleanliness performance of DC. The test evaluation also demonstrates that it is possible to determine harmful airborne pollutant concentrations attributed to DC activities while still maintaining industrial performance standards of surface cleanliness. Currently, no protocol exists that objectively evaluates indoor concentrations of airborne biocides and particles attributed to DC activities. By determining indoor concentrations of these harmful pollutants, this new protocol addresses a very important gap, and mitigates potential health problems associated with their exposures. In summary, the new protocol provides a significant improvement for testing the impact of HVAC cleaning and restoration on IAQ in commercial office buildings.

Keywords: Duct cleaning; test protocol; HVAC cleaning and restoration; emissions; biocides; particles; surface assessments.

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1 INTRODUCTION

1.1 Background

An important subtask of the NRC Institute for Research in Construction's (NRC-IRC) Indoor Air Research and Development Initiative, part of the Federal Government's Clean Air Agenda, involves the development of detailed protocols for assessing technologies/services that claim to enhance IAQ. The objective of this subtask is to develop means for evaluating the true effectiveness of three of the most relevant air quality solutions and technologies currently used in IAQ management. These include portable air cleaners (PACs), duct cleaning (DC) and heat recovery ventilators (HRV). This report provides the test evaluation results of the new protocol dealing with DC, specifically, testing its effectiveness and impact on airborne particles, mold and biocide levels in commercial office buildings.

Development of the protocol began with a literature search to uncover existing standards that could be applied to DC, identifying knowledge gaps in the existing standards. A stakeholder workshop was held in December 2009 to discuss on priorities of areas for protocol development. Under the advice and guidance of the TAC, a new protocol was prepared.

Currently there is no test protocol that assesses in a standardized manner, the airborne concentrations of harmful pollutants associated with DC activities (Zuraimi, 2010). While airborne concentration measurements in indoor environments where DC activities are performed can provide partially useful information, factors such as ventilation rates, indoor source and outdoor contributions can confound the results. For example, airborne particles and molds attributed to DC activities may be derived from outdoor sources (Wallace, 1996; Baxter et al., 2008). The new protocol addresses this problem by establishing a consistent ventilation routine under pre- and post- DC periods to assess reduction or increase in airborne pollutants concentrations in a standardized manner.

The new test protocol is the first standardized method to address biocide use for DC and assess its concentrations in indoor air. Firstly, it requires DC service providers to provide explicit declaration of permissible biocide use for HVAC systems. Secondly, it provides a standardized method of determining concentrations of a comprehensive list of airborne biocides that are traditionally used in the industry.

While industry practice recommends visual inspection as a means of ascertaining surface dust cleanliness (NADCA, 2006), this approach is subjective in nature. The new protocol establishes a combination of visual inspection and vacuum test methods to ensure objectivity of surface cleanliness evaluation where possible.

The overall objective of this report is the application of the new protocol in actual commercial office buildings. The testing includes assessing DC performance via surface cleanliness evaluation and assessing airborne pollutant concentrations attributed to DC activities. The intent of the protocol is to protect building occupants from harmful airborne pollutants concentrations while at the same time maintaining, if not improving, surface cleanliness of HVAC systems as mandated by current industrial practices.

2 MATERIALS AND METHODS

2.1 Background

To limit duplication, this report will not discuss the step-by-step procedures that are detailed in the test protocol (Zuraimi et al., 2012). This report discusses the specific equipment and processes used in the test building to validate the test protocol.

2.1.1 Test Building and Measurement Floor

The building used for the application of the protocol was a three storey office building located in Saint-jean-sur-richelieu. Measurement was conducted on the second floor of the building. The floor is served by a dedicated HVAC employing a constant air volume (CAV) system supplying treated air via galvanized steel ducts which is internally insulated with a porous acoustic material. The indoor space has an area of slightly less than 1000m^2 with a height of 2.4 m. Pre- and post-DC ventilation routine was maintained throughout the evaluation.

There were about 20 occupants on the measurement floor. The space usage involved primarily clerical work. An indoor air sampling location was identified in an unoccupied office of the measurement floor while an outdoor sampling location was located outside the building at the nearest accessible point to the fresh air (outdoor) air intake. There were no cleaning activities on the measurement floor during the evaluation.

2.1.2 HVAC Cleaning and Restoration

The DC was conducted by one of the largest duct cleaning companies based in Montreal. The reason for DC in the building was normal cleaning maintenance service. DC was conducted by 2 personnel using brush cleaning and vacuum exhaust. The DC was conducted at night when the building was unoccupied. The company declared no use of biocide as part of their DC activities. Pre- and post-DC evaluations were performed on the 16th of February, 2011 and the 09th of March, 2011.

