Report on the Effectiveness of CosaTron Air Purification Systems in Reducing Outside Air for:

GFK Elementary School

Grand Forks, North Dakota

Contaminant Mass Balance Methodology

The Contaminant Mass Balance (CMB) calculation provides a scientific indication of the effect that CosaTron air purification systems will have on the contaminant within a controlled space. The CosaTron system accelerates the natural coagulation of particulate based on the space-charge in the room and in so doing, increases the effectiveness of the filter. In every case the amount of outside, or makeup, air can be reduced by installing CosaTron.

The calculation takes in to consideration the number of occupants, the volume, the type of activity and the filter efficiency. Values can then be calculated for 35% Make Up Air (MUA) scenario as ratified by the ASHRAE standards. We can now recalculate the amount the MUA can be further reduced by employing CosaTron air purification. In most cases the amount of MUA can be reduced by half and maintain the same level of contaminant in the space as at the 35% MUA leve.

Cotaminant Mass Balance Formula

$n := 194$ Number Of Occupants

$g := 0.93$ Contaminant Generation Rate Per Person (CFH)

$G := \frac{g \cdot n}{60}$ Total Contaminant Generation Rate (CFM) $G = 3.007$

Table 3, Chapter 11	Exhausting Effort	5.70	Mild Exercise Or Light Work	1.55
1991 ASHRAE Handbook	Strenuous Work Or Sports	3.80	Standing Or Desk Work	0.93
Carbon Dioxide Production	Moderate Exercise	2.50	Sedentary Or At Ease	0.82
			Reclining Or At Rest	0.47

$t := 0, 10 .. 240$ Time (Min) Start, Step, .. Stop

$q_3 := 20475$ Supply Air (CFM)

$q_0 := 1100$ Make Up Air Flow (CFM)

$q_2 := 0$ Infiltration Flow (CFM)

$q_1 := q_3 - q_0$ Recirculation Flow (CFM)

$q_1 = 1.938 \times 10^4$ CFM

$Cii := 325 \cdot 10^{-6}$ Initial Inside Air Concentration (ppm)

$Co := 325 \cdot 10^{-6}$ Outside Air Concentration (ppm)

$H := 9$ Ceiling Height (FT)

$A := 18453$

$V := H \cdot A$

$V = 1.661 \times 1\,ft^3$

Density Per 1000 Sq. Ft.

$dn := \frac{n}{A} 1000$

$dn = 10.513$

Air Delivered Per Sq. Ft.:

$q_4 := \frac{q_1 + q_0}{A}$ $q_4 = 1.11$

E Is Porportionality Constant For Contaminant Of Interest

E = (Deposition) (Volume)

$E := D \cdot V$

$k := 0.85$ Ventilation Effectiveness

$Fm := 0$ Filter Efficiency For Make Up

$Fr := 0$ Filter Efficiency For Recirculation

$Fmct := 0.15$ Filter Efficiency For Make Up With Cosatron

$Frct := 0.150$ Filter Efficiency For Recirculation With Cosatron

$D := .010$ Deposition Rate

$q_5 := \frac{q_0}{n}$ CFM Outside Air Per Person

$q_5 = 5.67$ CFM Per Person

$a := \frac{q_0}{q_3} 100$ $a = 5.372$ % Outside Air

$AC := q_3 \cdot \frac{60}{V}$ $AC = 7.397$ Air Changes Per Hour

Occupant Density: $\rho := \frac{A}{n}$ $\rho = 95.1\,ft^2$/ Person

Rr = Indoor Sink Removal Rate

Rr = (Deposition Rate)(Mass)

Rr = D·M

$Rr := D \cdot V \cdot Cii$

$Rr = 0.54$ CFM

Contaminant Mass Balance Equation 1

$$\frac{d}{dt}(Ci \cdot V) = k \cdot q_0 \cdot Co \cdot (1 - Fm) + k \cdot q_1 \cdot Ci \cdot (1 - Fr) + k \cdot q_2 \cdot Co - k \cdot (q_0 + q_1 + q_2) \cdot Ci + G - Rr$$

