# EXPLORING SPATIAL PLANNING AND FUNCTIONAL PROGRAM IMPACT ON MICROBIAL DIVERSITY AND DISTRIBUTION IN TWO SOUTH AFRICAN HOSPITAL MICROBIOMES

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## SUMMARY

This paper presents a theoretical and experimental research approach on the impact of spatial planning and functional program on the microbial load, distribution and organism diversity in hospital environments. The investigation aims to identify design markers and define potential risk environments in design and planning of buildings to facilitate appropriate design and administrative interventions. The investigation studies two hospitals in the Western Cape (WC) South Africa (SA), born from the same design brief but with varied typologies and building systems. The study period considers two seasons, and will start in 2015 with four sampling days per season. A three tier experimental methodology is followed: 1) microbial sampling using air samplers, fluorescent particle counter (FPC), and settling plates. Analysis will be done by total count and molecular deoxyribonucleic acid (DNA) techniques, polymerase chain reaction (PCR) and pyrosequencing 2) observational analysis, using space syntactical methods; and 3) static environmental monitoring using data loggers and weather stations. Ethical approval is under way and the initial results are planned for publication in late 2015. The study anticipates conclusive baseline data towards developing a framework for an architectural design microbial risk model (ADMRM) for hospitals.

## INTRODUCTION

The complexity in planning healthcare facilities coupled with the diversity of user clients, direct health application and varied disease profiles marks hospital environments as ideal baseline investigation environments for microbial data collection. In SA no microbiome data currently exists. This study will become the baseline dataset for future studies. The impact of *Tuberculosis* (TB) is both a global problem and an epidemic in SA. *Mycobacterium tuberculosis* (Mtb), human immunodeficiency virus (HIV) and healthcare associated infection (HAI) are of concern for developing countries and motivates this microbial investigation. The obligate aerobe nature of Mtb transmitted by airborne means places all with an immune deficiency disease i.e. HIV, unsuspected patients, healthcare workers and healthy people at risk of contagion, with the emphasis on immunosuppressed persons. Furthermore, studies seem to indicate that health care facilities are contributing to the spread of Mtb (Eshun-Wilson et al. 2008). In 2008 the World Health Organisation (WHO) ranked South Africa as the worst infected country in the world (per capita) for Mtb. A WHO assessment in 2008 indicated the epidemiological burden of TB and HIV co-infection in SA at an estimated 70%. WHO estimates that in SA, out of every 100 000 people approximately 768 are Mtb positive and 5.5 million people in SA have HIV Aids. These facts point to alarming risk exposure in hospital environments and the raised potential for HAI.

The spread of infectious bacteria, fungi, viruses and single cell organisms (prokaryotic & eukaryotic) specifically in hospitals are widely known to be first by human contamination (Hospodsky et al. 2012) and secondly dependent on environmental conditions (Basu. et al. 2007). This is exacerbated when microbial favourable environmental conditions are provided (Wolfaardt. et al. draft). HAI is prevalent worldwide in health care facilities but current research indicates that we might have overlooked a critical area in the response to non-tuberculosis bacteria (NTB), Mtb and other invasive pathogenic microbes. That is the microbial environment in which bacteria survive, live, are aerosolised and deposited. What benefit is there in studying the biome of an indoor environment? Does the built environment community (BEC) know the health impact of planning and construction decisions on building users? Both these questions are inherently the same. One needs to understand the ecology of the indoor environment to gauge the impact of design decisions. A microbial built environment study not only illuminates the need for microbial environment surveillance as part and parcel of the full building system planning, but also provides the data to create the tools required to facilitate BEC and building user clients in health design solutions.

Our research hypotheses postulate that the microbial load and diversity of the indoor biome bears a strong relationship to the functional use planning and functional program and that potential amplified microbial load and organism diversity can be correlated to occupancy, functional program and the environmental conditions as a direct result of the nominated building system. This study has fourfold objectives: 1) To analytically compare spatial design layouts and facility specific functional clinical program with the microbial load distribution and community diversity using two case study hospital sites; 2) To determine the variation in microbial load of two healthcare environments born of the same design brief but different building typologies and building systems: full mechanical ventilation and hybrid natural ventilation; 3) To identify risk patterns in design planning (identify and establish universal environmental markers) through microbial investigations; and 4) To establish an architectural design assessment protocol to assist in risk assessment of existing and new buildings.

## METHODOLOGIES

The study design investigates two hospital sites in the WC, SA over two seasons (winter and summer) with a sampling period of four days per season. The hospitals were selected based on similar burden of disease and patient load; distinction in building systems and typological responses; but born from a common design brief. The area of investigation is the Accident & Emergency (A&E) department of each facility.

