

Location Dependent Variability of Effective Ventilation Rates Within Hospital Isolation Rooms

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Introduction

- **Nosocomial infection rates have been on the rise**
- **Negative pressure rooms and isolation rooms are used in hospitals to protect patients, staff and visitors from the spread of infectious disease**

Design recommendations

- **Pressure differential > -0.01 in H_2O**
- **ACH > 12 (new and renovation)**
- **Airflow direction**
 - **Into the room**
 - **Clean to dirty airflow in room toward patient**

Quantitative evaluation

- **Containment checks using tracer gas and looking for leaks in adjacent air spaces**
- **In room mixing is complex and poorly understood**
- **Ventilation effectiveness in room is little studied**

Previous research

- **Study of effectiveness of UV for disinfection**
 - **Mean lifetime of particles in room does not reduce in proportion to increasing ventilation rate**
 - **Alani et al 2001**

Previous research

- **CFD studies**
 - Increased ACH useful only to a point
 - Position of inlet and outlets are important
 - 9 ACH optimum
 - 3 outlets
 - 8 ACH supplied (1 ACH infiltrate)
 - Huang and Tsao, 2005

Research questions

- **How much does air mixing (ACH) vary within in negative pressure rooms?**
- **Can simple room geometry characteristics account for air the air mixing variability that exists?**

Hypothesis

- **ACH at different locations in negative pressure rooms will not vary more than 30% from the mechanical ventilation rate.**

Hypothesis

- **Effective ACH at different locations in negative pressure rooms will be greater the closer the location is to a line drawn from the inlet to the outlet.**

Materials

- **9 negative pressure rooms**
 - Data collection is on-going
- **Aerosol generator**
 - Virtis SG-80
- **Particle counter**
 - MetOne Model 237
- **Balometer**
- **Hot wire anemometer**

Methods

- **Room geometry measured**
- **Mechanical ventilation measured**
- **At each of 9 locations in room**
 - Fan used to induce good mixing
 - Aerosol released
 - Fan turned off
 - Concentration decay of 1.0 μm aerosol measured