Equation 2 Ci = Cii at t = 0

$$Ci = \frac{k \cdot [q_0 \cdot (1 - Fr) + q_2] \cdot Co + G - Rr}{k \cdot (q_0 + q_1 \cdot Fm + q_2)} \left[1 - e^{-\left(\frac{k}{V}\right) \cdot (q_0 + q_1 \cdot Fm + q_2) \cdot t}\right] + Cii \cdot e^{-\left(\frac{k}{V}\right) \cdot (q_0 + q_1 \cdot Fm + q_2) \cdot t}$$

Equation 3 When R Is A First Order Function Of Ci The Solution Takes The Form :

$$Ci = \frac{[k \cdot (1 - FR) + q_2] \cdot Co + G}{k \cdot (q_0 + q_1 \cdot F1 + q_2) + E} \left[1 - e^{-\left[\left(\frac{k}{V}\right) \cdot (q_0 + q_1 \cdot Fm + q_2) + E\right] \cdot t}\right] + Cii \cdot e^{-\left[\left(\frac{k}{V}\right) \cdot (q_0 + q_1 \cdot Fm + q_2) + E\right] \cdot t}$$

Equation 4 Substituting E = DV And Equation 1 Into Equation 2 Leads To:

$$Ci = Cs \cdot e^{\frac{\alpha \cdot t}{V}} + \frac{\beta}{\alpha} \left(e^{\frac{\alpha \cdot t}{V}} - 1\right) \text{ Where}$$

$\alpha := -k \cdot q_1 \cdot Fr - k \cdot q_0 - k \cdot q_2 - D$ $\alpha = -2.596 \times$ $\alpha ct := -k \cdot q_1 \cdot Frct - k \cdot q_0 - k \cdot q_2 - I$ $\alpha ct = -5.066 \times 10^3$

$\beta := k \cdot q_2 \cdot Co + k \cdot q_0 \cdot (1 - Fm) \cdot Co +$ $\beta = 3.311$ $\beta ct := k \cdot q_2 \cdot Co + k \cdot q_0 \cdot (1 - Fmct) \cdot Co +$ $\beta ct = 3.265$

$C_1 := Cii \cdot e^{\frac{\alpha \cdot t}{V}}$ $C_2 := \frac{\beta}{\alpha} \left(e^{\frac{\alpha \cdot t}{V}} - 1\right)$ $Cct_1 := Cii \cdot e^{\frac{\alpha ct \cdot t}{V}}$ $Cct_2 := \frac{\beta ct}{\alpha} \left(e^{\frac{\alpha ct \cdot t}{V}} - 1\right)$

$C_1 =$ $C_2 =$ $Cct_1 =$ $Cct_2 =$

$C(t) := Cii \cdot e^{\frac{\alpha \cdot t}{V}} + \frac{\beta}{\alpha} \left(e^{\frac{\alpha \cdot t}{V}} - 1\right)$ $Cct(t) := Cii \cdot e^{\frac{\alpha ct \cdot t}{V}} + \frac{\beta ct}{\alpha ct} \left(e^{\frac{\alpha ct \cdot t}{V}} - 1\right)$

Converting to ppm $M(t) := C(t) \cdot 10^6$ $Mct(t) := Cct(t) \cdot 10^6$

Contaminant Concentation Without Cosatron (ppm)

By Letting (t) Approach ∞ Equation 4 Results in:

$$Mss := \left[\frac{k \cdot Co \cdot [q_0 \cdot (1 - Fm) + q_2] + G}{k \cdot (q_0 + q_1 \cdot Fr + q_2) + E}\right] \cdot 10^6$$

Contaminant Concentation With Cosatron (ppm)

$$Mssct := \left[\frac{k \cdot Co \cdot [q_0 \cdot (1 - Fmct) + q_2] + G}{k \cdot (q_0 + q_1 \cdot Frct + q_2) + E}\right] \cdot 10^6$$

Steady State Contaminant Concentration Without Cosatron

$Mss = 1.275 \times 10^3$

Steady State Contaminant Concentration With Cosatron

$Mssct = 644.54$

The Contaminant Mass Balance Calculation Formula

Results

The following are the results for the 6 Air Handling Units proposed at the GFK Elementary School.

