Technological Solutions to Mitigate Airborne Transmission of Infectious Diseases in the Built Environment

Problem Addressing

In a change, WHO says indoor airborne spread of coronavirus is possible

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LONDON (AP) — The World Health Organization is acknowledging the possibility that COVID-19 might be spread in the air under certain conditions — after more than 200

How can airborne transmission of COVID-19 indoors be minimised?

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Abstract

During the rapid rise in COVID-19 illnesses and deaths globally, and notwithstanding recommended precautions, questions are voiced

The COVID-19 pandemic is a global indoor air crisis that should lead to change: A message commemorating 30 years of Indoor Air

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Why indoor spaces are still prime COVID hotspots.

Dyani Lewis view affiliations

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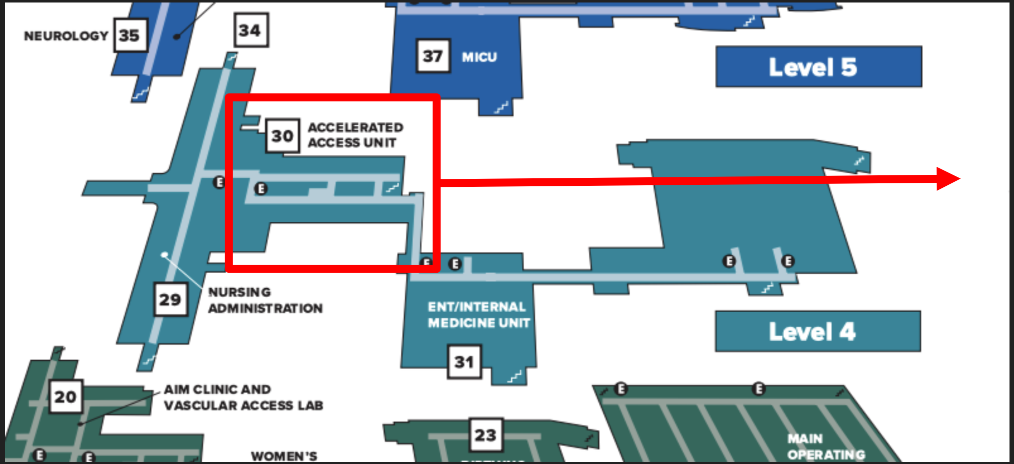
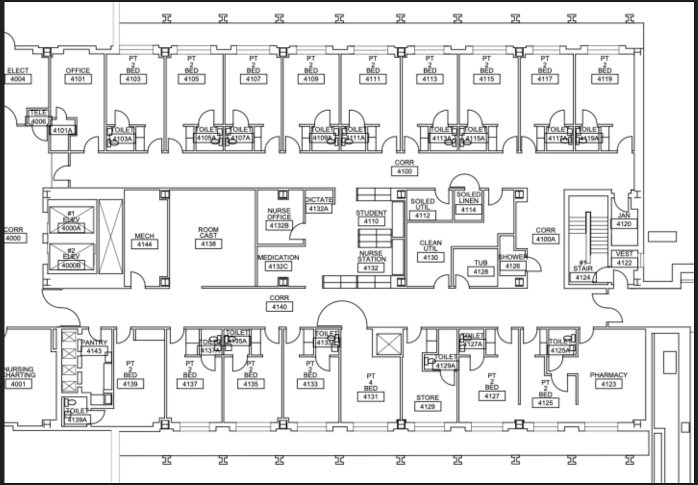
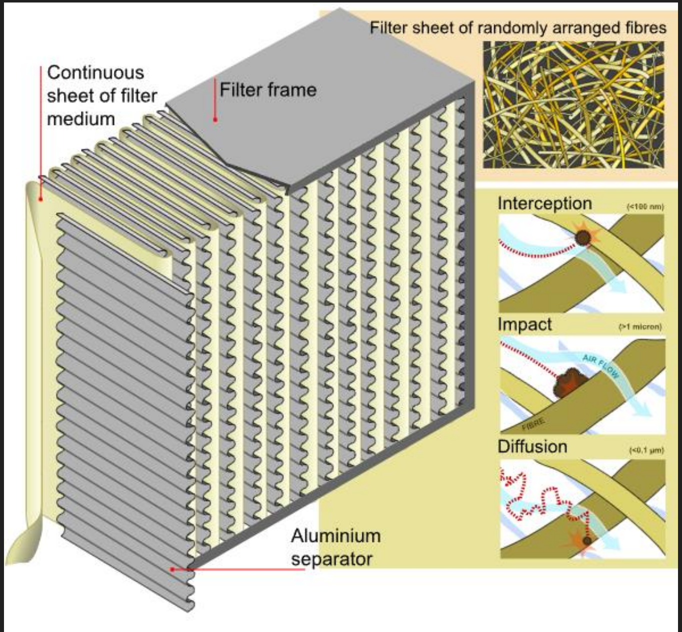