Example sample plan

Sampling Layout



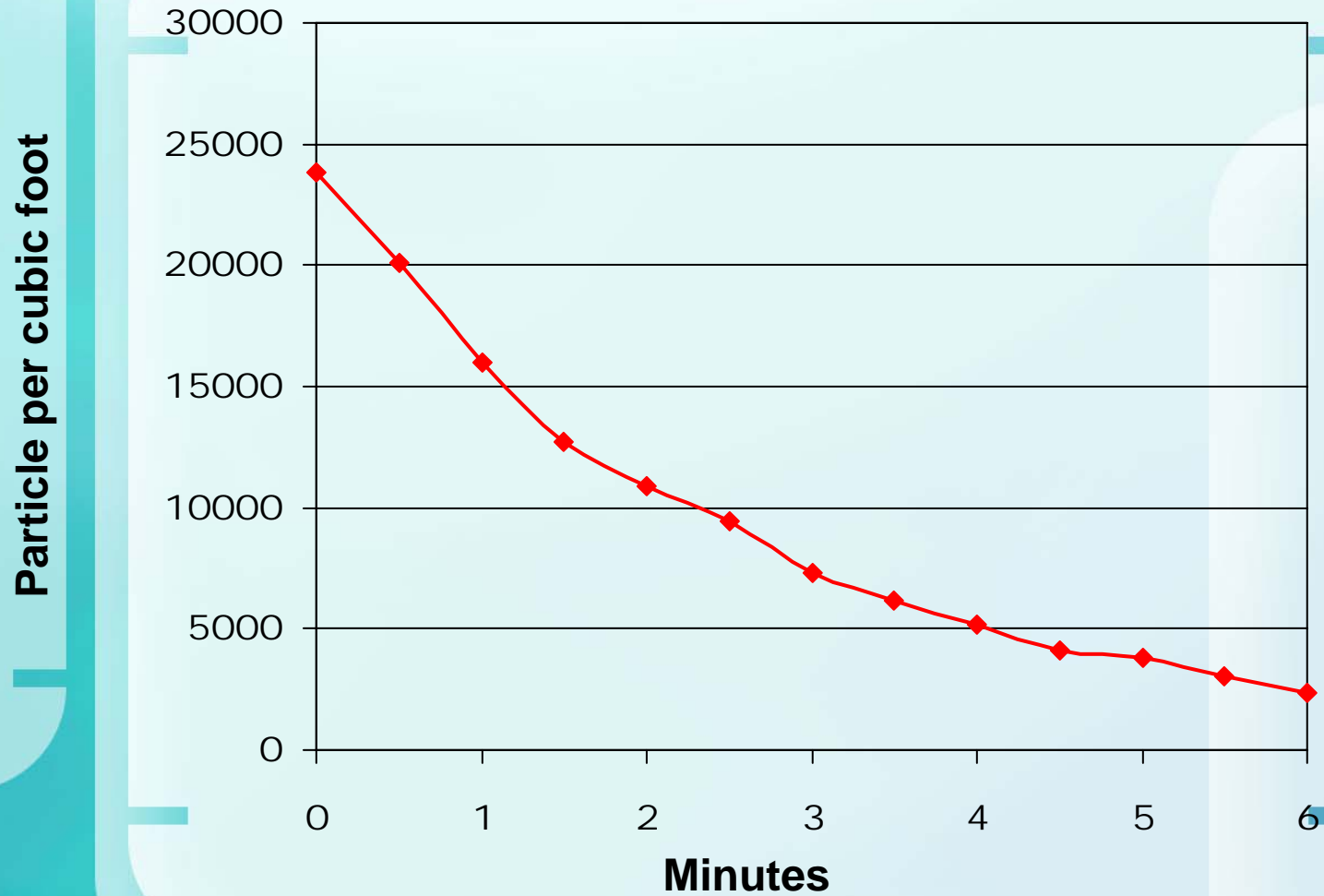
Methods

- **Aerosol concentration decay and room geometry used to determine ACH_{Local} and Q_{Local}**
- **In a well mixed room**

$$C_t = C_0 \cdot e^{\frac{-Q}{V} \cdot t}$$

- **For a location in an incompletely mixed rooms this represents the decay given the effective ventilation rate at that point**

