Ozone Surface Exchange to Vegetation and Growing Media

REU Symposium

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Background

What is Ozone?

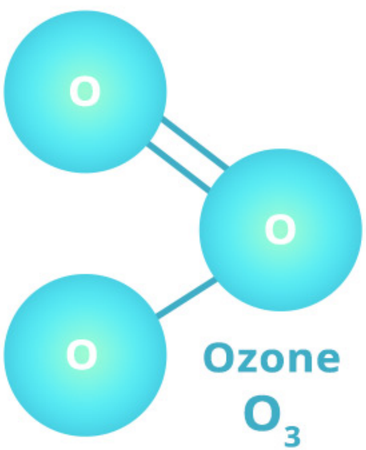
- Highly reactive gas
- Composed of 3 Oxygen Atoms

How is it Made?

- Formed in the upper atmosphere through chemical reactions between oxygen and UV light
- Formed in the lower atmosphere through reactions between nitrogen oxides (NOx), carbon monoxide (CO) and volatile organic compounds (VOCs), in the presence of sunlight

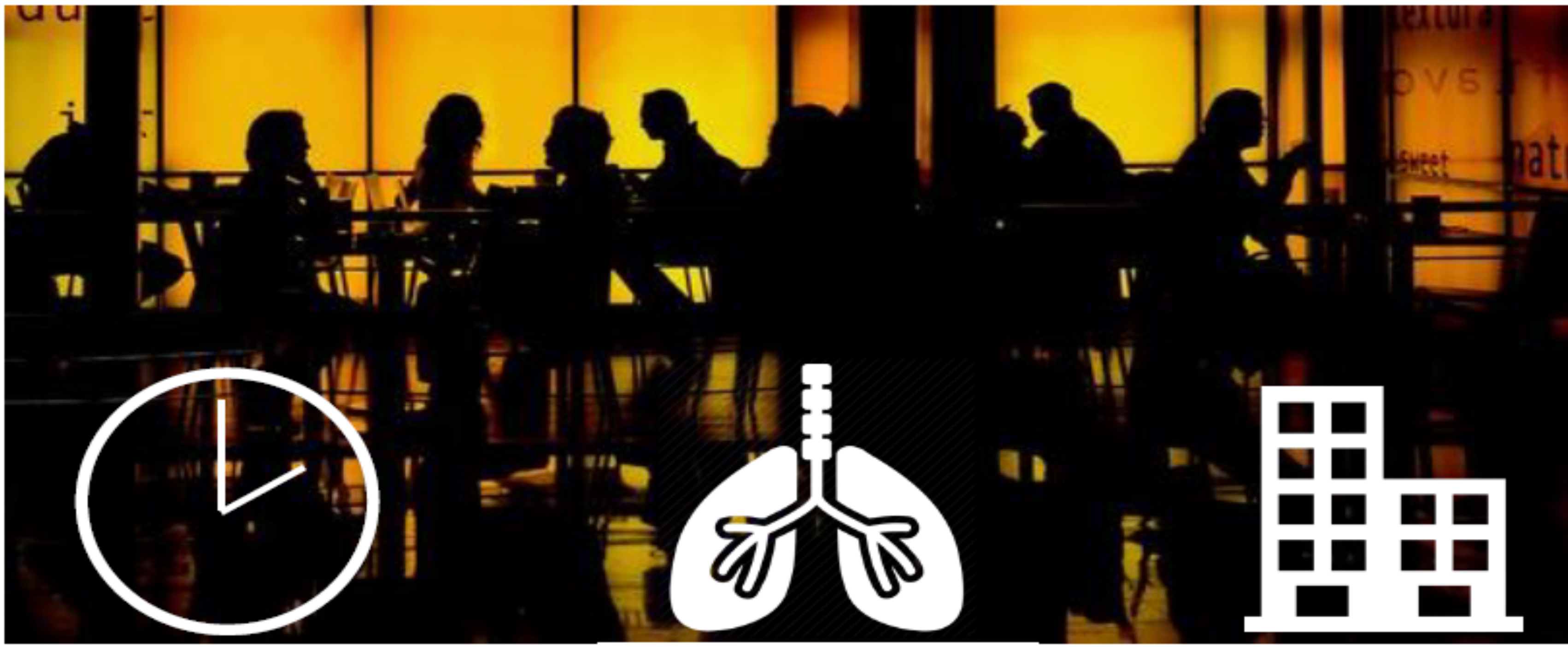
Concentrations?

- The EPA regulates outdoor ozone levels around 70 PPB
- Indoor levels are commonly found around 2-7 PPB
- Ozone gets into our indoor environment mostly from outdoor air



Indoor Air Quality

"Indoor air pollution is among the top 5 environmental risks to public health"[2]



We spend 90% of our time in buildings

We inhale ~20,000 L of indoor air each day

Building consume 41% of U.S. energy

Green Roof Impacts

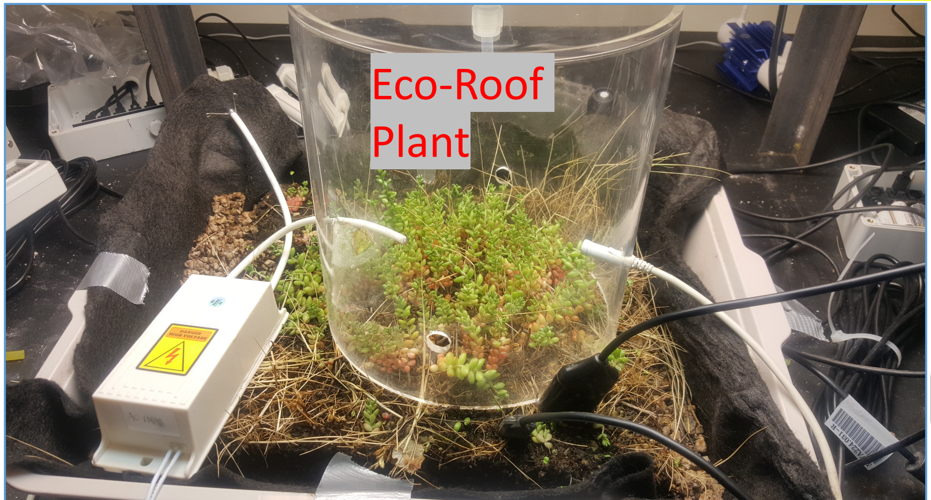
- The government mandates that businesses in big cities require Green Roofs

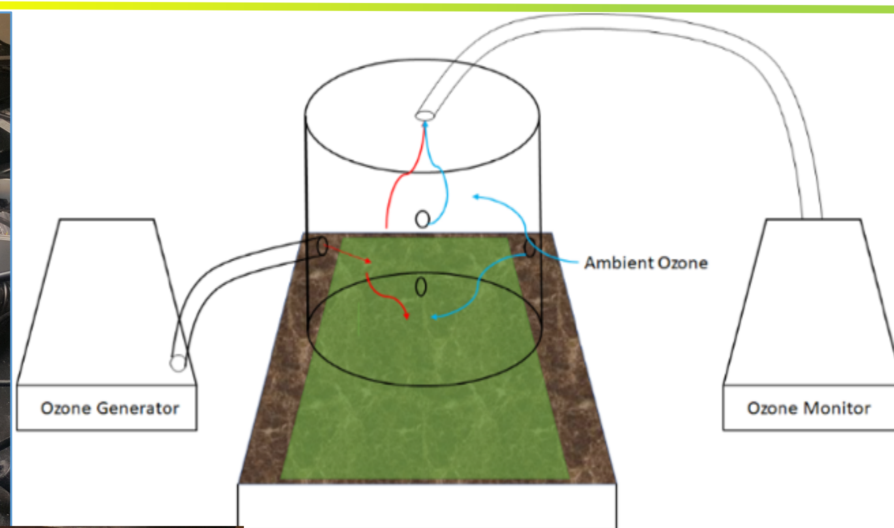
How does this affect our air quality indoors?

