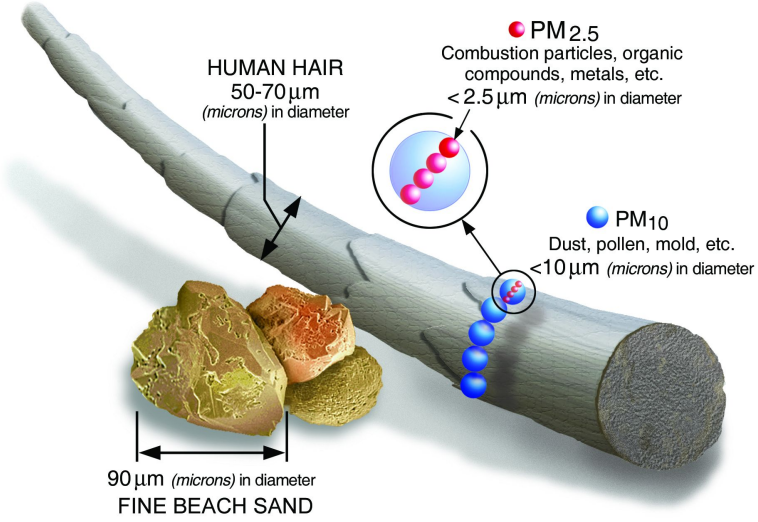
PM Distribution System

Client: Dr. Ben Nephew
Team: Mina Akdogan, Freddy Davaris, Baris Erdemli, George Pesmazoglou, Faris Shamsi

Problem Background

- Ever since the industrial revolution in the 19th century, environmental pollution is becoming increasingly prevalent.
- The most worrisome forms of pollution are the fine particulate matter as these are particles that are small enough to be inhaled and can penetrate deep into the lungs.
- In particular there has been increased attention to investigating the effects of particulate matter on developing autism.



Particulate Matter Size Comparison

Problem Statement

- Our task is to design and construct the setup of an experiment that delivers tunnel Particulate Matter (PM) in aerosol form to a total of 6 cages containing the test animals (rats).

- Our client would like to investigate autism occurrences as a result to PM exposure.

- We must ensure the safety of the test animals as well as the surrounding scientists while maintaining ideal conditions during the 5 hour PM exposure period, 3 times a week.

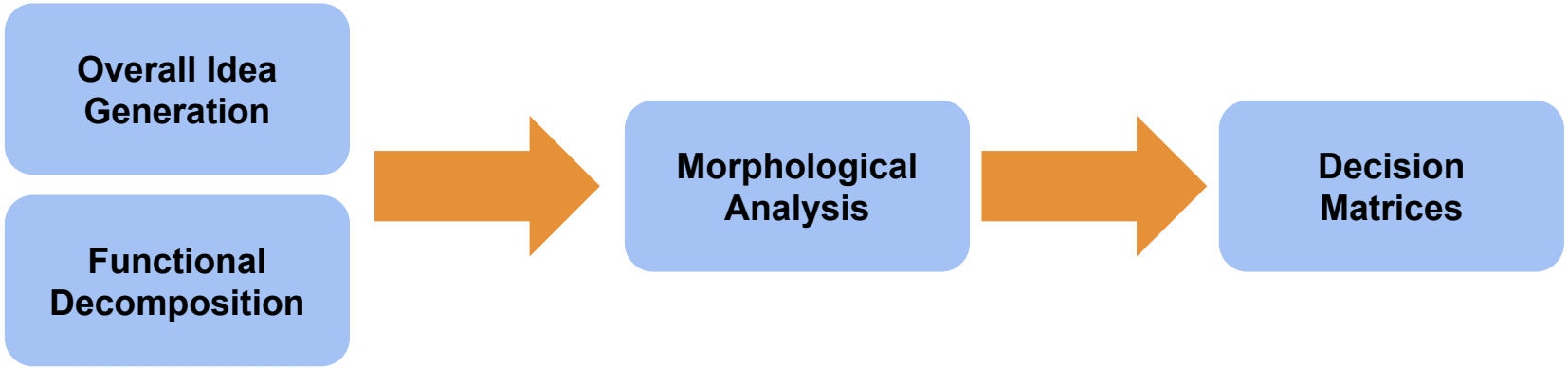
Weighted Matrix of Requirements and Needs