Example decay - Ped Exam 5 location #2



Methods

- **The decay equation can be linearized**

$$C_t = C_0 \cdot e^{\frac{-Q}{V} \cdot t}$$

$$\frac{C_t}{C_0} = e^{\frac{-Q}{V} \cdot t}$$

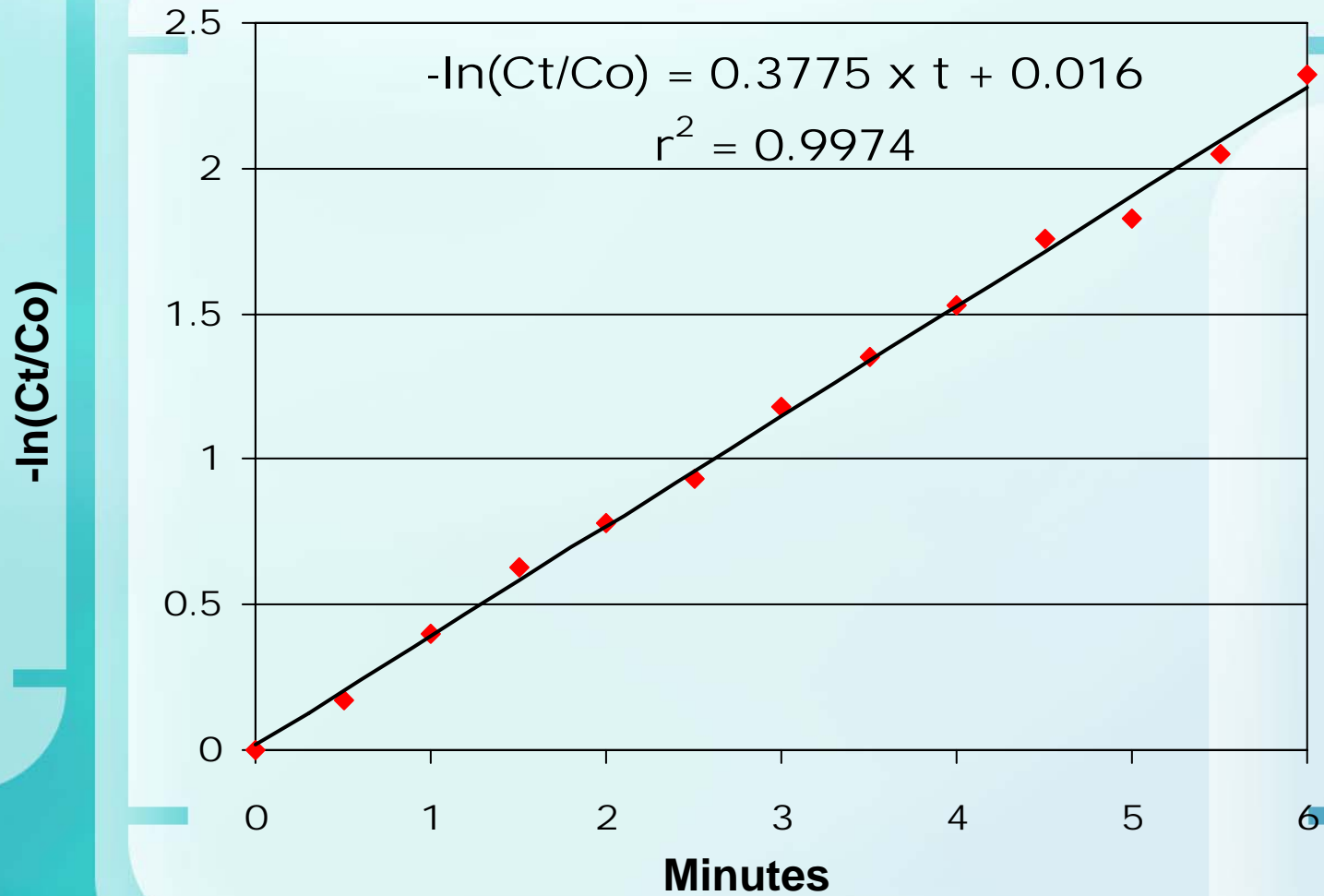
$$-\ln\left(\frac{C_t}{C_0}\right) = \frac{Q}{V} \cdot t$$

Methods

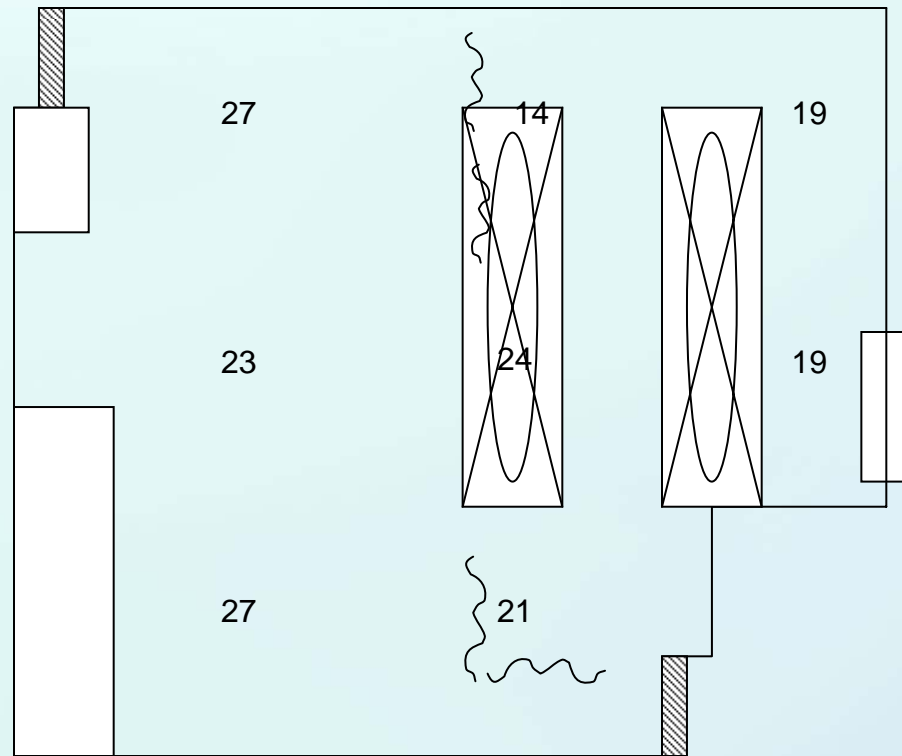
$$-\ln\left(\frac{C_t}{C_0}\right) = \frac{Q}{V} \cdot t$$