- Interactions between air pollutants such as ozone and plant emissions can produce potentially harmful byproducts
- Infiltrate RTU

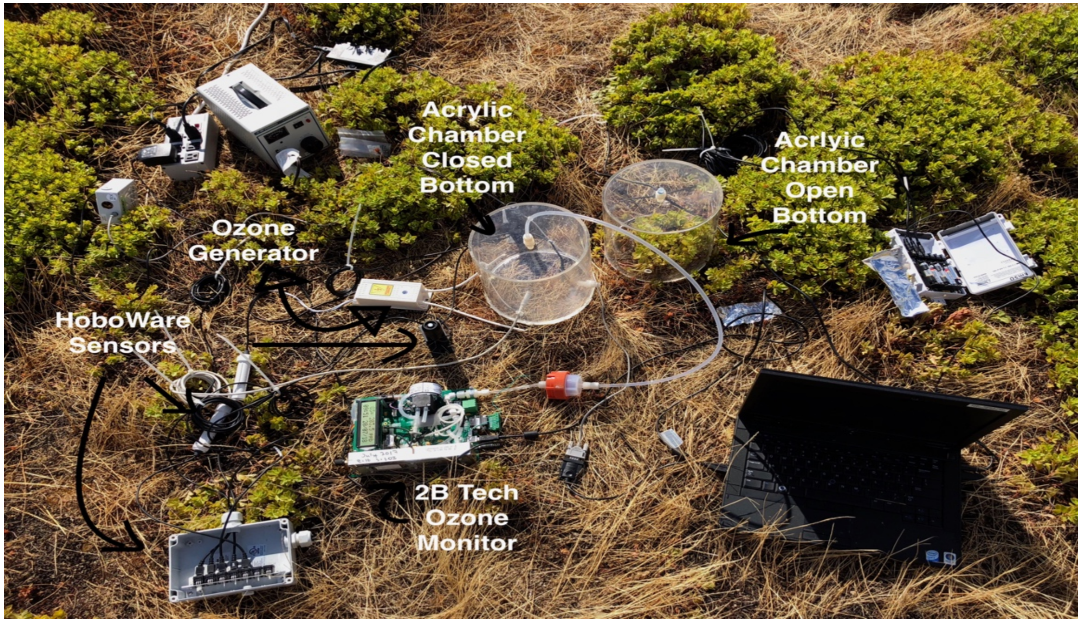
Ventilation Units

Experimental Setup Lab

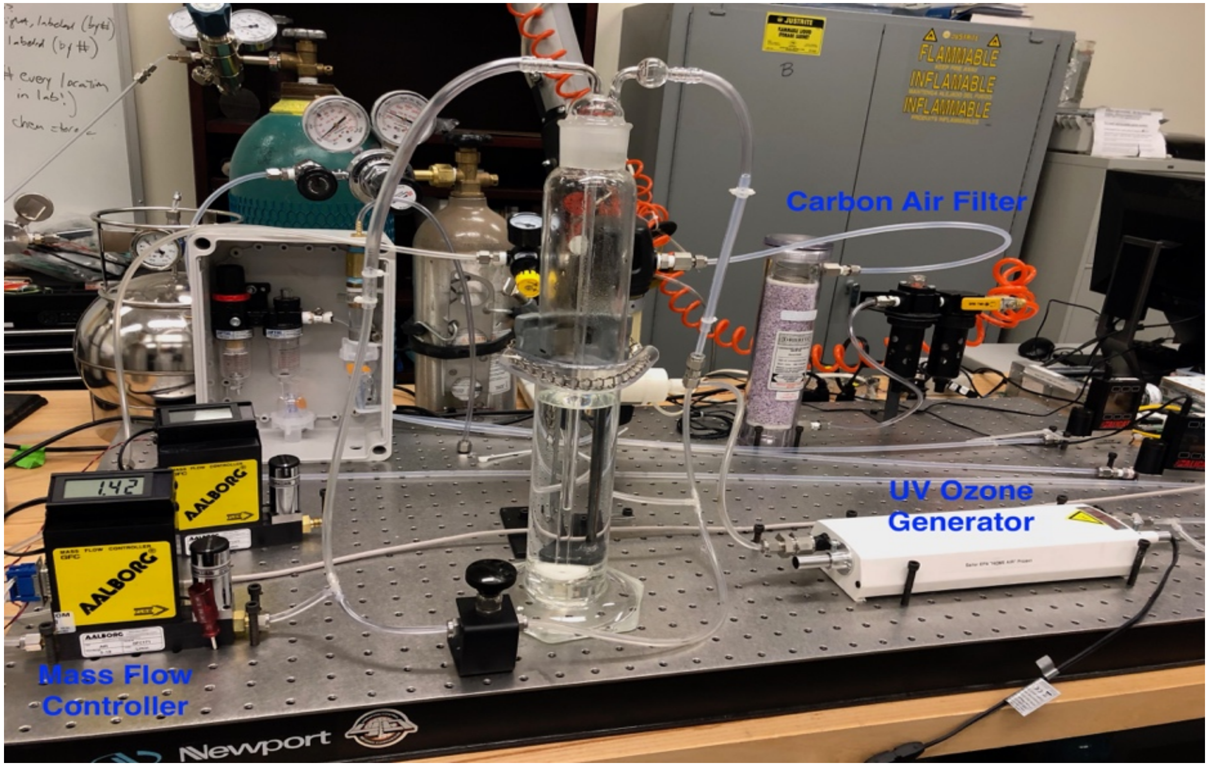




Experimental Setup Field



Experimental Setup



Finding Deposition Velocities

$$\forall \frac{dC}{dt} = Q(C_o - C) - V_{dS1}A_{S1}C - V_{dS2}A_{S2}C - \cdots$$