Need	Description	Weight	Size	Flow Rate	Cost	Pressure	Safety	Concentration
Accuracy	It should evenly distribute the PM to 6 different cages	2	8	7	3	6	3	9
Repeatability	Experiment must be repeated with similar results	4	2	8	2	2	6	8
Accuracy	Keep the concentration constant	2	7	7	1	3	7	9
Durability	Setup must last at least 6 months (duration of experiment)	4	5	1	7	4	4	4
Usability	Easy to gain access to enclosures	3	6	1	4	1	5	1
Usability	Easy to assemble/disassemble	1	9	1	6	1	1	1
Safety	Avoid leakage of pollutants to lab atmosphere	4	1	4	2	7	10	5
Safety	Keep the concentration of PM below a harmful level	5	1	8	3	8	10	4
Total Sum			94	124	85	114	166	128

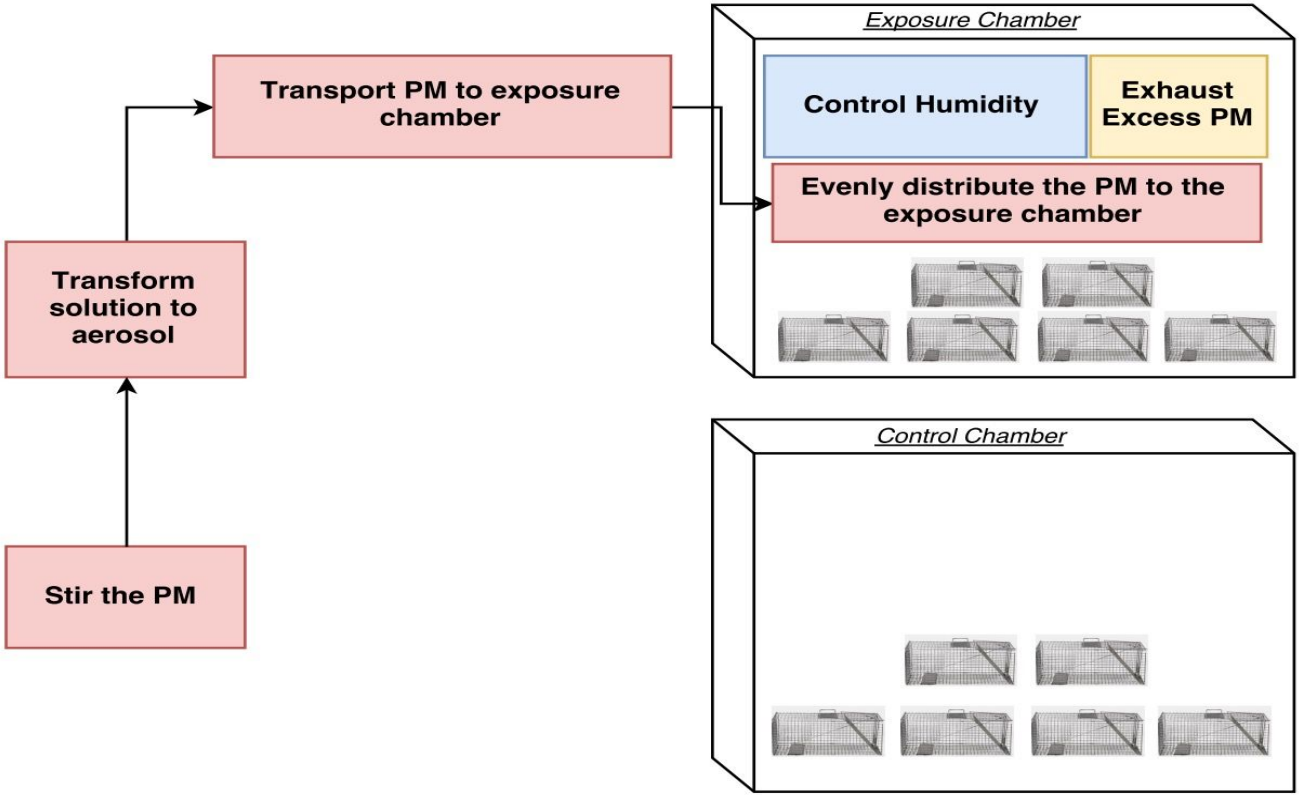
Weighted Matrix of Requirements and Needs