2.2 Surface Cleanliness

2.2.1 Visual Inspection

Since the duct surfaces were internally lined with a porous acoustic material, the NADCA vacuum test was not performed. Only visual inspections were made before and after DC assisted by the use of a digital camera. The interior surface is noted for its visible cleanliness and whether it is free from non-adhered substances/debris. Pre- and post-DC visual inspections were performed with the HVAC system turned off. Visual inspections were conducted in the supply air, return and fresh air ductworks.

2.3 Airborne Concentrations

2.3.1 Biocide Measurements

Although no biocides were used for the DC, the research team performed random measurements of selected biocides which include glutaraldehyde and ozone.

Glutaraldehyde samples were derivatized using cartridges filled with silica impregnated with an acidified solution of 2,4-dinitrophenylhydrazine (2,4-DNPH) (Waters, Sep-Pak Aldehyde Sampler). Samples were obtained in the indoor location at a height of 1.1 m and outdoor location. DNPH cartridges sampling was conducted using mass flow controlled sampling pumps at 200 mL/min with sampling time set at 30 minutes. A laboratory blank was employed for the indoor and outdoor samples. The amount of glutaraldehyde measured in the samples was corrected for possible contamination by subtracting the mean amount found in blanks.

Analysis of glutaraldehyde was performed according to NIOSH 2532 (NIOSH, 1994a). The derivatized form of the sampled glutaraldehyde in the cartridges was first extracted using acetonitrile under gravity feed into volumetric flasks. The samples were transferred to vials and then

analyzed by reverse phase high performance liquid chromatography (HPLC) with a UV-VIS detector at a wavelength of 360 nm (Varian Model 9012 Solvent Delivery System/9050 Variable Wavelength UV-VIS Detector/Prostar 410 Autosampler). Twenty microliters of the analyte was injected onto two Supelcosil LC-18 columns (length 250 mm, inner diameter 4.6 mm; particle size 5 µm) in series, which was maintained at 30 °C. A gradient of acetonitrile in water from 60% to 100% was used. System calibration was performed using a seven point calibration.

Ozone concentrations at one indoor and one outdoor locations were measured every minute using two calibrated UV absorbance ozone analyzers (2B Technologies model 202). Simultaneous sampling was conducted from 8 am to 4 pm. Outdoor sampling of ozone was conducted via a Teflon tube attached to the analyzer stored in thermal box maintained at 23^{o} C.

2.3.2 Total Airborne Particles

Prior to sampling, gravimetric analysis was performed on filter cassettes containing filter media (37mm PVC; 0.8 microns pore size). Filter cassettes containing filter media were equilibrated in a controlled environmental room for at least 2 hours. Using a microbalance (Mettler-Toledo XP-56) of 0.001mg sensitivity and equipped with an anti-static source, at least three measurements of each filter weight were made.

Simultaneous sampling of total airborne particle was conducted in one indoor and one outdoor location from 8 am to 4 pm using calibrated diaphragm pumps set at an air flow rate of 1 L min^{-1} (NIOSH, 1994b). The total air flow volume through each filter cassette was 480 L. A field blank was also collected for each of the indoor and outdoor samples.

The filter cassettes were then labeled and transported back to the laboratory for post sampling gravimetric analysis. Post sampling gravimetric analysis was similar to prior sampling gravimetric analysis. The filter weight was then recorded and the blank corrected particle levels measured. Concentrations of total airborne particles were determined by dividing the blank corrected particle weight with the volume of air that passed through the filter cassette.

2.3.3 Total Airborne Mold Counts

Two Zefon Air-O-Cell cassettes (slit samplers) attached to calibrated pumps at a flow rate of 15 L/min were used to sample indoor and outdoor mold simultaneously (Zefon, 2004). Sampling was conducted at

10 am for 10 minutes giving a total sample volume of 150 L. The air flow rates through the Air-O-Cell cassettes were verified prior to each sampling. A field blank was employed for the indoor and outdoor samples each.

After sampling, the cassettes were brought back to the laboratory for mold spore counting. The collection slide was placed sample side up onto a clean microscope slide and each spore encountered was enumerated using a Zeiss AX10 microscope. After their total counts were evaluated, the total mold concentration accounting for blanks was then determined in spores/m^3.