General Overview about HEPA filters

1. HEPA filters are essential for maintaining clean indoor air quality by effectively trapping airborne particles
    a. Utilize multiple mechanisms for filtration
    b. H14 grade removes 99.997% of particles.
    c. Capture particles as small as 0.3 microns in diameter
2. HEPA filters intercept, impact and diffuse
    a. Catches large particles
    b. Catches smaller particles that got through the initial filter
    c. Trapped by fibers within the filter



Costs HEPA filters

1. Cost of a single HEPA air filter is between $20 and $10,000
    a. Hospitals often need to change out filters once every half a year at minimum
    b. The average cost to replace one air filter is around $300

Solution thought/example

1. If a hospital replaced all 100 HEPA air filters it would be around $20,000
    a. Each air filter is around $182
    b. Camfil air filtration systems typically lower their HVAC energy costs by 15 to 30 percent

$$T = (N_R \times C_R) + (N_{ICU} \times C_{ICU}) + (N_{OR} \times C_{OR}) + (N_{other} \times C_{other})$$

Literature Review

Technologies to mitigate airborne transmission

1. High-Efficiency Particulate Air (HEPA) Filters
   - Increasing filter MERV rating

Type	Filter efficiency (MERV)	Depth (inches)	Initial pressure drop @ 500 fpm ("H2O)	Filter cost per filter unit area ($/ft^2)	Expected service life (months)	Labor cost per filter unit area ($/ft^2)	Annual VAV fan energy cost per filter unit area ($/ft^2)	Total annual cost per filter unit area ($/ft^2)
Pleat	8	2	0.31	$2.98	3	$5.00	$5.83	$37.73
Pleat	8	4	0.27	$4.88	4	$5.00	$5.08	$34.70
Pleat	13	2	0.41	$7.23	2	$5.00	$7.71	$81.06
Pleat	13	4	0.33	$13.16	3	$5.00	$6.21	$78.86
Bag	13	12	0.52	$22.23	12	$6.00	$9.78	$38.01
Bag	13	15	0.48	$23.93	12	$6.00	$9.03	$38.95

1. Ventilation Control for Aerosol-Transmissible Pathogens in Healthcare
   - Method: dilution, filtration,disinfection,Pressurization, UVGI(Germicidal ultraviolet irradiation)
1. Bipolar Ionization
2. Air Purifiers / Hybrid ventilation / temporary negative-pressure rooms

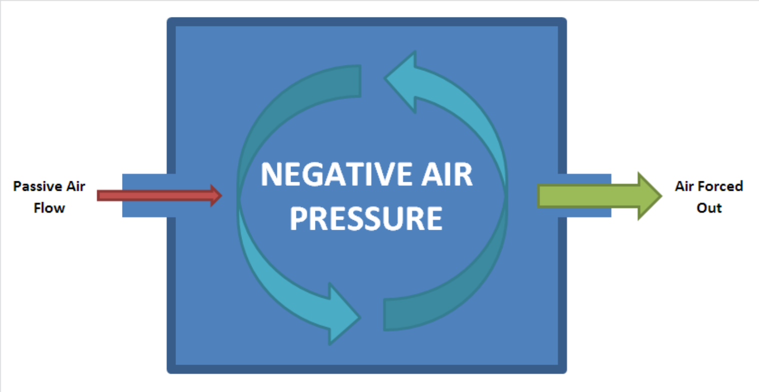
Literature Review (CONTAM Preparation)