Need	Description	Weight	Size	Flow Rate	Cost	Pressure	Safety	Concentration
Accuracy	It should evenly distribute the PM to 6 different cages	2	8	7	3	6	3	9
Repeatability	Experiment must be repeated with similar results	4	2	8	2	2	6	8
Accuracy	Keep the concentration constant	2	7	7	1	3	7	9
Durability	Setup must last at least 6 months (duration of experiment)	4	5	1	7	4	4	4
Usability	Easy to gain access to enclosures	3	6	1	4	1	5	1
Usability	Easy to assemble/disassemble	1	9	1	6	1	1	1
Safety	Avoid leakage of pollutants to lab atmosphere	4	1	4	2	7	10	5
Safety	Keep the concentration of PM below a harmful level	5	1	8	3	8	10	4
Total Sum			94	124	85	114	166	128

Concept Selection Approach



Overall Idea Generation/ Functional Decomposition



Morphological Analysis

Sub-Functions	Concept 1	Concept 2	Concept 3
Stir the PM	Magnetic Stirrer	Manual	Blender
Transform Solution to Aerosol	Dust feeder	Nebulizer	Rapid Cooling
Exhaust Excess PM	Hepa Filter	Pipe from exit hole to atmosphere	Open Ventilation (in lab)
Transport PM aerosol to E.C.	Manifold System	Common container	Attach device to E.C.
Evenly Distribute PM in E.C.	Flute	Double Input/Output	Single Input/Output
Control Humidity	Dehumidifier	Mix PM with dry air	Refrigerator Coil

Decision Matrices

Function: Stir the PM

Selection Criteria	Weight	Concepts					
		Magnetic Stirrer		Manual		Blender	
		Rating	Score	Rating	Score	Rating	Score
Safety	0.1	8	0.8	4	0.4	3	0.3
Cost	0.3	8	2.4	2	0.6	5	1.5
Speed	0.2	9	1.8	5	1	8	1.6
Size	0.2	10	2	3	0.6	4	0.8
Usability	0.1	8	0.8	8	0.8	6	0.6
Durability	0.1	2	0.2	7	0.7	6	0.6
Total Score			8		4.1		5.4

Magnetic Stirrer
Total Score: 8

Manual
Total Score: 4.1

Blender
Total Score: 5.4

Function: Transform Solution into Aerosol

Selection Criteria	Weight	Concepts					
		Dust Feeder		Nebulizer		Rapid Cooling	
		Rating	Score	Rating	Score	Rating	Score
Safety	0.1	8	0.8	9	0.9	6	0.6
Cost	0.3	2	0.6	10	3	4	1.2
Accuracy	0.2	9	1.8	7	1.4	7	1.4
Size	0.1	6	0.6	9	0.9	2	0.2
Usability	0.1	7	0.7	6	0.6	3	0.3
Durability	0.2	7	1.4	5	1	4	0.8
Total Score			5.9		7.8		4.5

Dust Feeder
Total Score: 5.9

Nebulizer
Total Score: 7.8

Rapid Cooling
Total Score: 4.5

Function: Exhaust Excess PM (from EC)

Selection Criteria	Weight	Concepts					
		HEPA Filter		Pipe from exit hole to atmosphere		Open ventilation (in lab)	
		Rating	Score	Rating	Score	Rating	Score
Safety	0.5	8	4	7	3.5	3	1.5
Cost	0.3	6	1.8	7	2.1	10	3
Size	0.05	7	0.35	2	0.1	10	0.5
Usability	0.05	9	0.45	3	0.15	8	0.4
Durability	0.1	6	0.6	5	0.5	7	0.7
Total Score			7.2		6.35		6.1

HEPA Filter
Total Score: 7.2

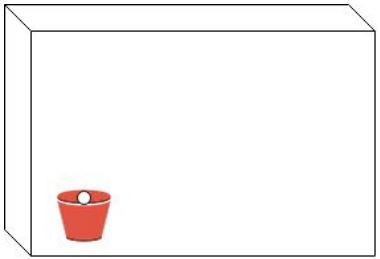
Pipe from exit hole to atmosphere
Total Score: 6.35