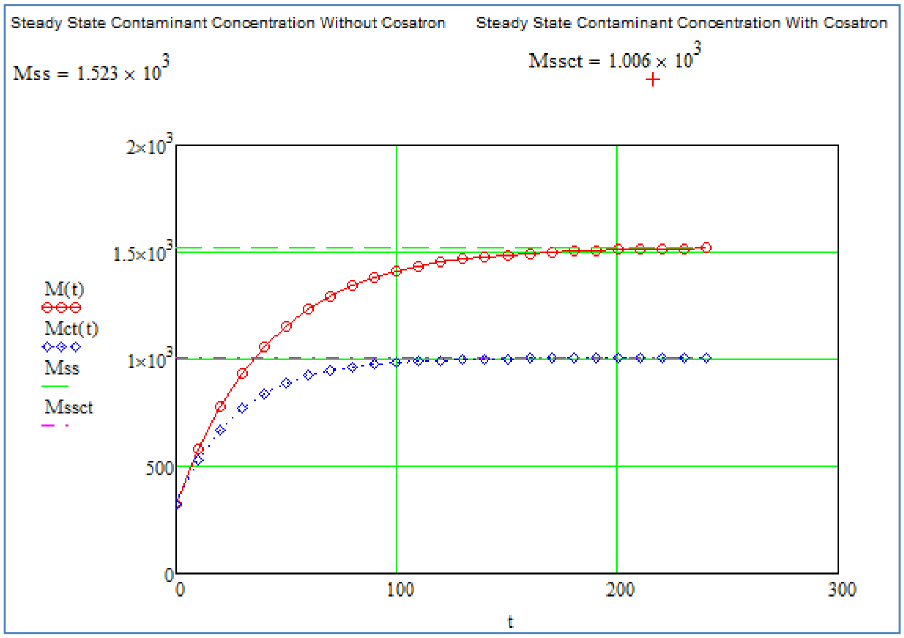
AHU #	Use	Max Occ.	SQ Ft	Total CFM	ASHRAE STD 35% MUA	MUA With CosaTron	% MUA With CosaTron	MUA Reduction
AHU 1	Classroom/office	307	16,728	16,000	$1.006X10^3$	2420	15.1	57%
AHU 2	Classroom	284	17,112	20,000	845.885	2510	12.5	64%
AHU 3	Cafeteria/reheat	245	5,411	8,300	$1.556X10^3$	1570	18.9	46%
AHU 4	Gym	85	5,580	9,000	$1.475X10^3$	1650	18.4	47%
AHU 5	Classroom	237	18,054	20,740	728.517	1940	10.1	71%
AHU 6	Classroom	194	18,453	20,475	643.728	1100	6.01	83%