- **This in the form of a linear equation**
 - **LHS: dependent variable**
 - **t: independent variable**
 - **Q/V: slope of the line**

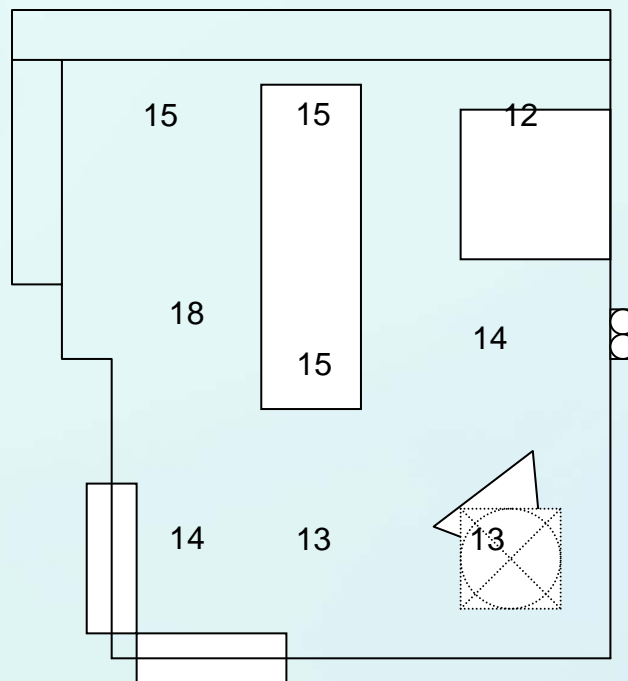
Local air change rate - Ped Exam 5 location #2