3 RESULTS AND DISCUSSION

3.1 Surface Cleanliness Assessment

Figure 1 illustrates the main supply air duct of the test building. It can be observed that based on visual inspection techniques, the surface cleanliness improved slightly after DC. The surface was free from non-adhered substances and debris. Therefore, the surface cleanliness criterion of the protocol was fulfilled.

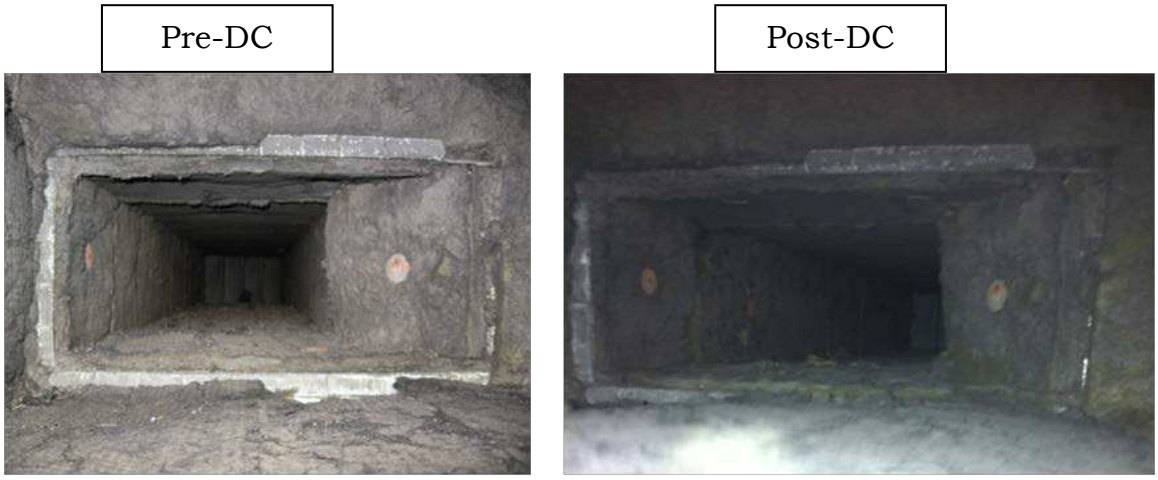

Figure 1 Visual inspection of supply air duct cleanliness pre-& post DC.

3.2 Airborne Biocide

3.2.1 Glutaraldehyde

Typically, glutaraldehyde should not be present in the indoor air of commercial office buildings. Glutaraldehyde was not detected in the

sample runs for pre- and post-DC measurements. Figure 2 illustrates a typical chromatogram for calibration, post-DC indoor and outdoor sample runs. Although glutaraldehyde was noted in the calibration runs, it was not detected in the indoor and outdoor samples. Thus, the DC did not contribute to any glutaraldehyde emissions in the test building.

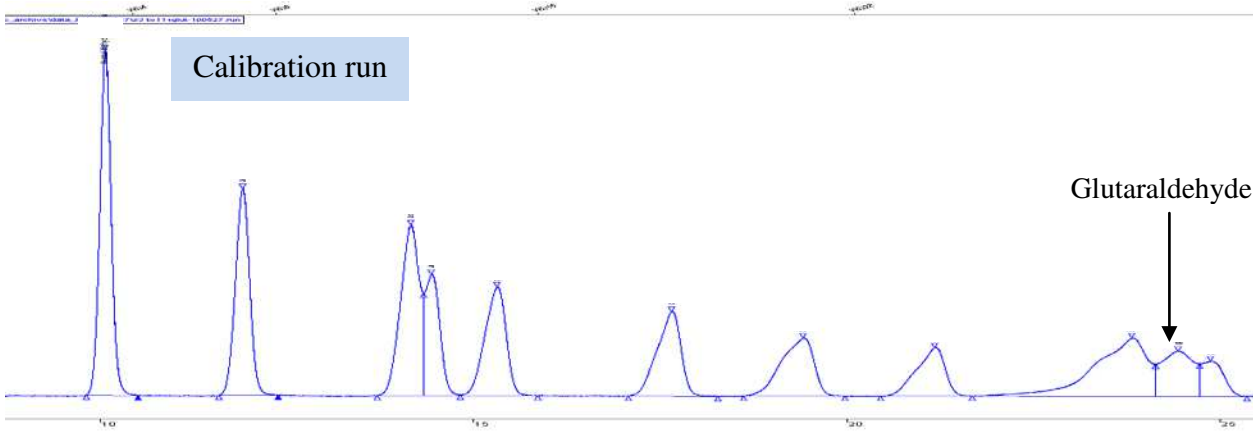

Figure 2 Calibration, post-DC indoor and outdoor chromatograms for glutaraldehyde HPLC runs

