Real-time Monitoring of Biological Airborne Particles in a Hospital Environment (ReM-BAPHE)

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Introduction

- Many studies have been conducted to examine the potential health effects of pollen, fungal spores and bacterial spores. The reason for this interest is because their biochemical compositions can promote allergic reactions and their small sizes allow them to enter our respiratory tracts.
- Indoor residential and occupational environments have been linked with a wide range of adverse health effects including contagious infectious diseases, allergies and cancer.
- However, conventional impaction/impingement sampling methods for counting and identifying airborne bacteria and fungi in hospitals are limited in the time interval that can be sampled (minutes to hours).
- Furthermore, these "snapshot" techniques restrict the types of organisms that can be detected and only allow retrospective analysis (days). This shortcoming limits their utility to quantify the role of airborne transmission in healthcare infection.
- Direct, continuous (real-time) bioaerosol sampling is being used increasingly to profile outdoor air. This approach combines laser scattering from individual particles to give information on size and shape. Fluorescence detection from bioaerosol components such as amino acids and NAD(P)H is then used to distinguish them from chemical dust and to provide clues to their actual identities.
- The Waveband Integrated Bioaerosol Sensor (WIBS) is a compact portable instrument with real-time detection capabilities and has been used recently to detect airborne pollen grains and fungal spores in a variety of outdoor environments.
- The aim of this campaign is to use WIBS instrumentation as a real-time, continuous monitor for airborne biological particles in a variety of hospital settings so as to characterise the small particle types present, to monitor changes over time and objectively evaluate potential empirical interventions to increase air quality.

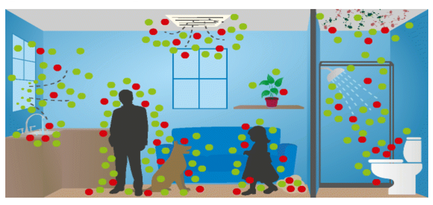
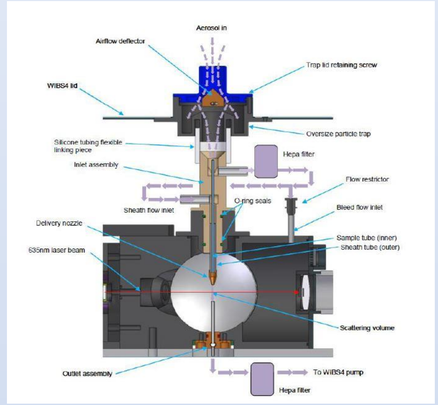
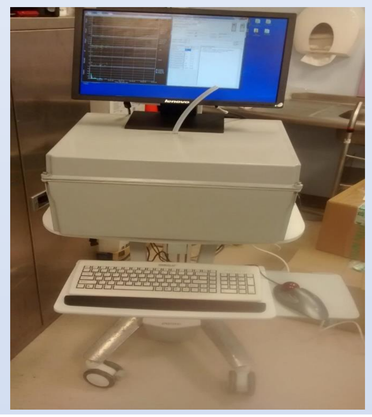


Fig 1.1 Sources of airborne microorganisms in a built environment

Methods

- The WIBS is a single aerosol particle fluorescence monitor that uses the ultraviolet light-induced fluorescence (UV-LIF) approach to detect fluorescent aerosol particles (FAP). This approach discriminates between most non-biological aerosols from biological aerosol particles.
- The method is based on identifying fluorescence signals from common amino acids like tryptophan, phenylalanine, tyrosine and the coenzyme nicotinamide adenine dinucleotide (NADH). These natural chromophores are universal markers for biological materials because these amino acids are present to some degree in all proteins.
- Counting ~2 × 10^4 particles per litre, the WIBS-4+ combines a continuous-wave diode laser at 635 nm for initial particle detection, a forward light-scattering quadrant photomultiplier for particle size and asymmetry factor ("shape") determination and two filtered xenon lamps that deliver two sequential ultraviolet pulses targeted at 280 nm (Xe1) and 37 0nm (Xe2) to investigate the fluorescence properties of incoming particles.
- Fluorescence emission is detected in three bands 310-400 nm (Band I), 420-650 nm (Band II) and 600-750 nm (Band III) delivering five fluorescence measurements for each individual particle.
- An Axiomatic Irisys Gazelle Thermal people counter was used simultaneously with the WIBS instrument. The people counter uses thermal detection to count numbers passing. It utilizes a downward facing configuration and functions by detecting heat emitted from people passing underneath. This creates a non-identifiable infra-red image which is recorded.
- The WIBS and people counter were remotely monitored over the internet using TeamViewer software *i.e.* no need for any ward-based supervision. (Generally the screen is not placed on top of the protective box, as shown below.)