$\forall$ *is the Volume of the space*

$\frac{dC}{dt}$ *is the change in concentration over the change in time*

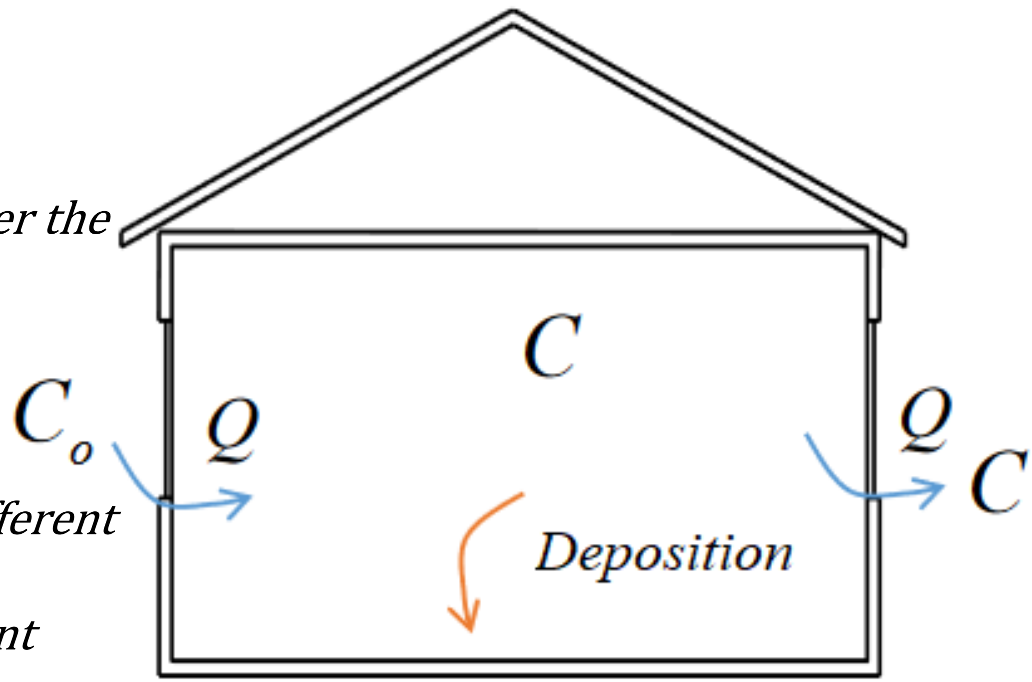
Q *is the flow rate*

C_o *is the outdoor concentration*

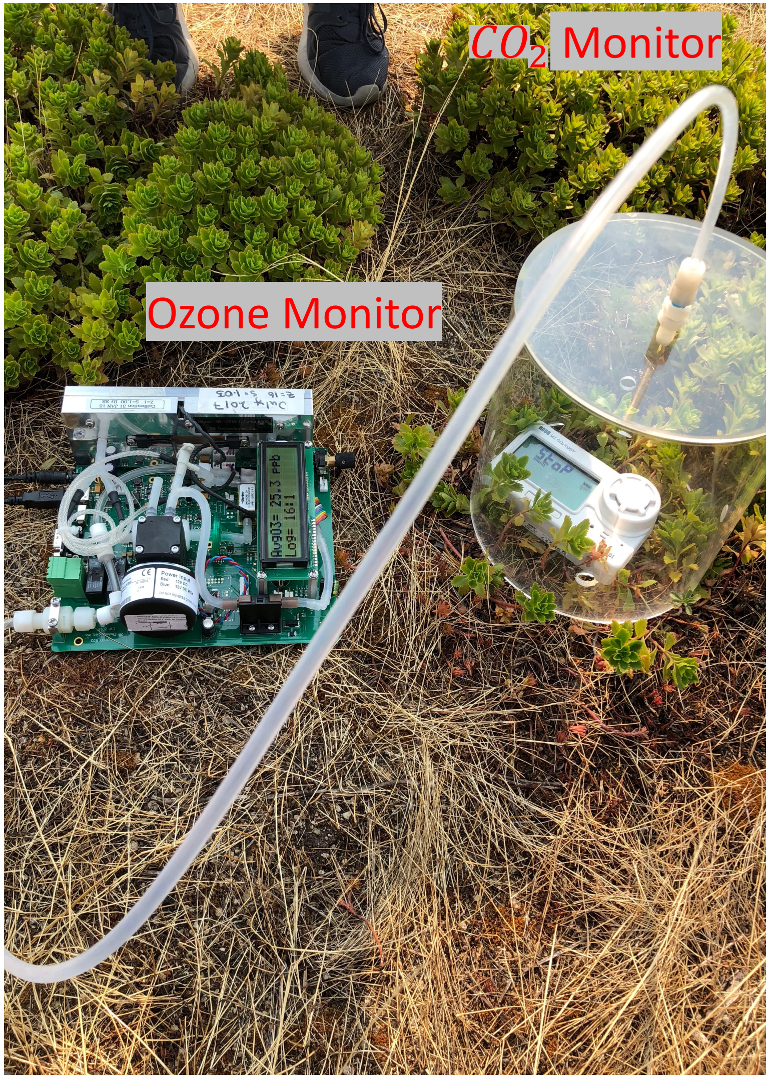
C *is the indoor concentration*

V_{dSX} *is the deposition velocity to different surfaces*

A_{SX} *is the surface area of the different surfaces*



Finding Vdb: CO_2 Decay



- CO_2 is a relatively stable gas

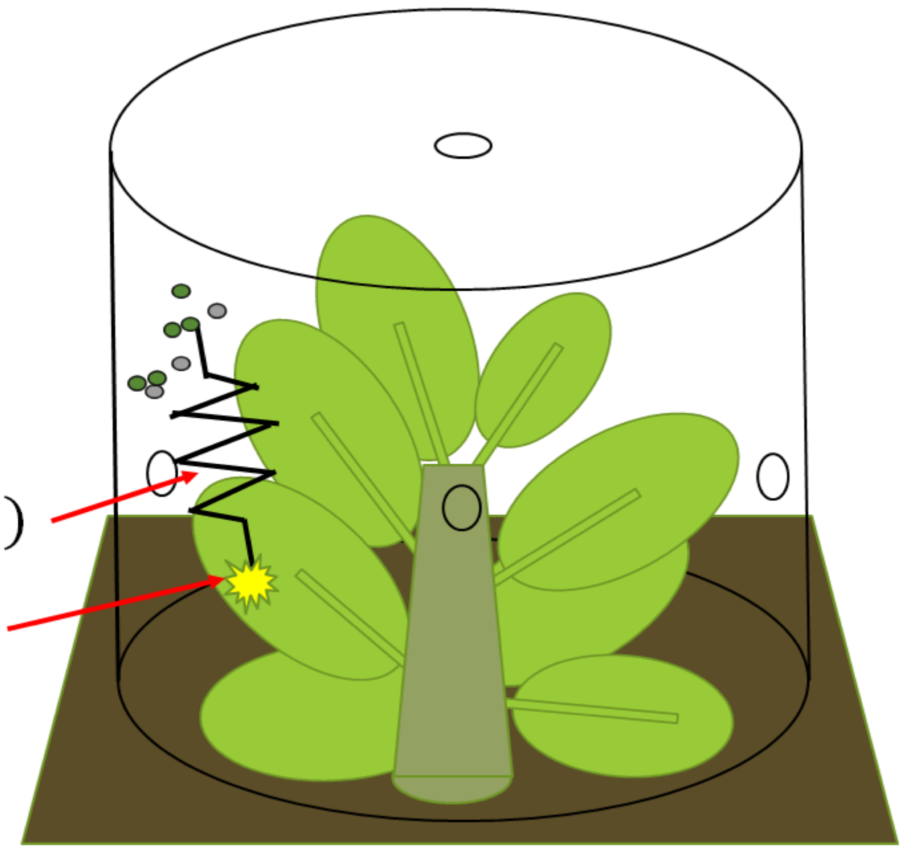
$$\lambda = \frac{Q}{V}$$

$$\lambda = Air\ Exchange\ Rate$$

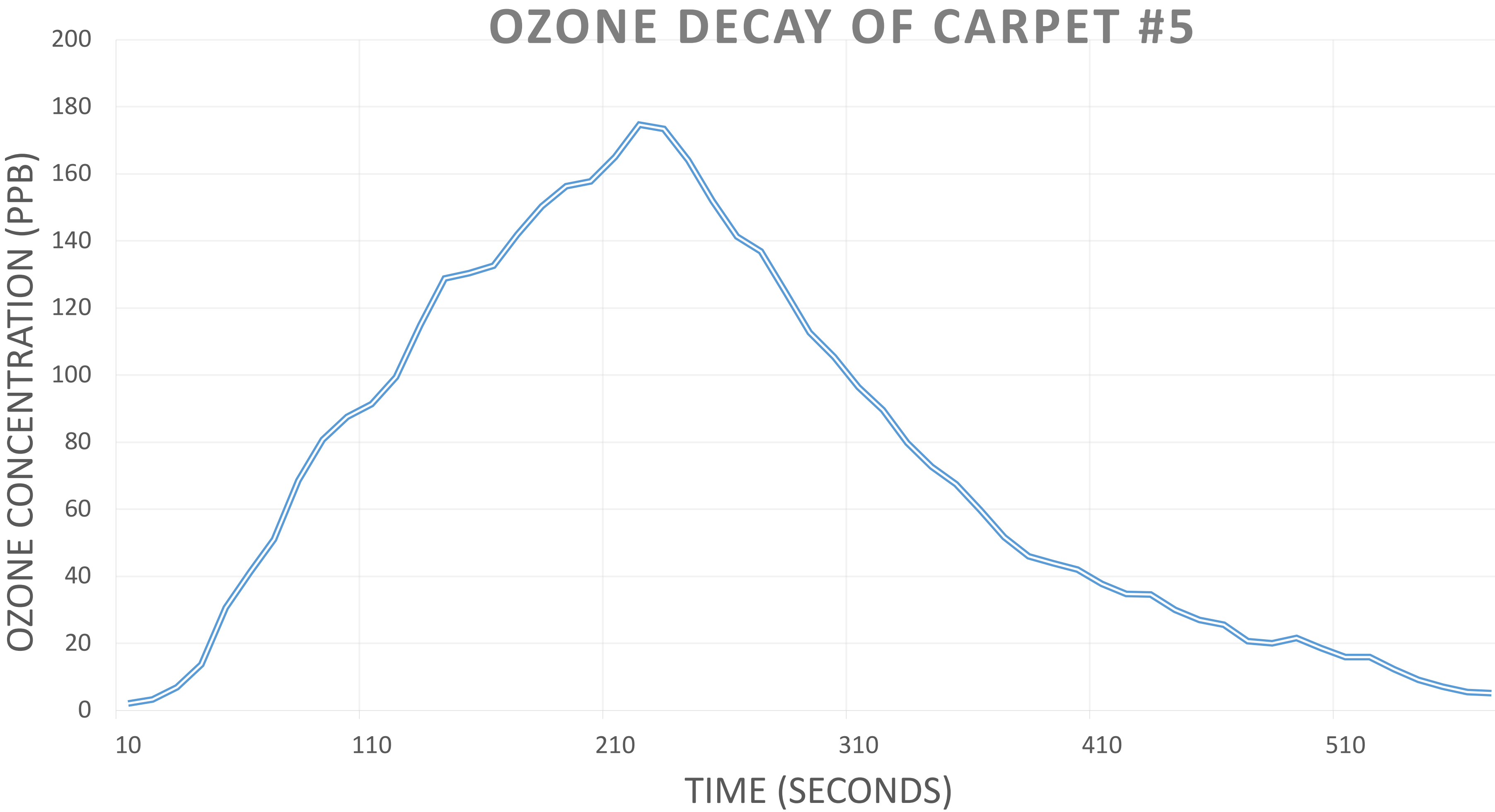
$$Q = \forall \frac{1}{\left(C_{CO_{2}\,o} - C_{CO_2}\right)} \frac{dC_{CO_2}}{dt}$$