Example results: EC PED 9-10



Example results: 586-16



Example results: MICU 1-2



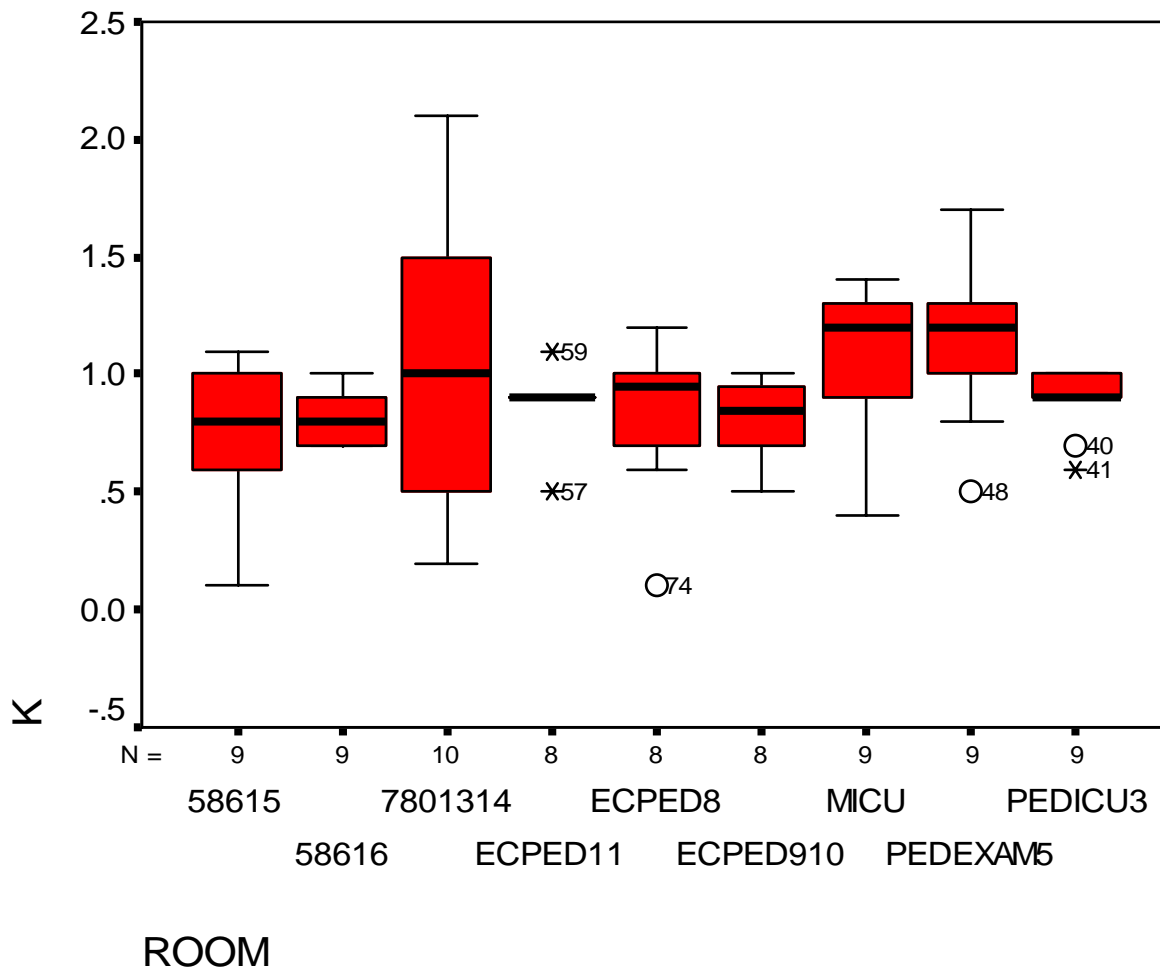
Results

Room	Mech ACH	Avg of locations	s	min	max
MICU	7.3	7.5	2.5	2.6	10
780-13	7.4	7.6	4.9	1.0	16
586-16	18	14	1.7	12	18
ECPED9	26	22	4.4	14	27
PEDICU	22	19	3.3	12	21
PEDEX5	14	15	4.5	6.9	23
586-15	19	14	6.0	2.1	21
ECPED11	14	12	2.3	6.7	15
ECPED8	13	11	4.5	1.2	15