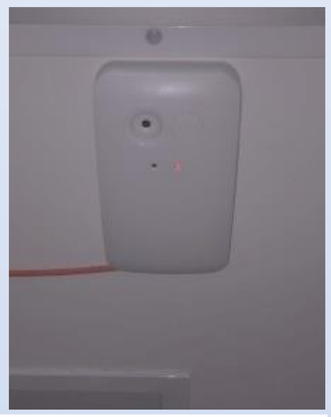


Fig 1.2 (Left) WIBS 4+ Aerosol Flow; (Middle Left) WIBS 4+ ; (Middle Right) WIBS-4+ in protective soundproof box for ward use; (Right) People counter positioned on ward ceiling.

Results, Discussion & Conclusion

- Results were obtained over a week-long campaign between 5th and 11th of January 2017 in a 6-bedded bay on Respiratory Ward 5B at Cork University Hospital.
- All data were recorded by the WIBS-4+ and analysed using Matlab, Igor and Excel software.
- Ward 5B has a constant HEPA filtered HVAC system. It is a heat recovery system in which air is extracted from the room and fresh air is then provided via the HEPA filter. It has an air change rate of 10 per hour.

- In Figure 2.1 peaks and troughs in the captured data show a 20-fold increase on an hour to hour basis. These periodic trends with regard to high particle concentrations are clearly observed. Interestingly, these periods are coincident with high levels of human traffic. Figure 2.3 shows such data extracted from the people counter.
- Observations from Figure 2.1 and Figure 2.3 are supplemented by a diurnal plot (Figure 2.2). Here the peaks and troughs of the periodization trend are smoothed into four and half peaks, most of which correspond to footfall. Very low counts are collected at night. Three of these major peaks correspond to > 1 × 10^9 m^3 fluorescent particles and all diurnal peaks represent at least 70-fold more particles than the night-time minima.
- The WIBS-4+ can discriminate between the FAP by size and shape as indicated in Figure 2.4. Histogram analysis shows that during periods in which high fluorescent particle counts are obtained the particles are both small (< 2μm) and spherical (< 15, asymmetry factor). These potentially correspond to coccoid bacteria or bacterial or fungal spores.
- The main advantage of the WIBS instrument is its real-time analysis capability. This feature is shown in Figure 2.5 with a plot of fluorescent particle size, analysed at one minute intervals over a three-hour period.

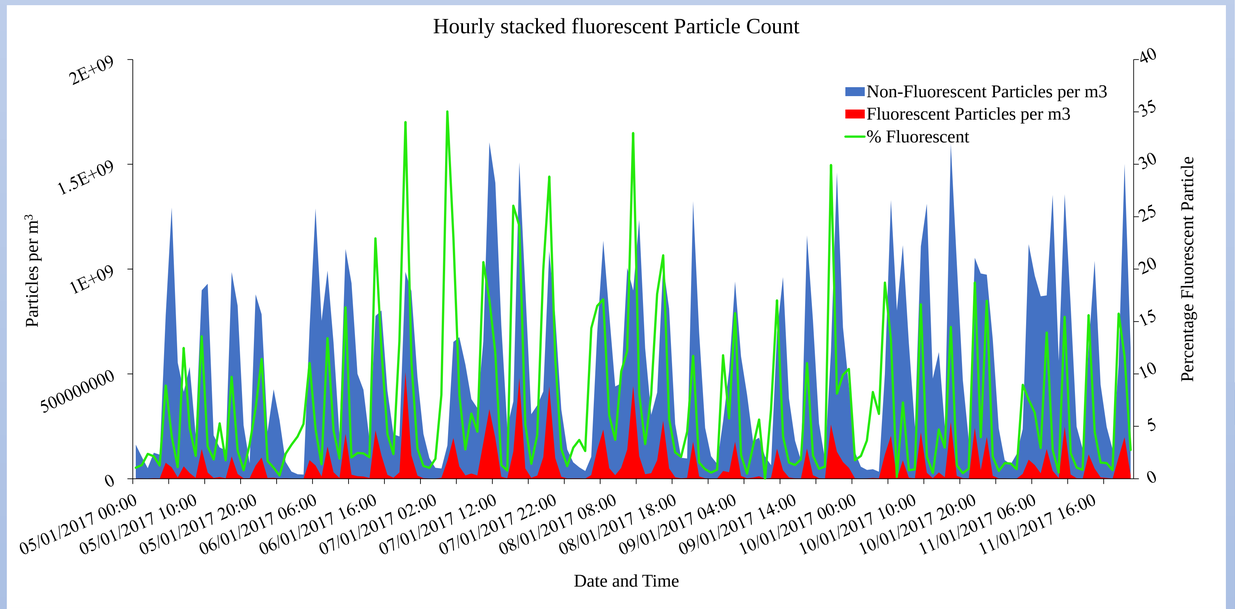


Fig 2.1 Hourly stacked time-series of total (blue) and fluorescent (red) particles counted throughout the campaign period. Percentage fluorescent particle count (black line), illustrating the hourly fluorescent particle concentration percentage for Ward 5B, January 5th to January 12th, 2017,

