Development of Predictive Maintenance Management System for tackling air-borne infection in Healthcare Facilities

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How can the spread of air-borne infection in health care facilities be effectively monitored and managed on a day-to-day basis to reduce fatalities?

Setting the Scene

❑Health Facilities are very complex organisations.

❑Technologically-led.

❑Highly-serviced.

❑24/7 management input to ensure effective functionality.

❑Difficult and costly to manage.

Management

More   **Less**

Type (A) **Effective with greater functionality but often costly**	**Type (D)** **Can be thoughtful and imaginative, but sometimes less user-friendly**

Cost

More Cost

Less Cost

Type (C) **Risky with performance penalties**	**Type (B)** **Effective and can be low impact but often small scale**

Technological Complexity of Buildings based on (Bordas & Leman 2001) model

The spread of infection relies on trio of factors:

- **Source.**
- **Mode(s) of transmission.**
- **Susceptible recipient(s).**

Source

- **A person.**
- **An Object.**
- **Environment.**
- **Substance from which the infectious. agent is transmitted to the host.**

When host- the primary source of cross-infection are factored into any equation the laws which represent logic are constantly being moved and become more difficult to predict and manage.

Mode(s) of transmission

Direct contact leading to cross-infection through

Touch.

Cross-contamination.

Air-borne through mechanical ventilation and air-conditioning systems.

a combination of one or more …

Environmental Factors

- Humidity level (RH).
- Temperature.
- Surface material and texture.
- Availability of nutrients and food particles.

Ventilation and Air-conditioning

"Health care environment is a secondary reservoir for organisms with the potential for infecting patients."

- Environmental conditions can affect the survival and persistence of hazardous micro organism on surfaces or indoor environment.

- **Indoor air quality** (patients spend 90% of their time indoor).

- **Air-tightness** (to comply with Part L of Building Regulations which might compromise environmental qualities) air permeability down to 3m³/h m2 at 50 Pa.

- **Indoor Relative Humidity (RH)** (keeping the relative humidity below 60%).

"Humidity levels are known to influence microbial survival and growth such as mould, mildew and bacteria inside ductwork and ventilation diffusers leading to high concentration of the production of allergens, odours and toxins in the ambient environment."