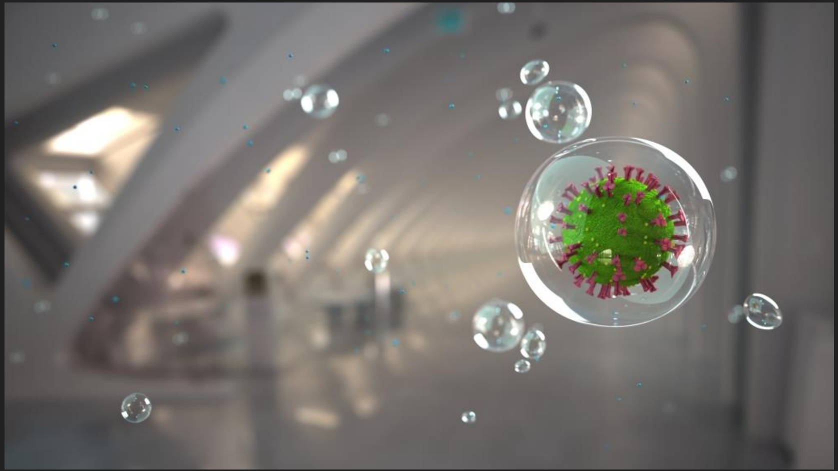
$$ACH = \frac{Q}{V}$$

where,

Q= Volumetric flow rate of air into space, cfm

V=interior volume of space, ft^3

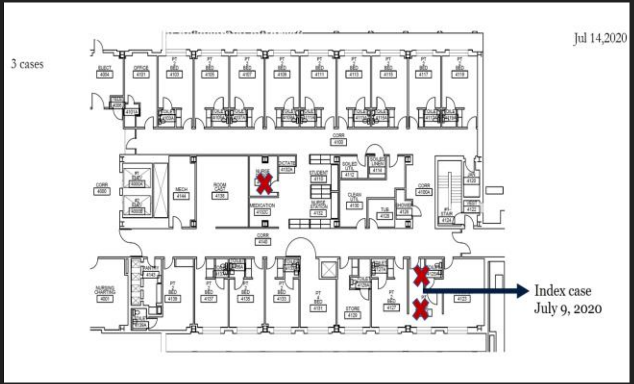




Data (Survival Analysis)

- Data: HIPAA Data East 4 Outbreak.
  - Date of Positive Covid-19 test
  - Patients’ contact information
  - Patients’ room numbers of Positive Covid-19 test
- Analysis:
  - Visualization of maps of infection
  - Survival analysis using Kaplan-Meier Estimation
- Challenges of Data:
  - Missing information for the positive COVID-19 test
  - Unbalanced sample sizes between staff and patient
- Solution:
  - Combine the information from both the maps of infection and Excel data file and analysis
  - Focus on infections before the duration of 26 days when comparing staff group and patient group
    - Missing information for censored data for the duration of 26 days.
    - All samples on the duration of 26 days are patient

Example of Map of



Kaplan-Meier Survivorship Table

Duration (Days)	Survival Probability	Number at Risk	Number of Events
0	0.9767	43	1
4	0.9535	42	1
5	0.9302	41	1
6	0.9070	40	1
11	0.8605	39	2
12	0.8372	37	1
13	0.7442	36	4
14	0.6279	32	5
15	0.5349	27	4
16	0.5116	23	1
26	0.1395	22	16