Open ventilation(in lab)
Total Score: 6.1

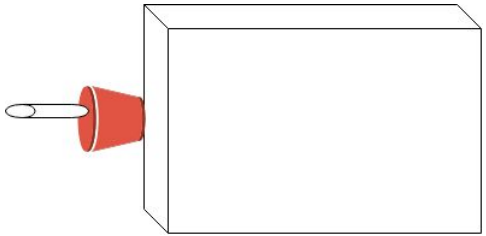
Function: Transport PM to the Exposure Chamber

Selection Criteria	Weight	Concepts					
		Manifold system		Common container		Attach device to EC	
		Rating	Score	Rating	Score	Rating	Score
Safety	0.2	8	1.6	2	0.4	5	1
Cost	0.3	7	2.1	9	2.7	8	2.4
Fabrication	0.25	4	1	6	1.5	3	0.75
Size	0.1	5	0.5	2	0.2	8	0.8
Usability	0.05	9	0.45	6	0.3	4	0.2
Durability	0.1	8	0.8	8	0.8	5	0.5
Total Score			6.45		5.9		5.65

Manifold System
Total Score: 6.45



Common Container
Total Score: 5.9

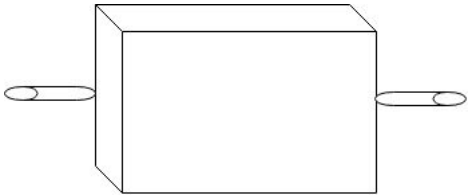


Attach device to EC
Total Scor: 5.65

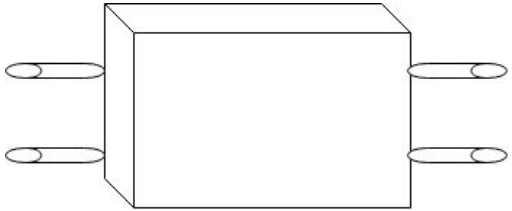
Function: Evenly distribute PM in EC

Selection Criteria	Weight	Concepts					
		Flute		Single Input/ Output		Double Input/ Output	
		Rating	Score	Rating	Score	Rating	Score
Safety	0.2	8	1.6	7	1.4	7	1.4
Cost	0.3	4	1.2	10	3	8	2.4
Fabrication	0.2	2	0.4	9	1.8	7	1.4
Size	0.05	5	0.25	9	0.45	6	0.3
Accuracy	0.2	9	1.8	6	1.2	8	1.6
Durability	0.05	7	0.35	8	0.4	8	0.4
Total Score			5.6		8.25		7.5