Finding Surface Resistances

$$R_c = \frac{1}{v_d} - \frac{1}{v_{dKI}}$$

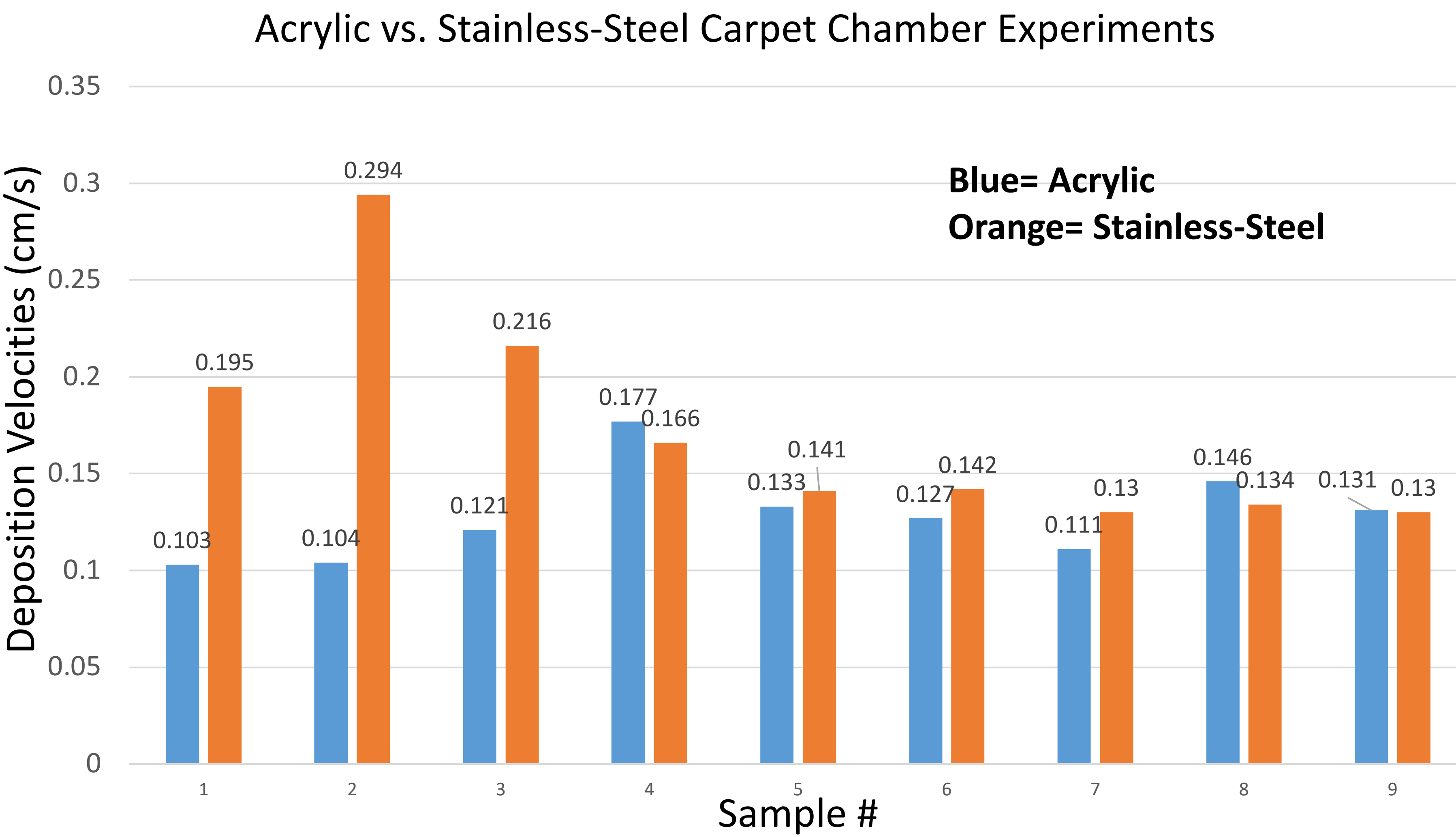


Decay



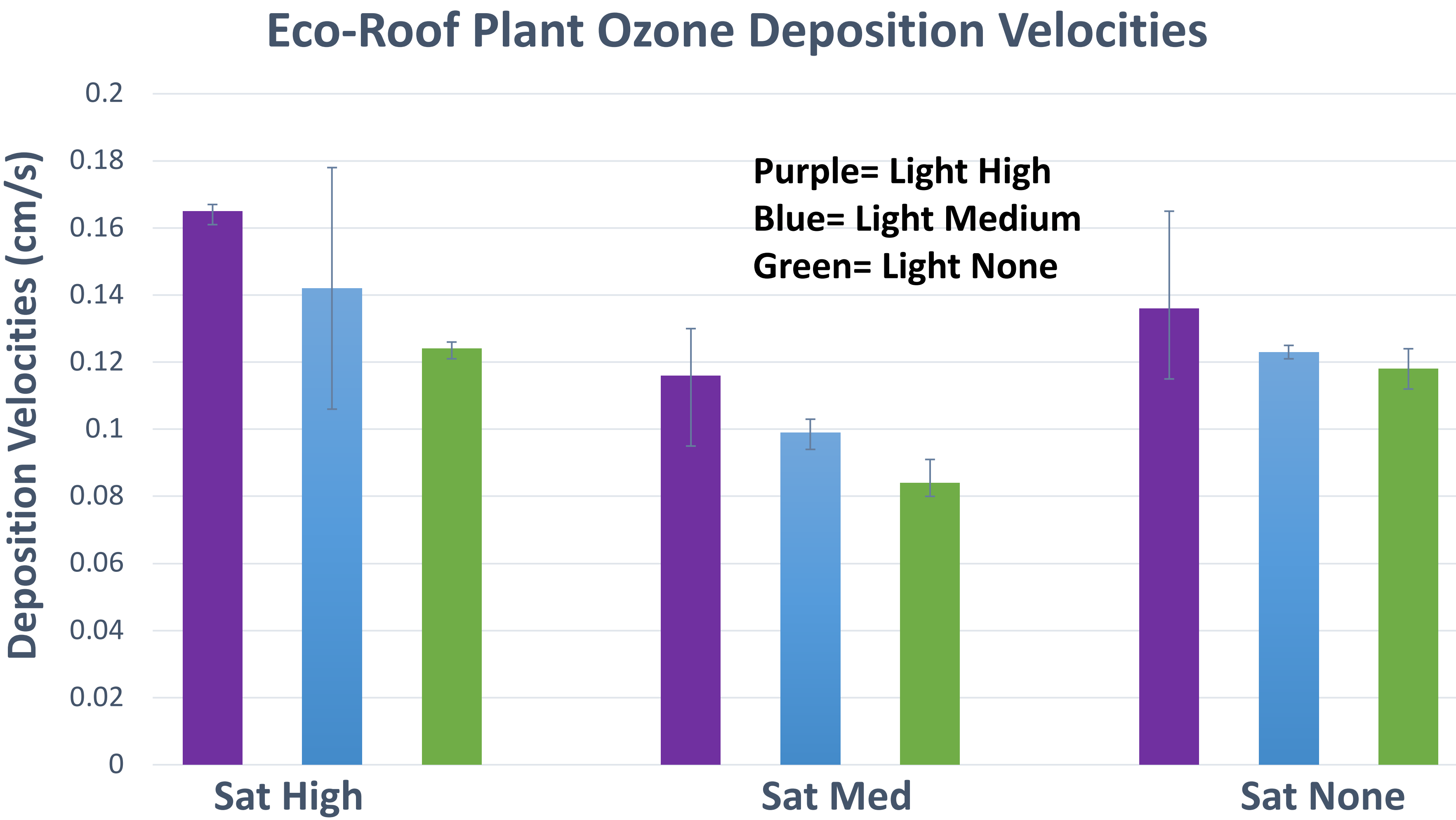
OZONE DECAY OF CARPET #5
OZONE CONCENTRATION (PPB)
200
180
160
140
120
100
80
60
40
20
0
10
110
210
310
410
510
TIME (SECONDS)