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Air-borne transmission is more likely to spread via ventilation and air-conditioning systems, internal surfaces of ducts and diffusers as much as cross-contamination via hard surfaces and floors.
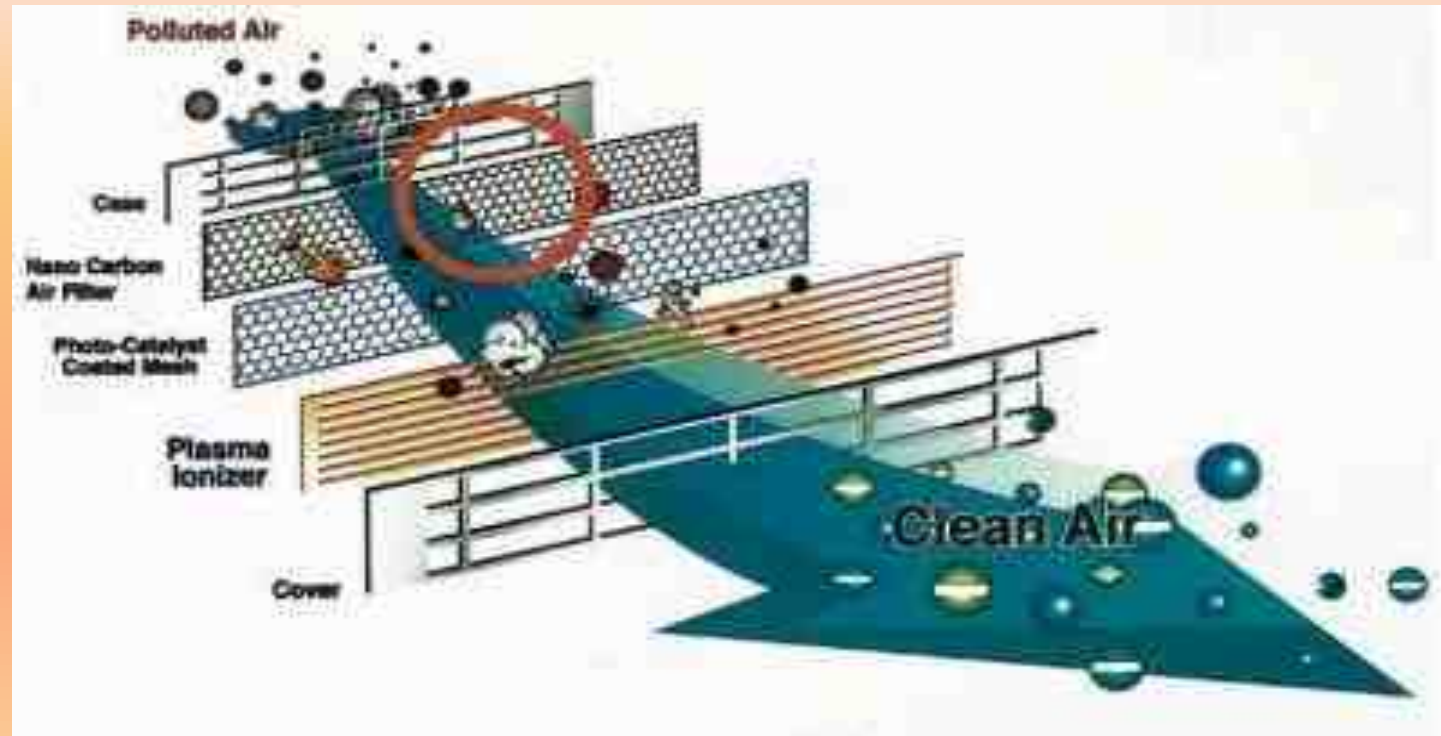
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CONTROLLING THE SPREAD OF INFECTION THROUGH VENTILATION & AC SYSTEMS
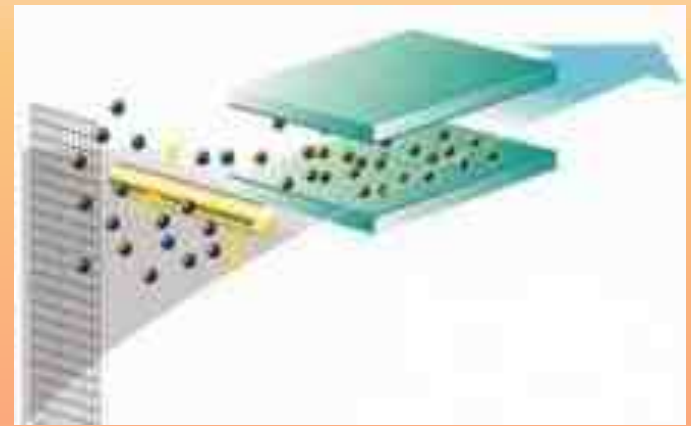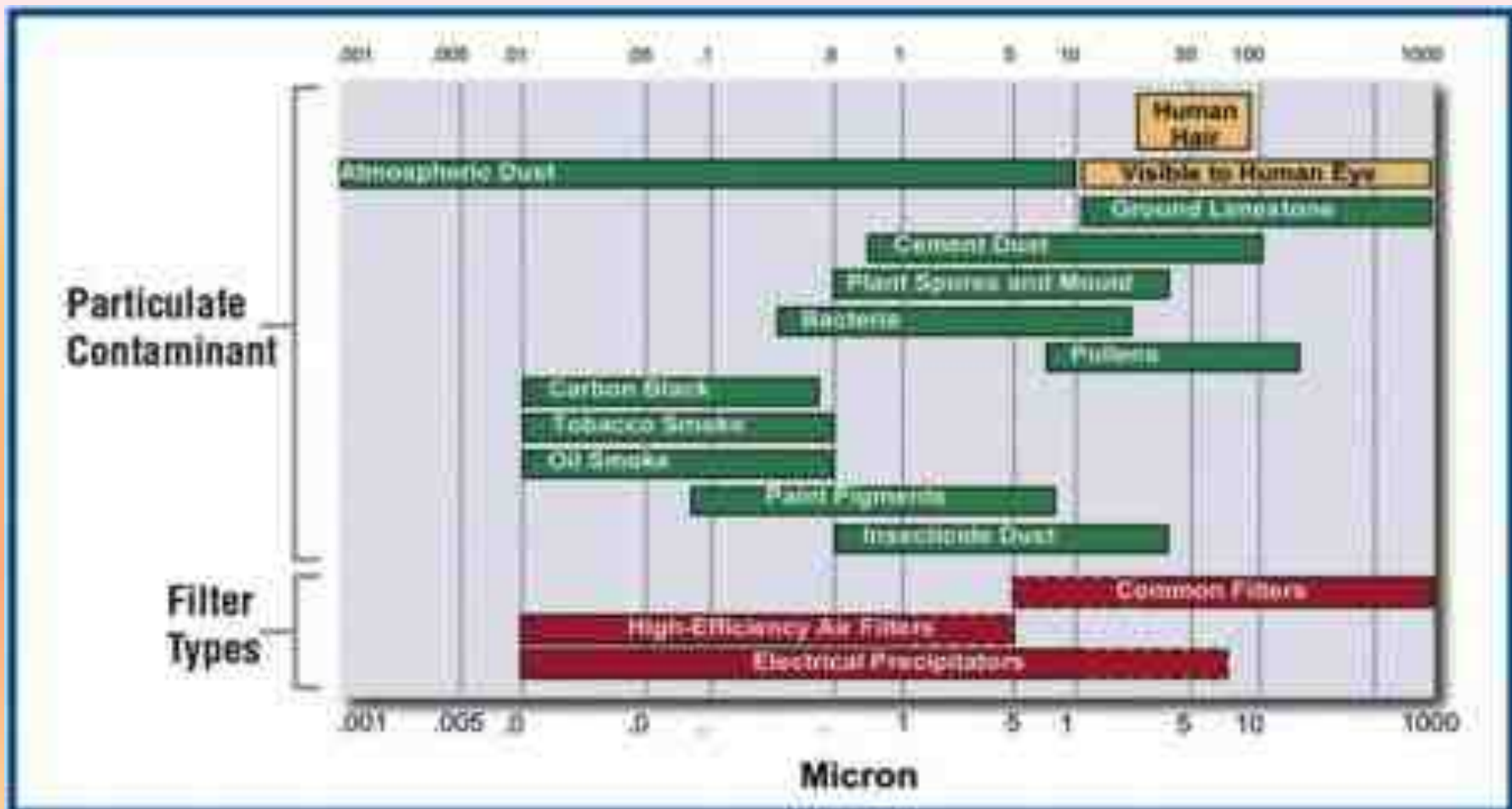
Filtration