Flute
Total Score: 5.6



Single Input/Output
Total Score: 8.25



Double Input/Output
Total Score: 7.5

Function: Control Humidity

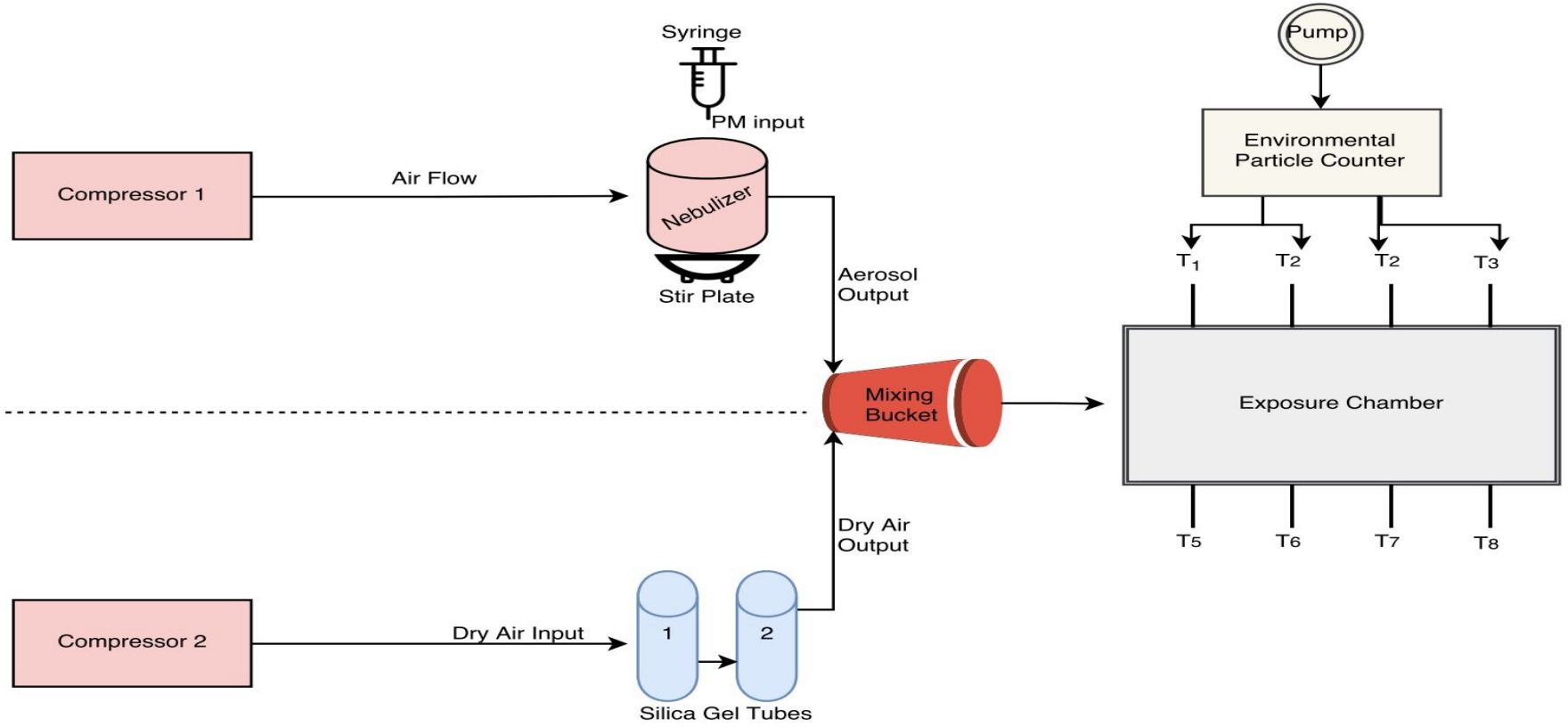
Selection Criteria	Weight	Concepts					
		Dehumidifier		Mix PM aerosol with dry air		Refrigerator Coil	
		Rating	Score	Rating	Score	Rating	Score
Safety	0.1	8	0.8	9	0.9	6	0.6
Cost	0.4	3	1.2	7	2.8	4	1.6
Fabrication	0.2	4	0.8	7	1.4	4	0.8
Size	0.1	5	0.5	9	0.9	6	0.6
Accuracy	0.15	6	0.9	5	0.75	9	1.35
Durability	0.05	9	0.45	8	0.4	6	0.3
Total Score			4.65		7.15		5.25