Results



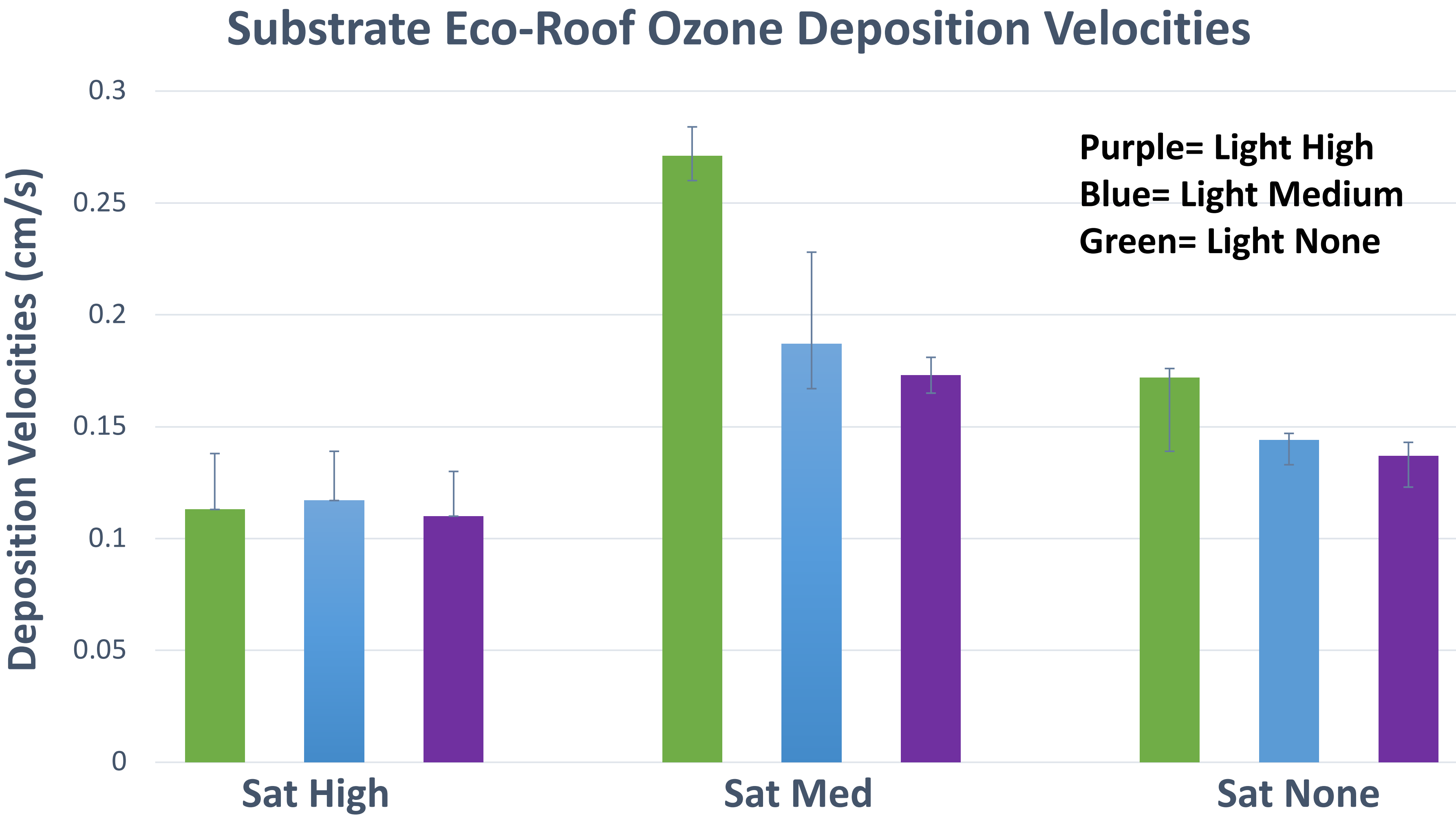
Acrylic vs. Stainless-Steel Carpet Chamber Experiments
Deposition Velocities (cm/s)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Blue= Acrylic
Orange= Stainless-Steel
0.103
0.195
0.104
0.294
0.121
0.216
0.177
0.166
0.133
0.141
0.127
0.142
0.111
0.13
0.146
0.134
0.131
0.13
1
2
3
4
5
6
7
8
9
Sample #