3.2.2 Ozone

In the absence of an indoor source, ozone concentrations outdoors would typically be higher compared to indoors (Weschler et al, 1996; Weschler, 2000). Indeed, this was observed in the ozone concentrations measured indoors and outdoors of the test buildings during pre- and post-DC periods (Figure 3). Indoor and outdoor concentrations measured were lower for post – DC (Indoor: 26.1 vs 14.7 μg/m^3; Outdoor: 59.1 vs 77 μg/m^3). These levels were comparable to those reported in a review study on ozone exposures (Weschler, 2000). Post DC indoor ozone concentration was lower than the threshold guideline of 0.05 ppm (40 μg/m^3) set in the protocol. Furthermore, indoor-outdoor ozone concentration ratio (I/O) was lower for post-DC period. Therefore, there was no ozone formation effect attributed to the DC in this building.

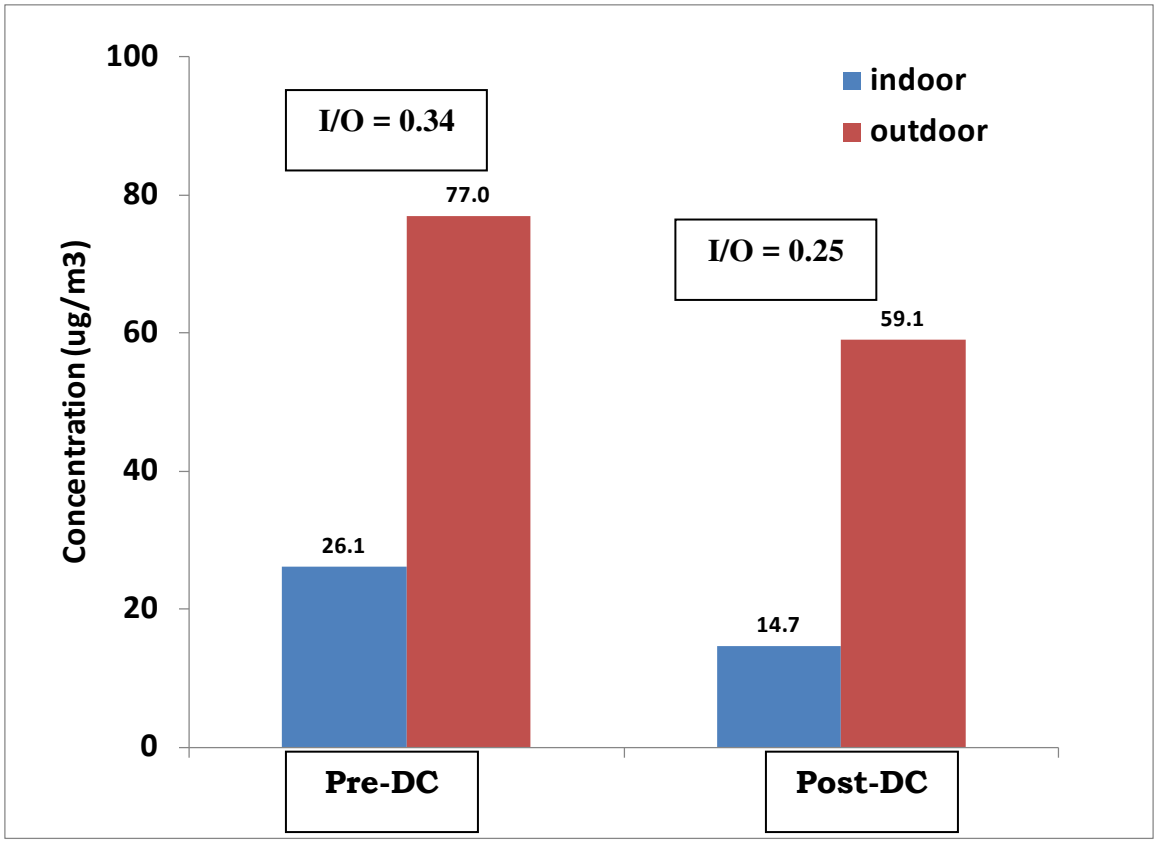

Figure 3 Indoor and outdoor ozone concentrations measured during pre- and post-DC periods.