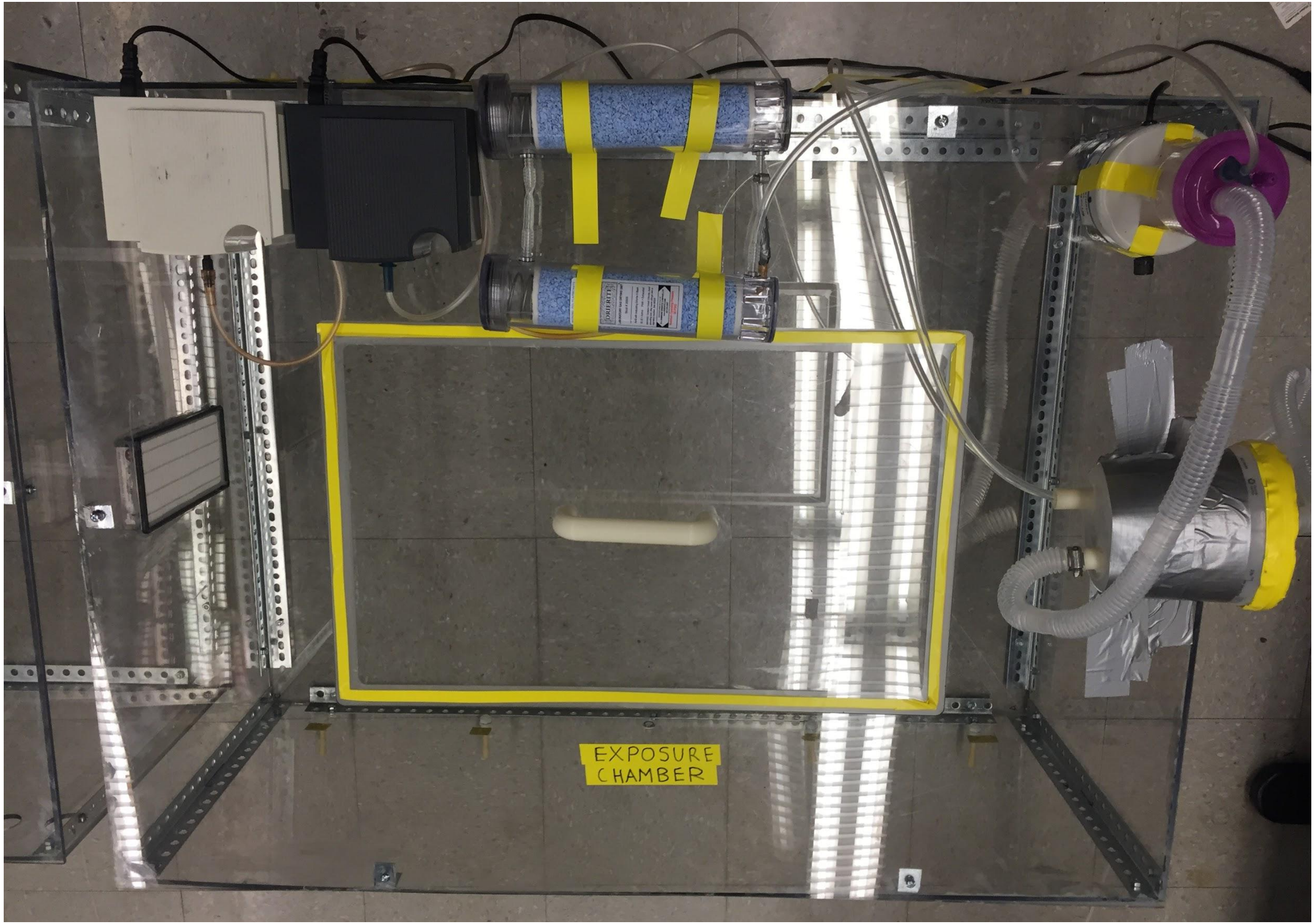
Demuhidifier
Total Score: 4.65

Refrigerator Coil
Total Score: 5.25

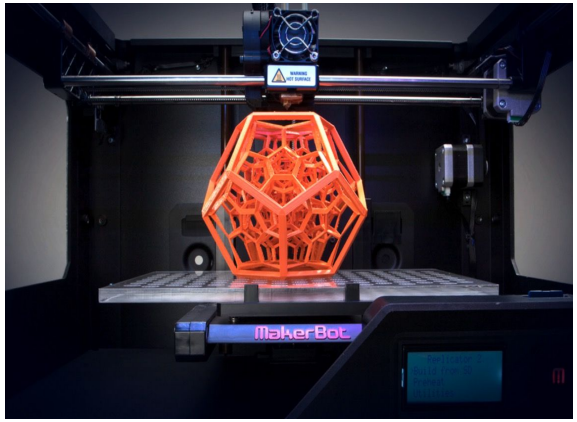
Mix PM Aerosol with dry air
Total Score: 7.15

Flow Schematic

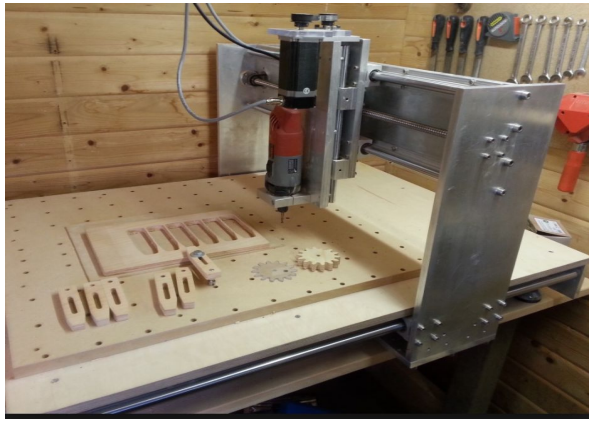



EXPOSURE
CHAMBER

Fabrication Processes



3D Printer



CNC (Computer Numeric Control)