Results



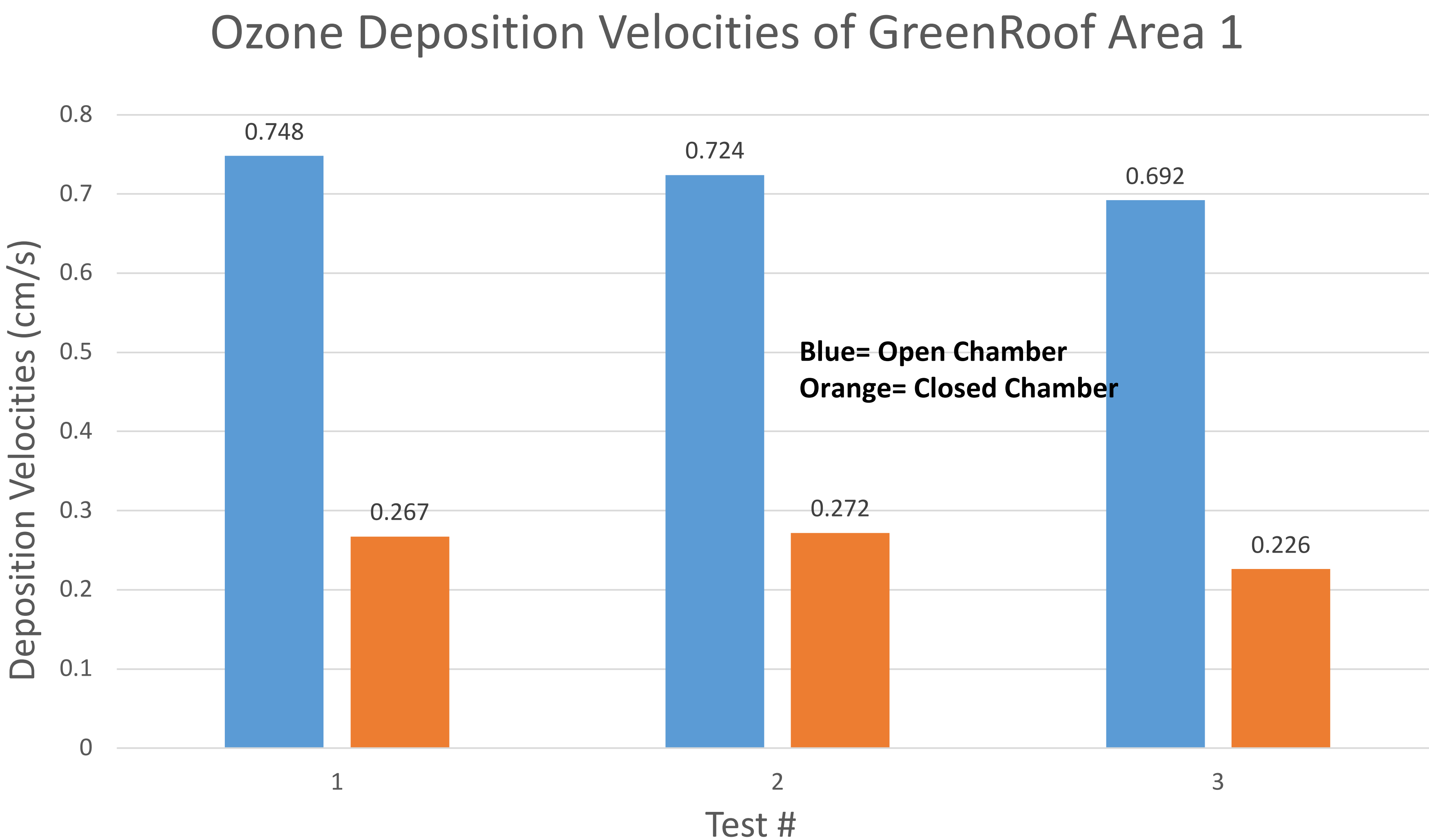
Eco-Roof Plant Ozone Deposition Velocities
Deposition Velocities (cm/s)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Purple= Light High
Blue= Light Medium
Green= Light None
Sat High
Sat Med
Sat None

Results



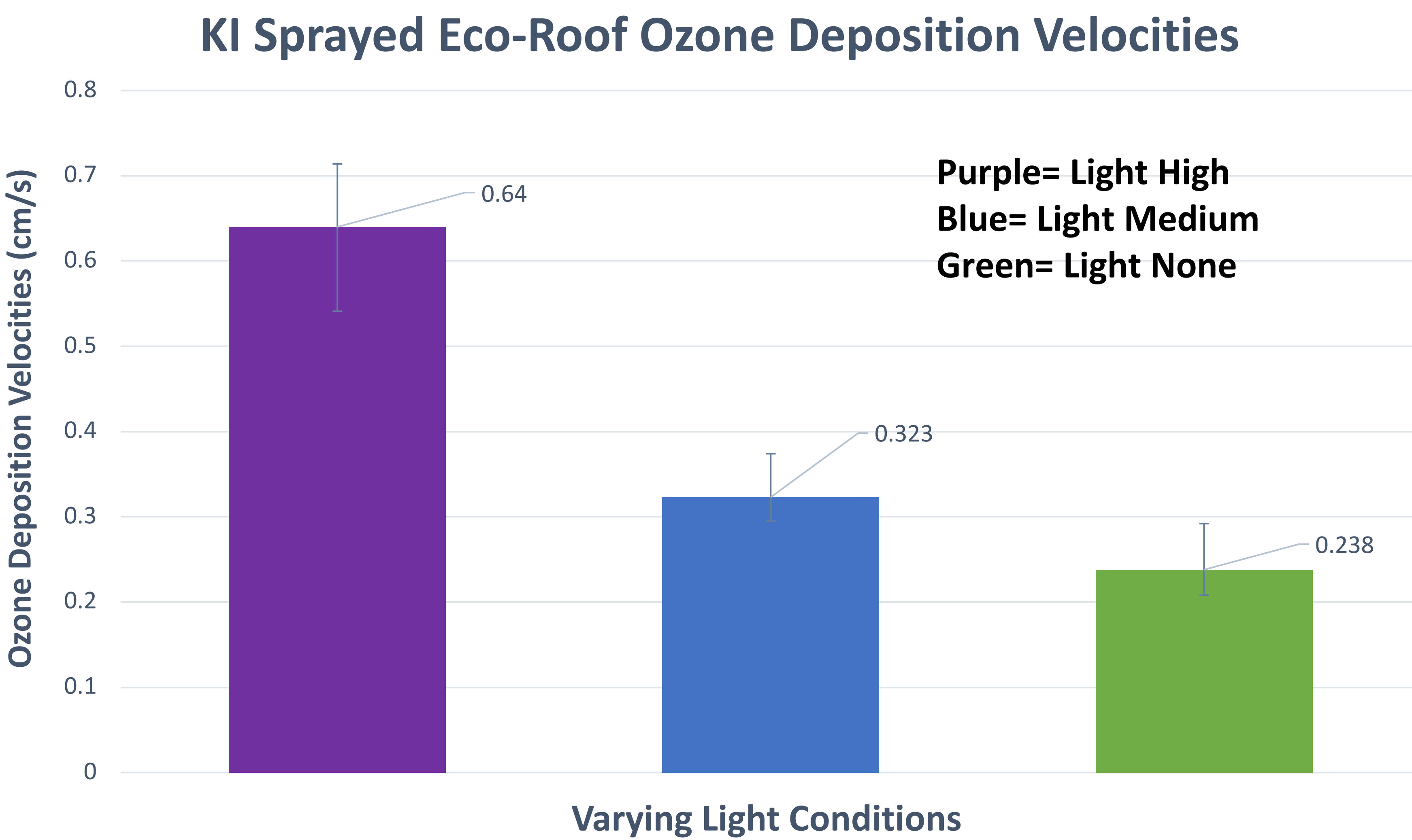
Substrate Eco-Roof Ozone Deposition Velocities
Deposition Velocities (cm/s)
0.3
0.25
0.2
0.15
0.1
0.05
0
Purple= Light High
Blue= Light Medium
Green= Light None
Sat High
Sat Med
Sat None