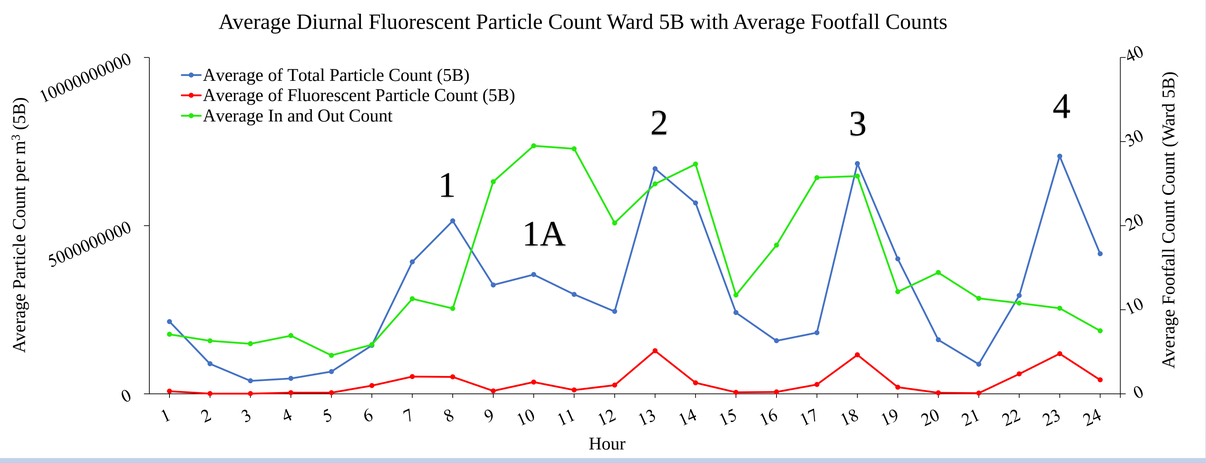


Fig 2.2 Average Diurnal Fluorescent Particle Count Ward 5B with Average Footfall Counts.

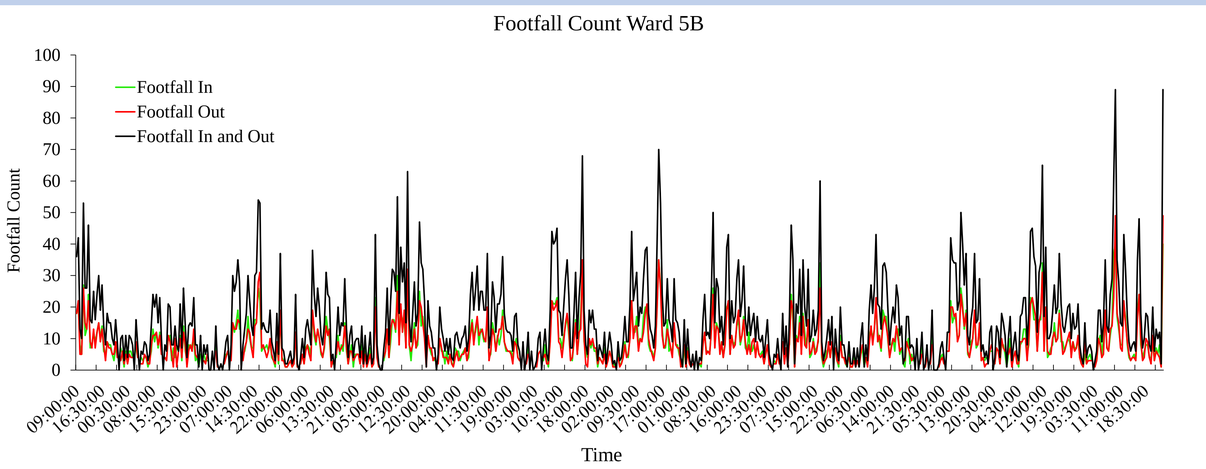


Fig 2.3 Time series of the week period with the colour key within indicating the Footfall in, out or total.