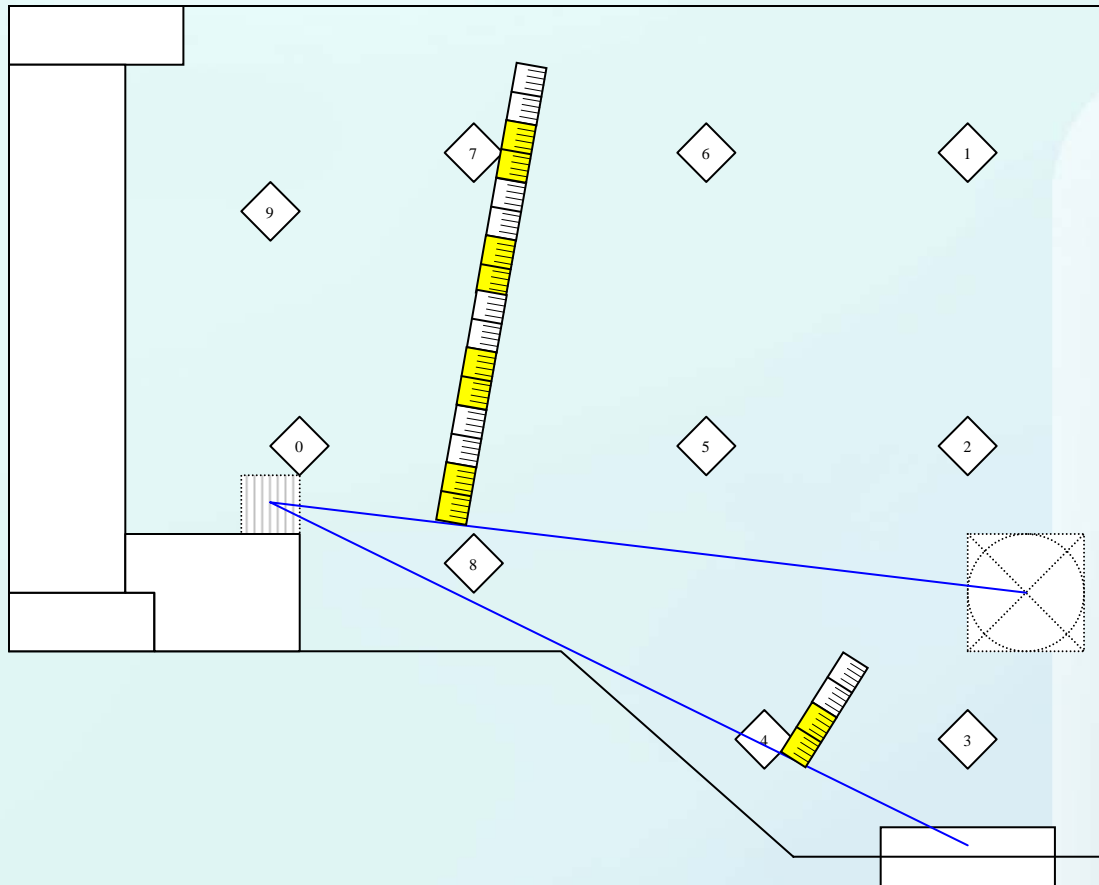
Local mixing

- **Because different rooms have different mechanical ventilation rates**
- **Local ACH as a fraction of mechanical ACH used for analysis**
- **k**

Variability within rooms

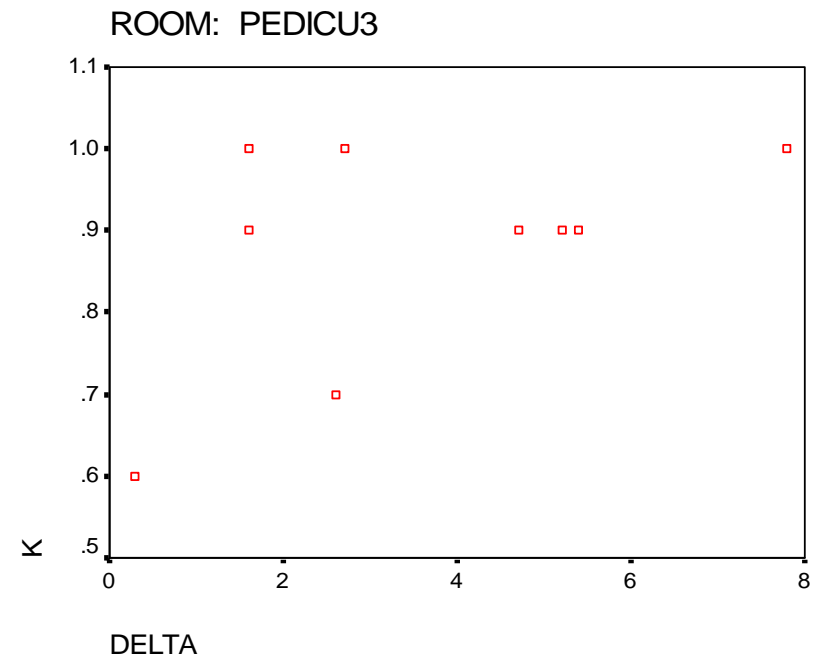


Effect of distance from "straight flow line"