Results



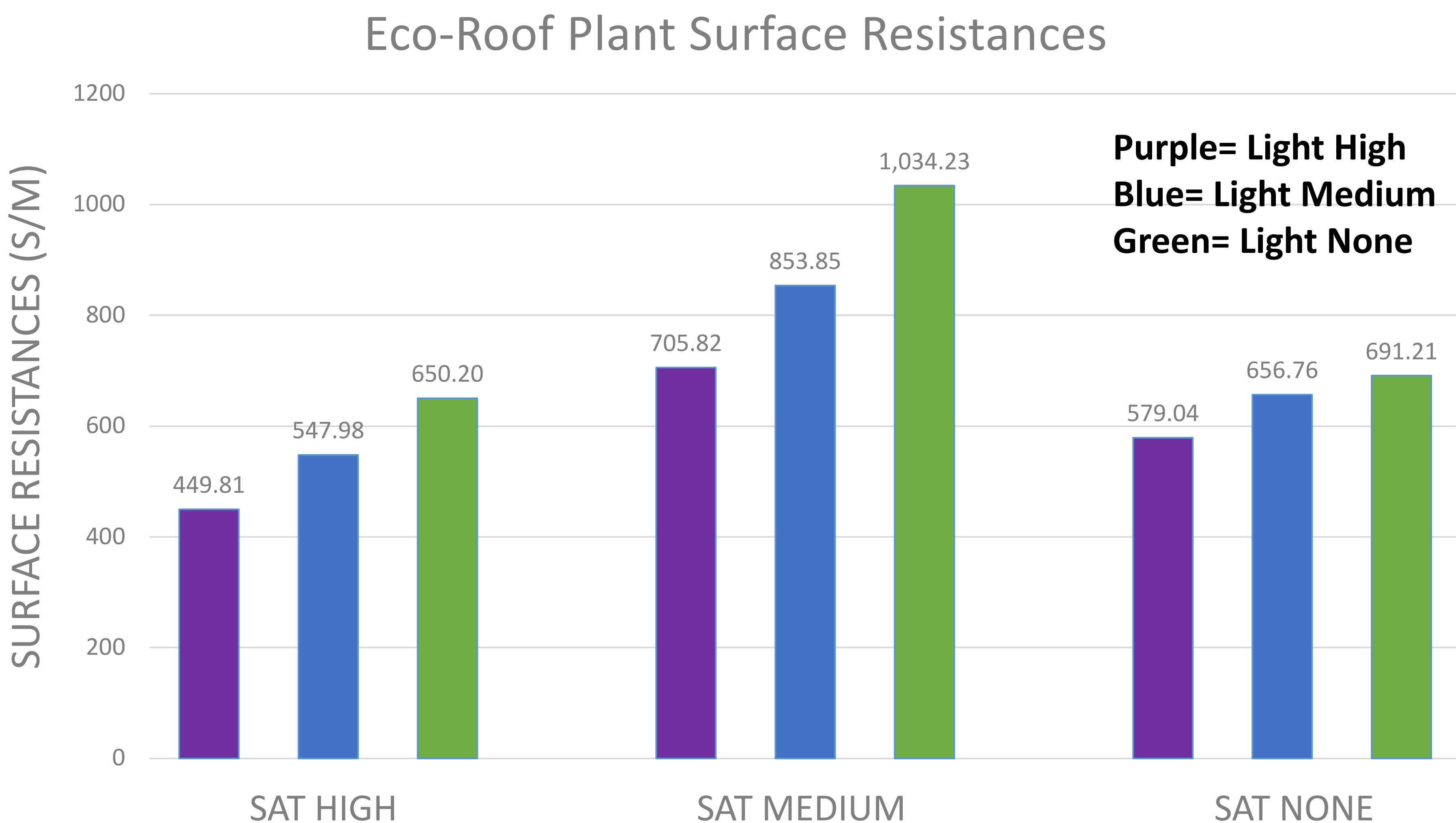
Ozone Deposition Velocities of GreenRoof Area 1
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Deposition Velocities (cm/s)
0.748
0.267
0.724
0.272
0.692
0.226
Blue= Open Chamber
Orange= Closed Chamber
1
2
3
Test #

Results



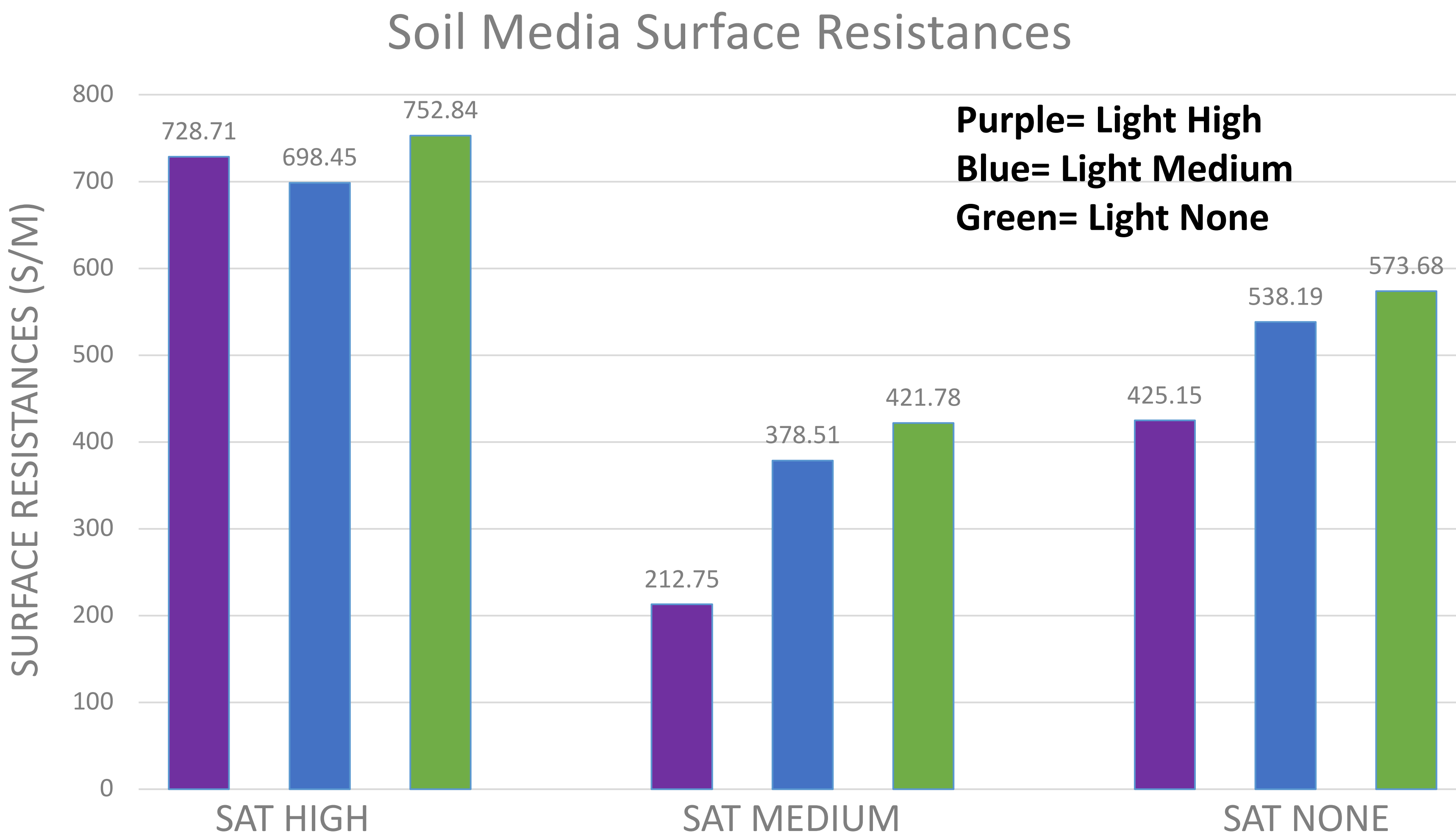
KI Sprayed Eco-Roof Ozone Deposition Velocities
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Ozone Deposition Velocities (cm/s)
0.64
0.323
0.238
Purple= Light High
Blue= Light Medium
Green= Light None
Varying Light Conditions