### Microbial Investigation

A pre-experimental sampling run has been developed to gauge efficacy and quantity in sampling intervals. Five zones have been selected to study in each facility ranging from high occupancy spaces to low occupancy clinical spaces. 1) For surface sampling the study will utilise settling plates with universal agar base as guided by standard microbiological methods with an exposure duration estimated at 20 min. 2) For air sampling the study intends to use two standard microbiological techniques, including: A) an Andersen air sampler with a flat membrane filter of 5μm, positioned at a height of 1.1 m and 1.5 m away from solid stationary objects. The samples are to be collected at a flow rate of 28.3 L/min for 20 minutes as described by Chunyang et al. B) using a fluorescent particle counter (FPC) as per standard microbiological techniques (Chunyang et al. 2015). A sampling duration of four days with two samples in each zone daily over two seasons. The total planned settling plates and air samples amount to 320 excluding the FPC.

**Analysis**

Two molecular techniques will be applied using the MXIS BE standard data set. 1) PCR for specific taxa with total DNA gene pool of each sample searching for selected bacteria based on most common United States of America (USA) HAI pathogens, this is done in the absence of an SA standard (Ducel et al. 2002): *Staphylococcus aureus, Pseudomonas aeruginosa,* and airborne pathogens common to South African indoor risk environments: *Pneumocystis carinii pneumonia, Mycobacteria Tuberculosis.* 2) Pyrosequencing of each sample to determine the full community and quantity of organisms. The total planned analysis by PCR: 1280 samples, and by Pyrosequencing: 320samples.

**Observational Investigation**

The observation methodology used in this study is based on University College London (UCL) Architecture Department, Space Syntax software manuals with author variations where required. The Space Syntax observational manual were developed by Tad Grajewski in 1992 and updated by Laura Vaughan in 2001. A two-task process is to be followed by observers over the period of a day for the total study duration (four days, two seasons). A 12-hour period will be observed at each facility following a mapped route of the study sites.

- Task 1: "Mental snap shot" Requires a floor plan at 1:50 scale of the selected department. Following a mapped tour covering all rooms that are frequently used to ensure that all spaces (excluding storage areas) are observed (based on pre observation test and questionnaire). The observation assessment will be conducted hourly, by manually inscription on the 1:50 scale drawings in each space. Information collected include the number of people and user task using a defined coding system.
- Task 2: "Movement tracer" This technique will collect precise routes taken by people moving through the same spaces. This assessment enables one to determine space use and flow through the space. Following on task 1, the observer will spend 3-5 min in each of the rooms/spaces marking movements of people entering or exiting the space, then manually record and trace all the movement through the space, and notate exit routes. This exercise will be done twice hourly following the same route plan. The collected data will be analysed through Depth Map (DM) software (Al_Sayed et al. 2014). DM software provides graphical representation and analytical prediction of flow and space use.

**Static Environmental Monitoring**

The study will utilise data loggers and weather stations. 1) Data loggers are preconfigured manufactured units by CO2Meter, Inc. (Ormond Beach, FL, USA, CM0018AA). The unit includes built in sensors collecting $CO_2$, Temperature and relative humidity (RH) data as well as date and time stamp. A pre-sampling study will be undertaken to check feedback and calibrate the logger units. The study site matches the previous two investigations. The study duration will be continuous over the prescribed four days in the two seasons, utilising a total of five loggers matching the 5 identified zones. The loggers are placed either on a surface at counter height (900 mm) or suspended in the air (2100 mm). The data is recorded via secure digital (SD) card that will be disseminated on completion of the investigation using GasLab® software 2) A weather station will be mounted on each hospital building collecting ambient outdoor weather conditions. The unit will measure outdoor temperature, wind direction, wind speed, CO2 and RH.

## RESULTS AND DISCUSSION

By correlating the observational syntactical findings with environmental and microbial data to determine potential microbial spread, which could be linked to risk. This could enable prediction of transmission through flow and user space use modelling. Variation of the floorplan layouts present the variation in the impact of architectural program and user program changes if planning is altered. The results will be used towards developing a theoretical framework of a quantitative model for risk design guidance. This research contributes to known evidence that the indoor biome of an environment does directly relate to its user; but in addition, that dispersal is a direct consequence of functional use and flow patterns in planning. Thereby confirming that spatial configuration does have an impact on disease spread, highlighting the impact of architectural planning on health risk.

## CONCLUSIONS

When considering sustainable design, a microbial architectural built environment study illuminates the need for microbial environment surveillance as part and parcel of the full building system planning. Developing world countries and associated health burdens requires sustainable solutions that are designed into buildings to reduce cost, and promote sustainable infrastructure, while providing equitable safe low risk environments for all patients aimed at mitigating HAI. The potential development of intelligent design review tools in current building information modelling software platforms could inform designers on predicted high risk planning decisions. Furthermore such an application provides guidance as to alterations and recommendations to facility staff in considering risk when planning clinical programs within a given building envelope.

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