Correlation of Distance from line and k

- **No statistical correlations**
- **However in many cases it is a point or two that impact the analysis**

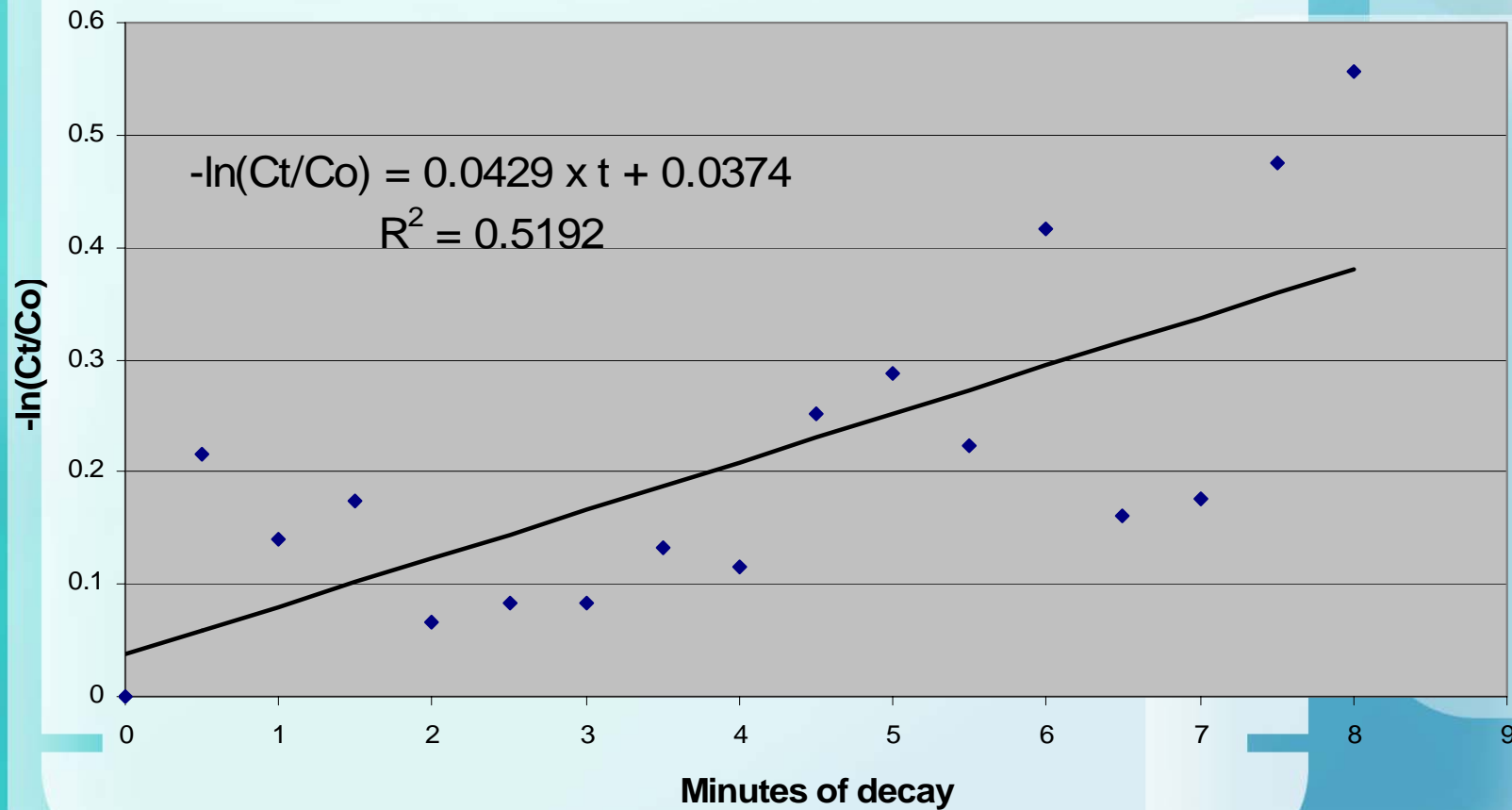


Variability at a given location

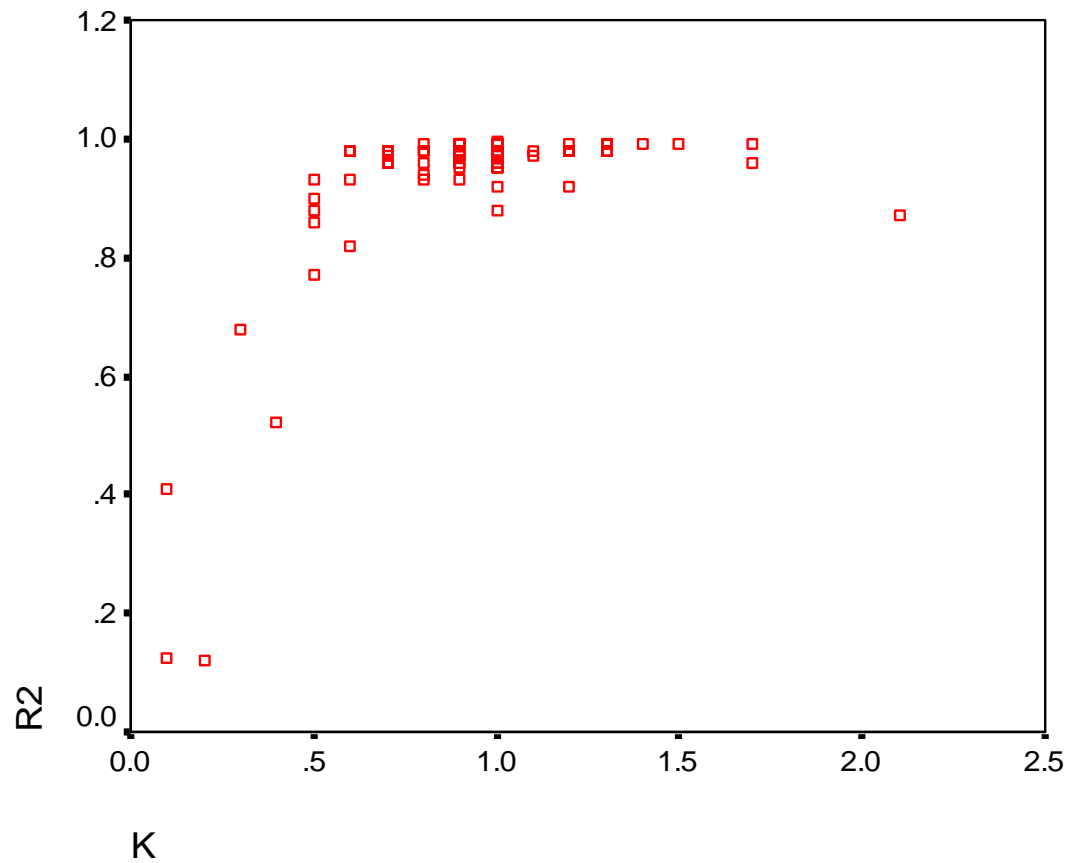
- **Lower k values in general had the most variability in local mixing**
- **Expressed as variability in linearized decay curve**
 - r^2

Variability at a given location

MICU location 4



Variability at a given location



Conclusions

- **All rooms had at least one location that the local air change rate was 30% or more below the mechanical ventilation rate**

Conclusions

- **Simple room geometry metrics are not sufficient to predict the effective mixing rates at locations within a negative pressure room**
- **Visual inspection of maps of mixing variability often identifies the reason for an outlier to a simple predictive approach**
- **How to capture this in an algorithm is being explored.**