Conclusion

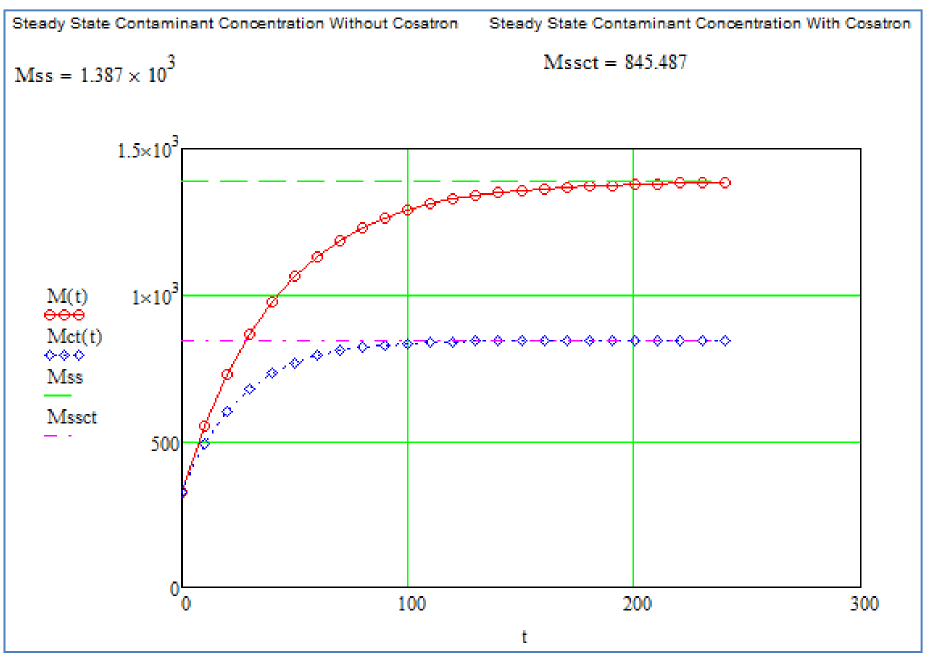
The calculations indicate that the school can expect a 61% reduction in MUA and maintain acceptable levels of contaminant as defined by the ASHRAE standard by deploying CosaTron throughout the facility.

Advanced Technology for Indoor Air Quality

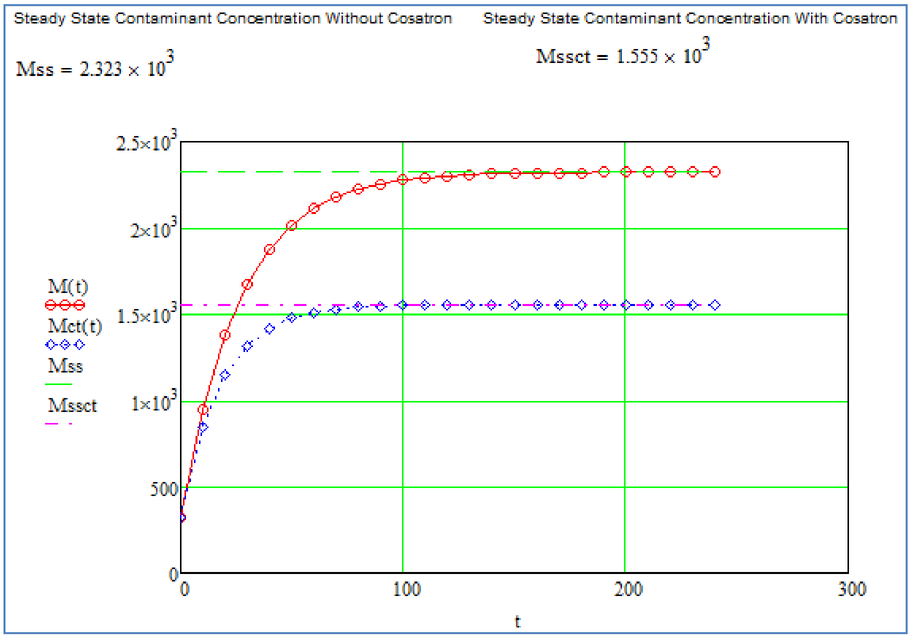
AHU 1: MUA Required to Match ASHRAE Standard: 15.1% or 57% MUA Reduction