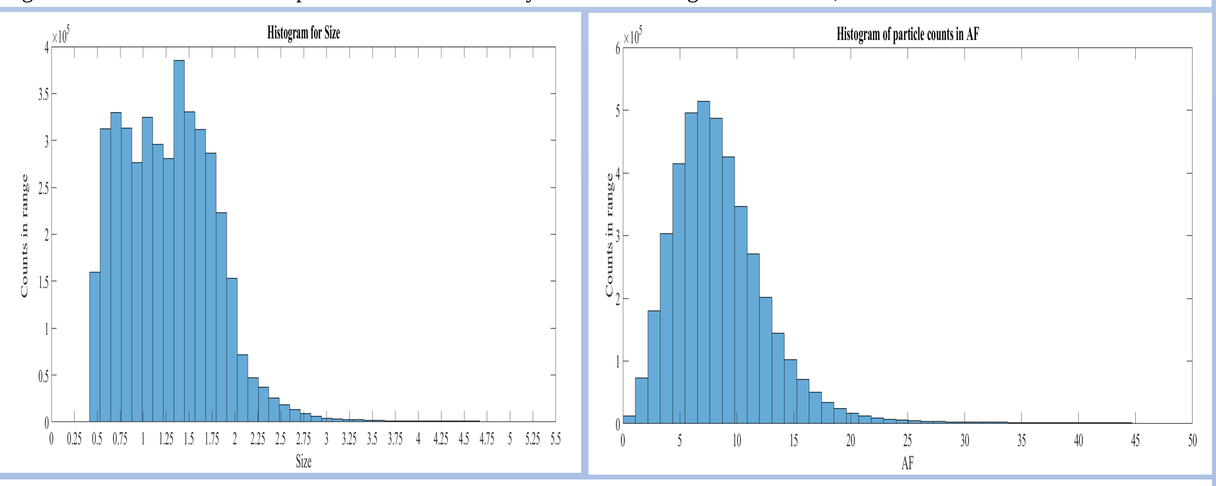


Fig 2.4 Histogram of fluorescent particles indicating the size and asymmetry factor ranges of the particles.

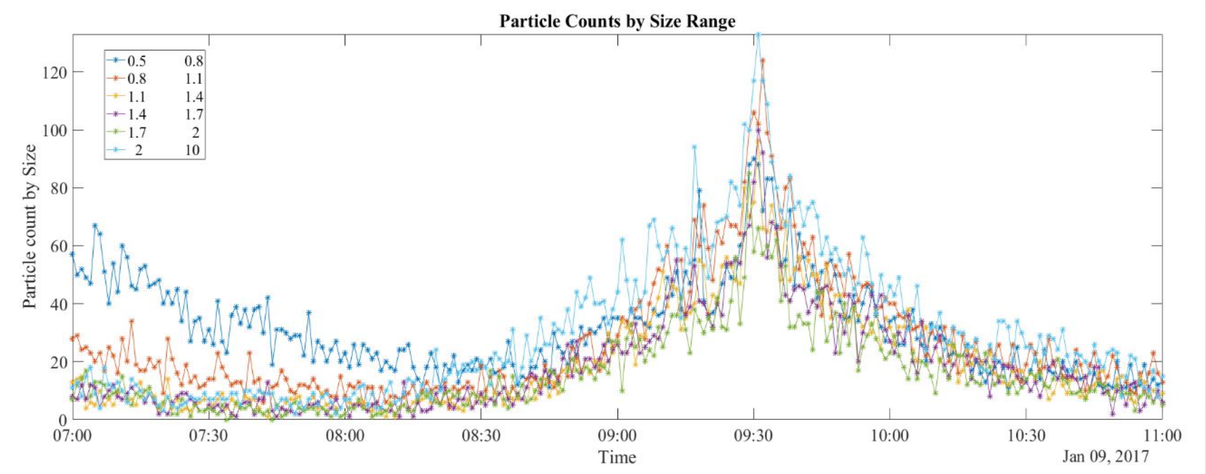


Fig 2.5 Time series of 07:00 – 11:00 January 9th period with the colour key within indicating the size ranges of the particles

References

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Future Work

- To measure air quality in different hospital settings and to compare results with the effect of different interventions to reduce airborne biological/fluorescent particles. Culture-based air counts and metagenomic analyses will be compared with the WIBS results.
- To assess the application of real-time data biological particle analysis as a method for: (i) setting objective, standard levels for hospital air quality; (ii) providing early warning of deteriorating air quality and increased risk of airborne infection.

Acknowledgements

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