3.3 Airborne Particles

3.3.1 Total Airborne Particles

In the absence of an indoor source, total airborne particle concentrations outdoors are typically higher than indoors (Wallace, 1996). Total airborne particle concentrations measured indoors and outdoors during pre-and post-DC periods are illustrated in Figure 4. Although indoor concentration of total airborne particles was marginally higher for post – DC (Indoor: 10.2 vs 12.4 μg/m^3). However, this could be due to the elevated outdoor concentrations measured during the post-DC period (103 μg/m^3). Post-DC indoor total airborne particle concentration was lower than the threshold guideline of 1000 μg/m^3 set in the protocol. Furthermore, indoor-outdoor total airborne particle concentration ratio (I/O) was lower for post-DC period. Thus, it was determined that there was no total airborne particle formation effect attributed to the DC in this building.

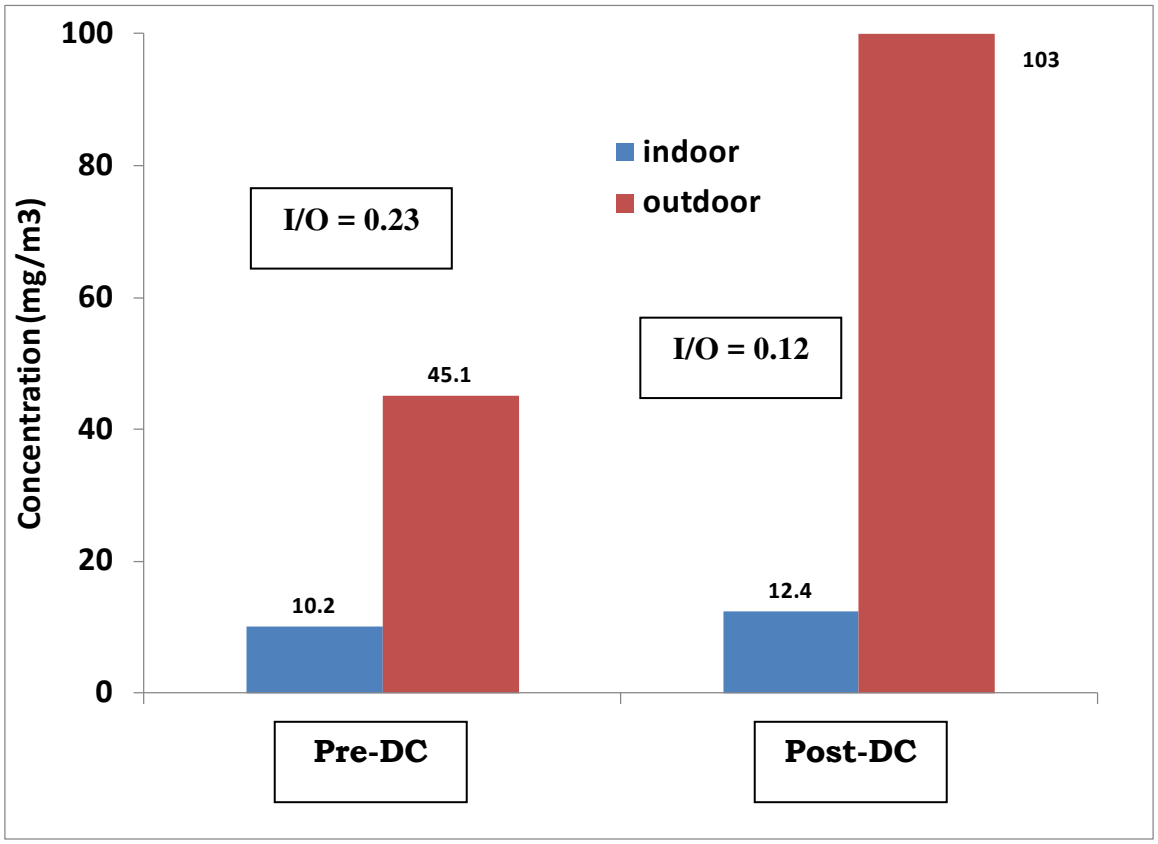

Figure 4 Indoor and outdoor concentrations of total airborne particle measured during pre- and post-DC periods.

3.3.2 Total Airborne Mold

In the absence of an indoor source, total airborne mold concentrations indoors are typically lower than outdoors (Baxter et al., 2008). Total airborne mold concentrations measured indoors and outdoors during pre- and post-DC periods are illustrated in Figure 5. The indoor levels are typical of a "normal" office environment (Baxter et al., 2008). Indoor concentration of total airborne particles was higher under post – DC period (Indoor: 3379 vs 1165 spores/m^3). However, this could be due to the elevated outdoor concentrations measured under the post-DC period (8755 spores/m^3). In addition, indoor-outdoor total airborne mold concentration ratio (I/O) was not higher for post-DC period. Thus, there was no total airborne mold formation effect attributed to the DC in this building.