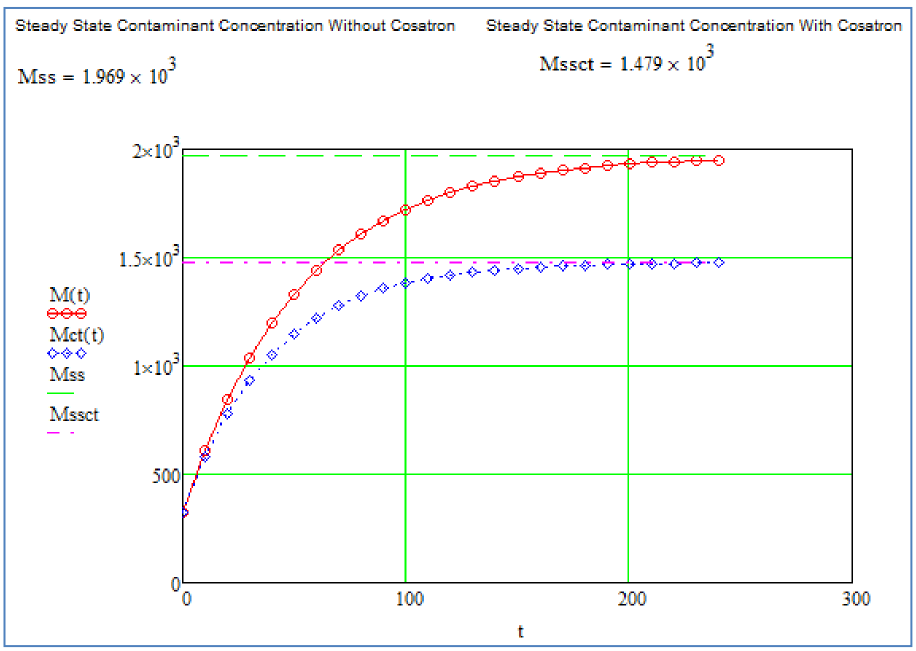
AHU 2: MUA Required to Match ASHRAE Standard: 12.5% or 64% MUA Reduction



AHU 3: MUA Required to Match ASHRAE Standard: 18.9% or 46% MUA Reduction



AHU 4: MUA Required to Match ASHRAE Standard: 18.4% or 47% MUA Reduction



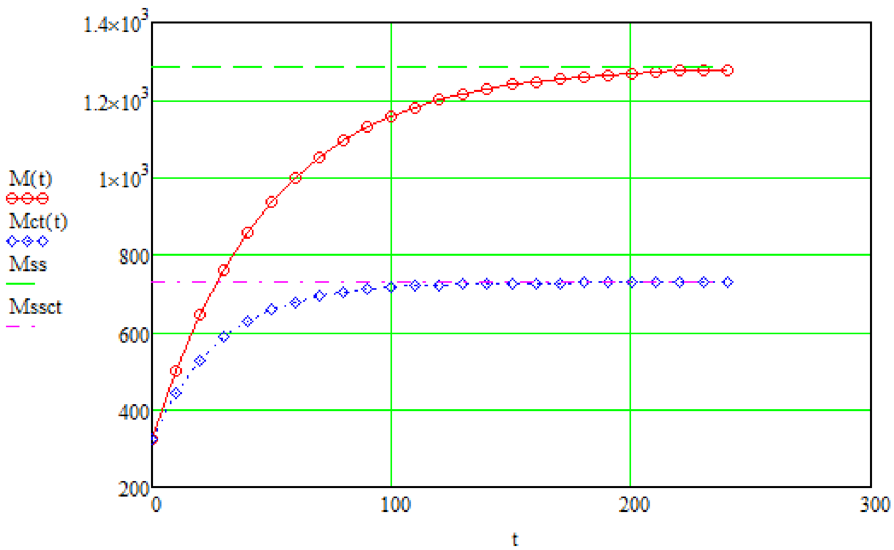
AHU 5: MUA Required to Match ASHRAE Standard: 10.1% or 71% MUA Reduction

Steady State Contaminant Concentration Without Cosatron

$Mss = 1.286 \times 10^3$

Steady State Contaminant Concentration With Cosatron

$Mssct = 728.115$



AHU 6: MUA Required to Match ASHRAE Standard: 10.1% or 71% MUA Reduction

Steady State Contaminant Concentration Without Cosatron

$Mss = 1.275 \times 10^3$

Steady State Contaminant Concentration With Cosatron

$Mssct = 644.54$