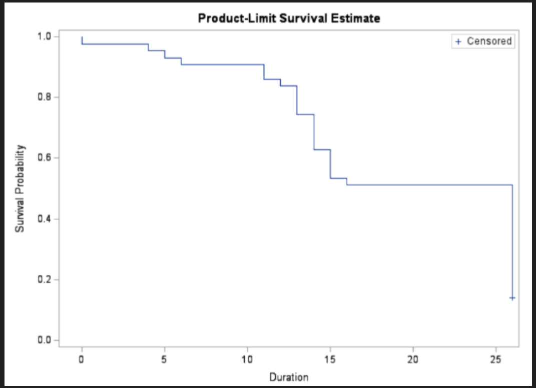
Data: KM Curve

Note: Survival Probability is the non-positive test probability

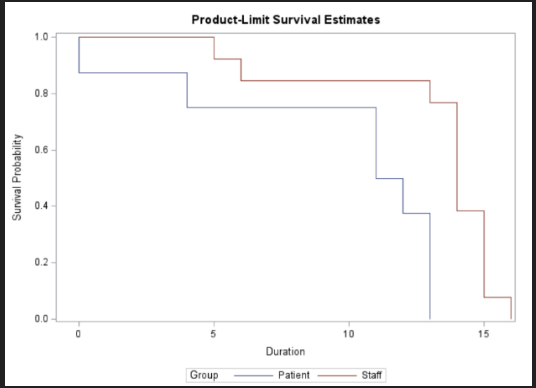
- The initial survival probability is high at 97.67%, and drop down steadily before day 13. Between day 13 and day 15, there is a significant decline in survival curves (dropped from 0.8372 to 0.5349). The median survival time appears between day 16 and day 26.

- From the stratified KM graph, we can see staff got COVID-19 later than patients, and based on the log-rank test p-value = 0.0008, we have enough evidence to conclude that there is a significant difference between staffs and patients.