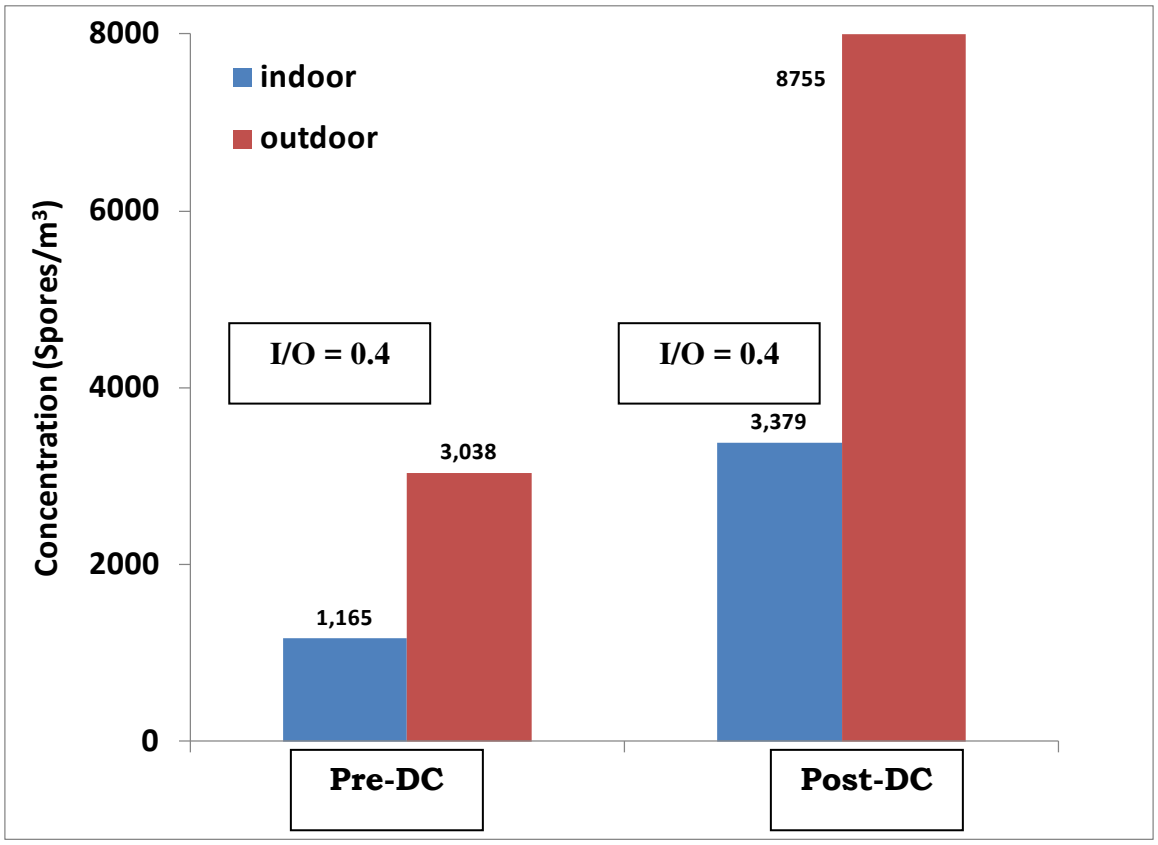

Figure 5 Indoor and outdoor concentrations of total airborne mold measured during pre- and post-DC periods.

4 CONCLUDING REMARKS

The protocol for determining effectiveness of DC and its impact on airborne particle, mold and biocides in commercial building was successfully tested in a commercial office building in Saint-jean-sur-richelieu, Quebec. Surface cleanliness assessments and airborne concentrations attributed to DC activities such as biocides and particles were evaluated. Specifically for this test building, the protocol has found satisfactory DC performance in terms of surface cleanliness assessments via visual methods. In regards to airborne particles and mold concentrations, elevated post-DC concentrations were observed indoors. However, this is due to environmental factors exterior to the buildings and cannot be attributed to DC activities. Indeed, their indoor to outdoor concentration ratios did not increase after DC suggesting no emissions for airborne particles and mold attributed to the DC activities. There were no glutaraldehyde and ozone emissions attributed to possible use of biocides.

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