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Air Purification

Anti-bacterial filters

A multi-stage filtration air-conditioning system by Toshiba

Filters based on silver nano-particles held in plasma

Ultraviolet catalysis

Under ceiling unit

UVGI Technology

UVG Heating Ventilation Unit

What have we learnt so far?

- Both hard surfaces and ventilation/AC systems might be influential to transmission.

- There seem to be several interrelated factors involved in the spread of air-borne infection.

- Lack of critical evaluation of the spread of air-borne infection

  – **Methods of interventions are quite limited in their scope and are mostly corrective.**
  – Highly fragmented (cleaning vs finishing specifications) .
  – Prescriptive in their scope ignoring the role of human factor in spreading infection- **might simultaneously act as a trigger for spreading the infection**

  Monitoring the efficacy of intervention is no-existent and largely ad hoc.

Aims and Objectives

- **To assess the commercial viability of integrating intelligent predicative management system in monitoring air-borne infection in health care facilities**

- **To develop an early alert system to monitor the spread of air-borne infection in health care facilities incorporating purpose built 3-D building Information modelling software for mechanical ventilation and air-conditioning system.**

- To generate a web-based knowledge management system easily accessible by maintenance and facilities managers (FM) to address infection control in the light of the wealth of knowledge-base generated over the past few years.

Anticipated Benefits and Outcomes?

- To empower NHS decision makers, stakeholders and facilities managers (FMs) in proactively addressing the problem of duct cleaning.

- Better understanding of the mechanism of how air-borne infection is spreading in health care facilities.

- Predicative Infection Criticality Model (PICM) for monitoring and managing the spread of air-borne infection in critical hotspots of mechanical and air-conditioning systems including in particular air-handling units (AHU), supply and return ductwork, T-junctions, connectors, diffusers and fire dampers.

- Robust Infection monitoring management system with the potential of being fully integrated into the building management system (BMS).

	Slightly Harmful	Moderately Harmful	Extremely Harmful
Temperature	<16 c	22-24 c	>24 c
Humidity	<40 %	40-60 %	<60%
Dust Accumulation	<0.05 mm minor accumulation	0.05 – 1.00 mm	>1.00 mm major accumulation
Air Velocity	>20	20-5	<5
Very Unlikely	1	2	3
Unlikely	4	5	6
Likely	7	8	9

Environmental parameters level of risks based on NHS risk model

Failure risk and the strategy for managing the risk is determined using the model developed by NHS Estates. It uses a 3 x 3 matrix to determine the level of risk with regard to failure of items or elements of an installation

Sensor type	Green status	Yellow alert status	Orange alert status	Red alert status	Violet status
	Acceptable risk	Moderate risk	Substantial risk	Intolerable risk	**Extreme risk**
Temperature	<16 c (1)	16-21 c (2)	21-24 c (3)	24-26 c (4)	>26 c (5)
Humidity	<30% (2)	30% -45% (4)	45%-60% (6)	55-60 (8)	>60 (10)
Dust (µm)(applies to extract ducting) **Dust** (µm) (applies to supply ducting)	15-30 <30 (3)	30-60 30-90 (6)	60-90 90-180 (9)	120-150 180-240 (12)	>150 >240 (15)
Air Velocity m/s	>20 (4)	20-15 (8)	15-8 (12)	8-3 (16)	<3 (20)

1-10	**Insignificant**	**Acceptable/Tolerable**
11-15	**Low**	
15-29	**Medium**	**Tolerable**
30-35	**High**	**Unacceptable/Intolerable**
>35	**Critical**	

Traffic Light model based on grand total weighting score o f the risk associated with environmental parameters.

Action Plan

- An intelligent "safety by design" management system for tackling the spread of air-borne infection in health care facilities.

- A real-time predicative intelligent system for managing the spread of air-borne infection in ventilation and air-conditioning systems.

- An integrated web-based knowledge management system to enable maintenance and facilities managers to access the latest state of affair and know-how about the best way for tackling the spread of air-borne infection

Thank You