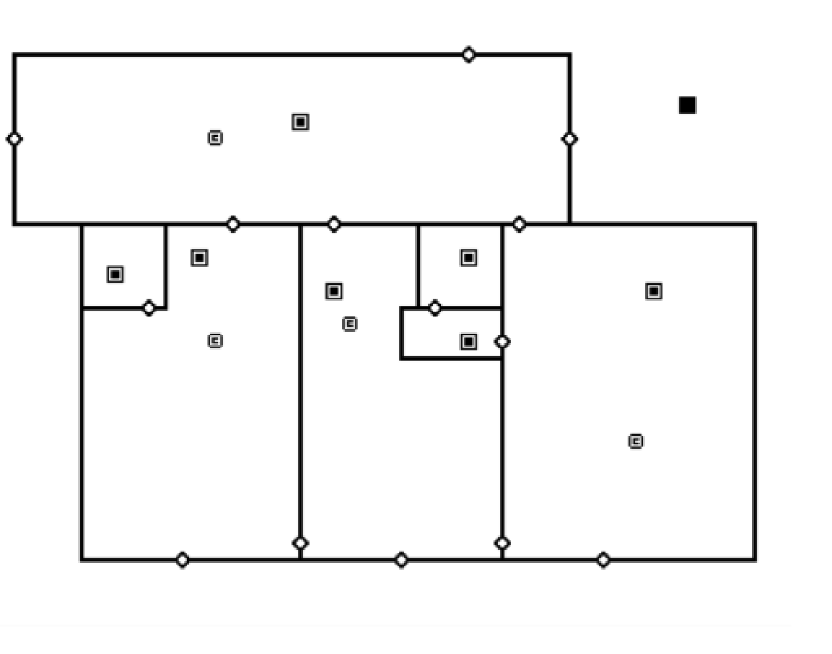
Kaplan-Meier Survival Curve

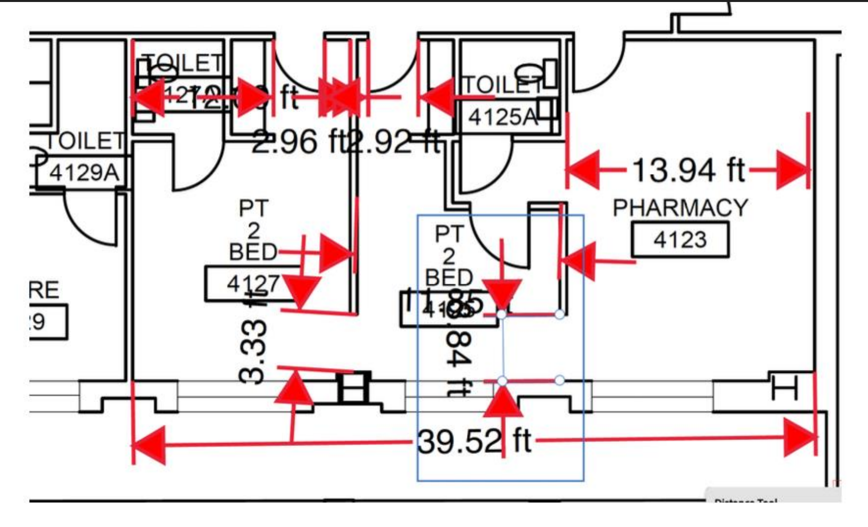


Stratified Curve for Staff and Patient before day 26

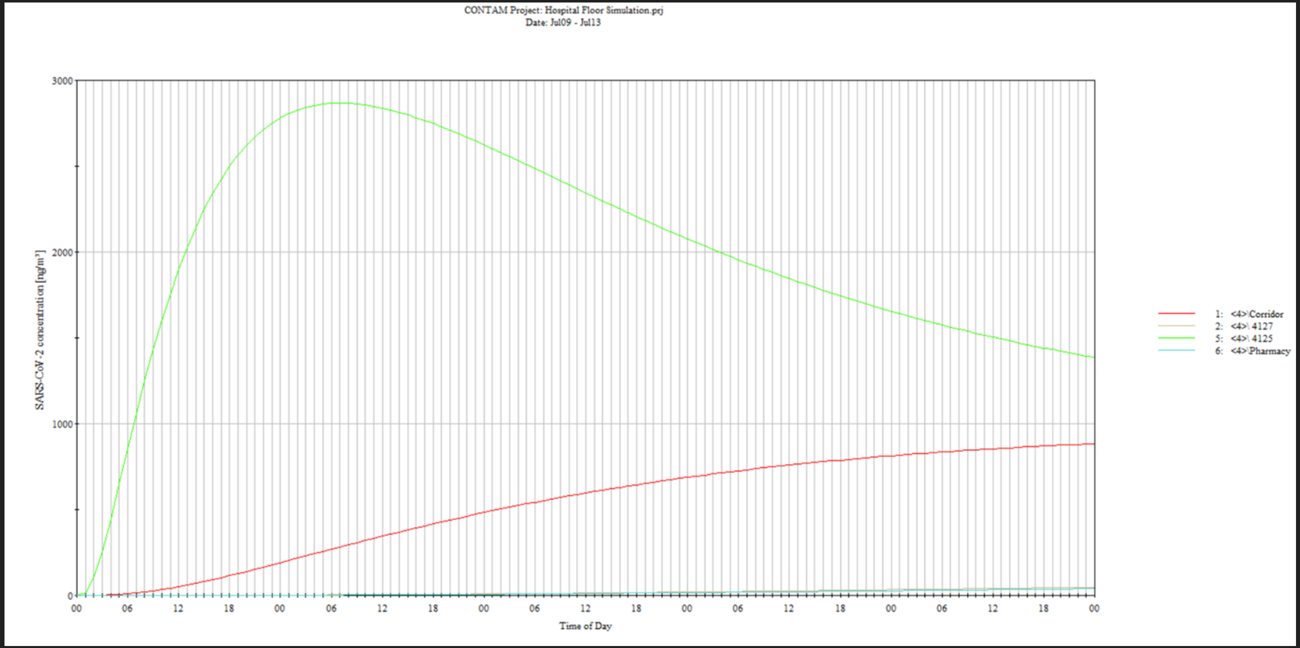