Laser Cutter

Humidity and Temperature Regulation

- According to “Guidelines for the Housing of Rats in Scientific Institutions”:
  - Humidity: >40%
  - Temperature: 17-30C
- Using a HOBO Temperature/Relative Humidity 3.5% Data Logger we measured:
  - Humidity: 50-55%
  - Temperature is not altered by introducing aerosol and thus temperature should be regulated in the room in which the chambers are located.

Exposure Chamber Concentration Testing

- PM2.5 Yearly Concentration in the US **= 12µg/m^3**
- Desired Concentration level in Exposure Chamber = **24µg/m^3**
- 1µg/m^3 =1x10e-9 g/L

Testing Method

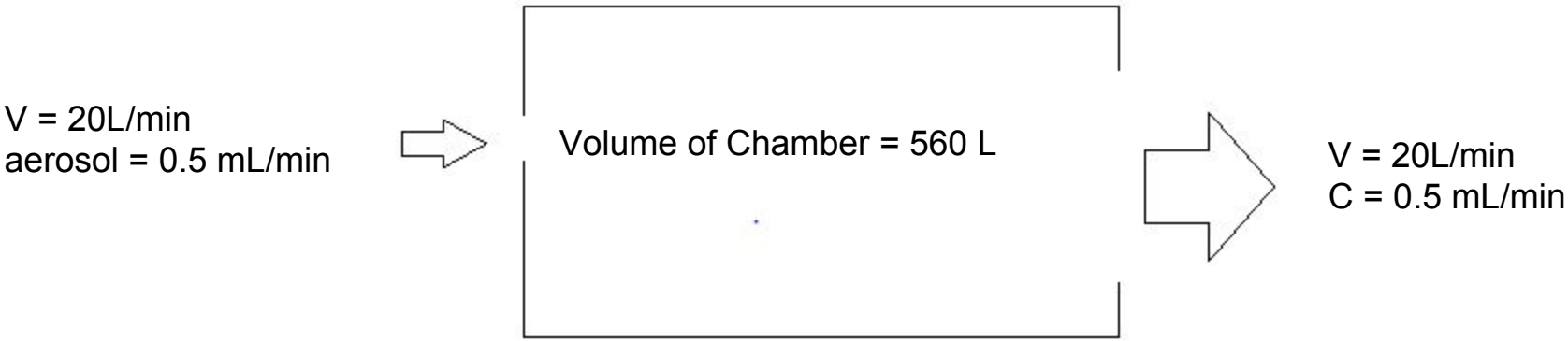
- After 1 hour of overhead time the system is in a steady state
- We are going to measure the concentration of PM in the box for different concentrations of PM in the solution, we will plot those points to find their relationship
- Our goal is for the concentration of PM in the box to be at a constant level of twice the PM in the atmosphere, for the duration of 5 hours

Analysis

Assumptions:-

- Uniform Flow
- Steady State
- Each Compressor Output = 10LPM (According to Product Specifications)
- Rats intake and fur absorption is negligible

Technical Engineering Analysis



Target concentration: 24 µg/mL
Volume of aerosol in chamber: 280 mL
Residence time: 560/20 = **28 min**
Aerosol: 28 min * 0.5 mL/min = 14 mL
Mass of PM: 24 µg/m3 * 0.560 = 13.44 g
Concentration of solution: ~ **1µg/mL**

Special Thanks to....

- Prof. Kristen Wendell, Tufts University
- Pat Fennessy, Tufts University
- Dr.Ben Nephew, Cummings School of Veterinary Medicine, Tufts University
- Ben & Marya, Tufts University
- Joy Lawrence, Harvard School of Public Health
- Prof. John Durant, Tufts University
- Dr. John Godleski, Harvard School of Public Health

Questions