Results



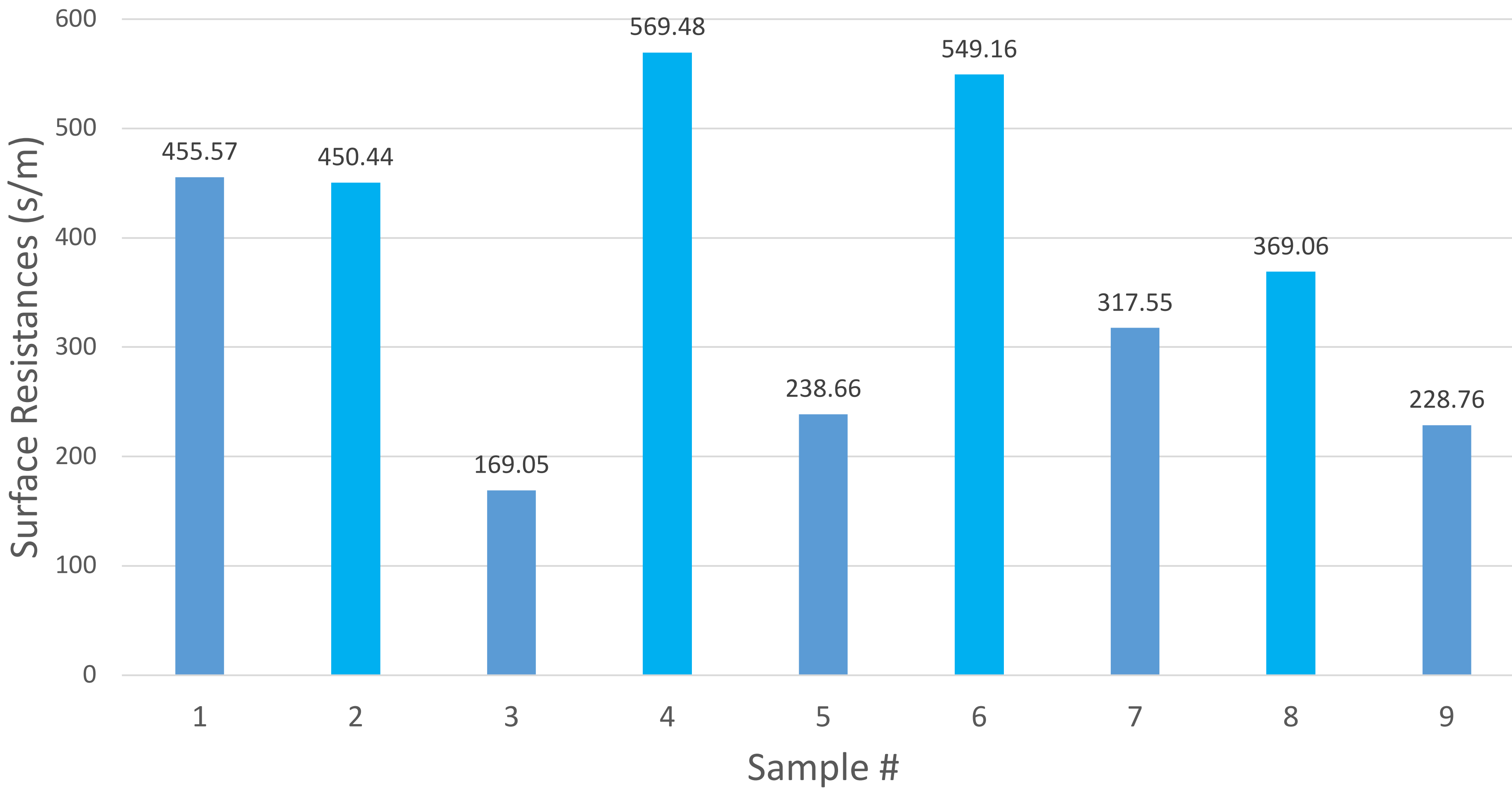
Eco-Roof Plant Surface Resistances
SURFACE RESISTANCES (S/M)
1200
1000
800
600
400
200
0
Purple= Light High
Blue= Light Medium
Green= Light None
449.81
547.98
650.20
705.82
853.85
1,034.23
579.04
656.76
691.21
SAT HIGH
SAT MEDIUM
SAT NONE

Results

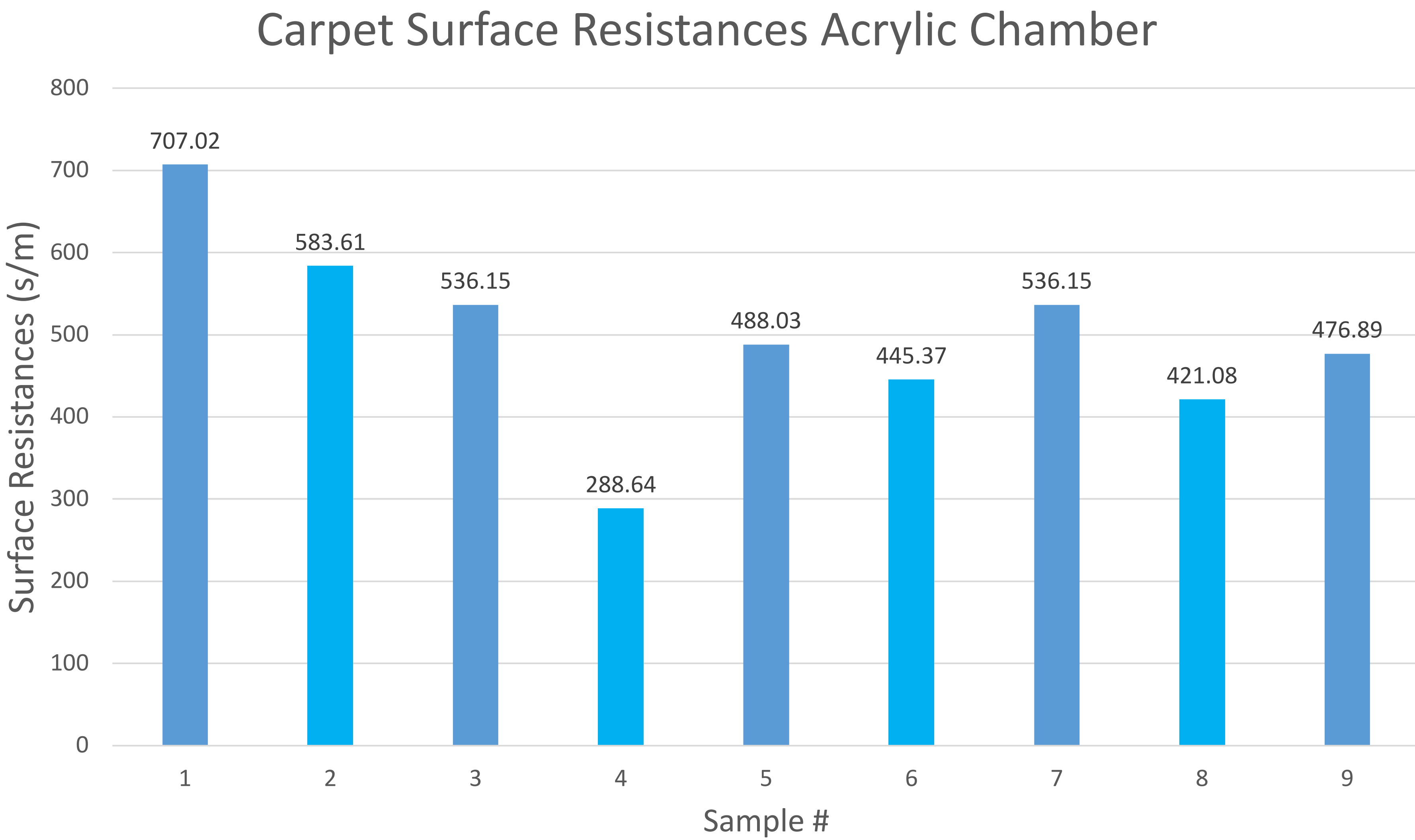


Soil Media Surface Resistances
Purple= Light High
Blue= Light Medium
Green= Light None
SURFACE RESISTANCES (S/M)
800
700
600
500
400
300
200
100
0
728.71
698.45
752.84
212.75
378.51
421.78
425.15
538.19
573.68
SAT HIGH
SAT MEDIUM
SAT NONE

Carpet Surface Resistances Stainless-Steel Chamber



Results



Carpet Surface Resistances Acrylic Chamber
800
700
600
500
400
300
200
100
0
Surface Resistances (s/m)
707.02
583.61
536.15
288.64
488.03
445.37
536.15
421.08
476.89
1
2
3
4
5
6
7
8
9
Sample #

Conclusion

- The Eco-Roof Plant yielded the highest surface resistance under no light and medium saturation at 1,034 s/m
- The Eco-Roof Soil Media under high light and medium saturation produced the lowest surface resistance at 212 s/m
- The Walmart Eco-Roof field test had greater deposition velocities than Eco-Roof lab tests

Future Work

- More Acrylic vs. Stainless Steel Chamber Comparisons for further validation
- Experiments to find the conditions for a passive ozone sink for the indoor environment
- Further studies on how aerosols and other air pollutants interact with Eco-Roofs to affect the indoor air quality
- Tests to observe the byproducts formed when ozone reacts with Eco-Roofs

Acknowledgments

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Questions

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Sources

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