CONTAM: Sketchpad

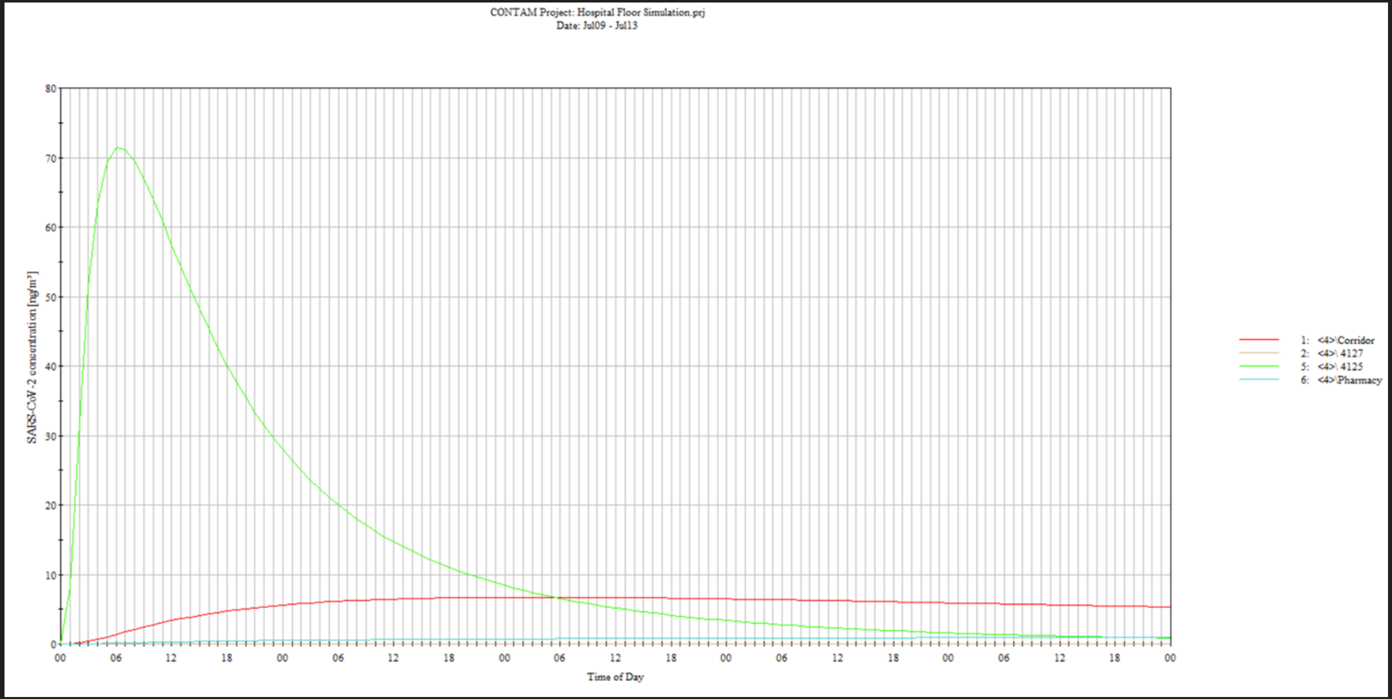




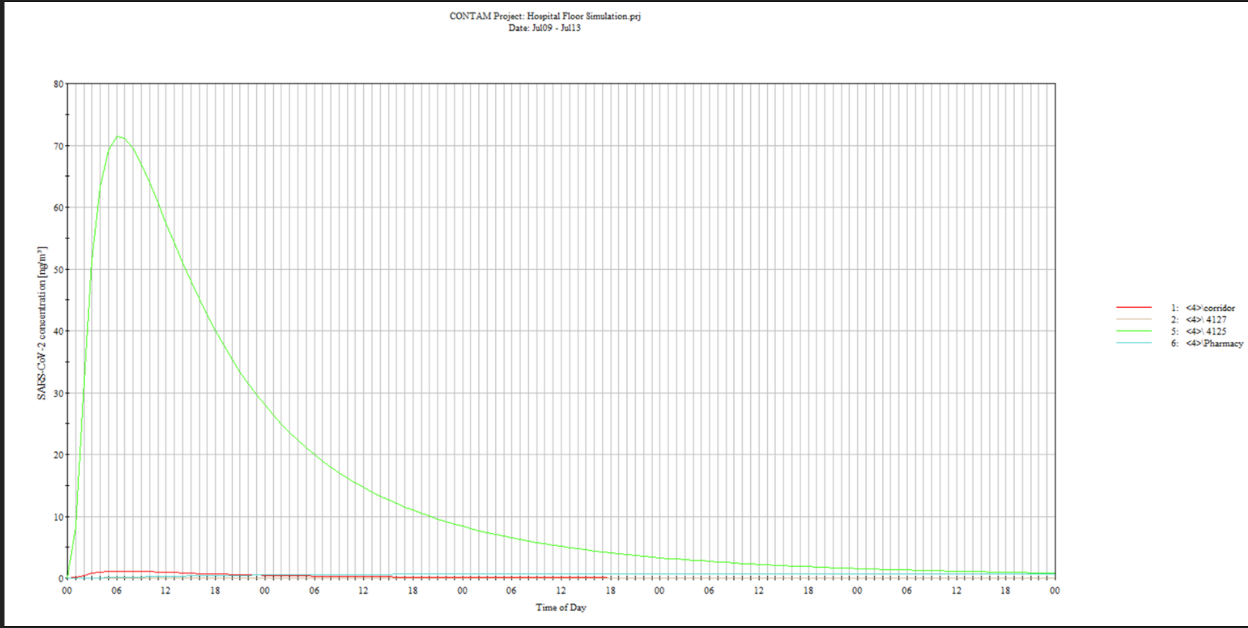
CONTAM: No Ventilation + No HEPA



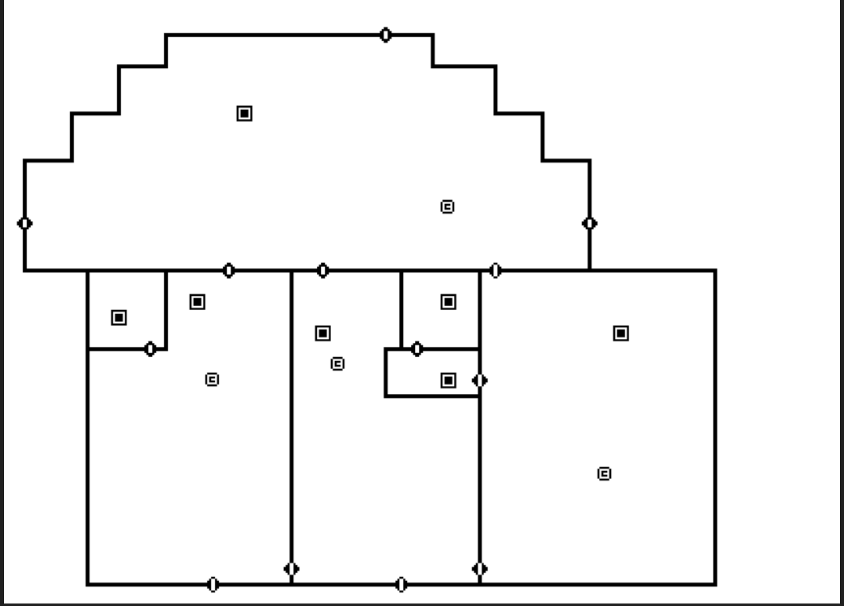
CONTAM: Ventilation + No HEPA

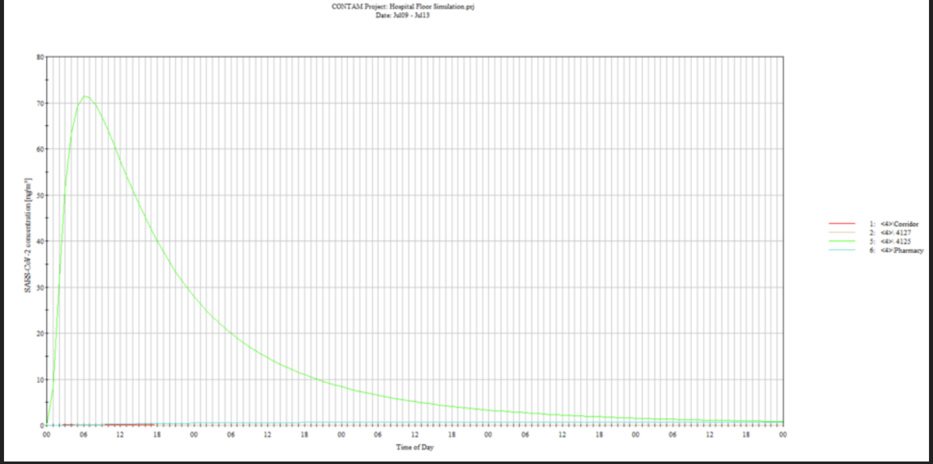


CONTAM: Ventilation + HEPA



CONTAM: Spatial Redesign





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THANK YOU!!!!