American Chemistry Council

Solvents Industry Group

Controlling Reactivity to Achieve Greater Reductions in Ozone-Forming Potential

Del Rector, Chair
Solvents Industry Group

September 25, 2007

The Issue

- Current regulations have reduced mass of emissions and total ozone formation, but:
- Not all VOCs are equal
- Mass-based limits are leading formulators to select higher-reactivity VOC's in many categories
- Leading to missed opportunities for additional ozone reductions (less reduction than desired/expected).
- A shift to lower reactivity solvents for sustainable approach requires regulatory help to get there.

The Analysis

- Used ARB Architectural Coatings Surveys and Reactivity Analysis reports for 2000 and 2004.
- Calculated maximum ozone formation per pound of VOC emitted (OFP per pound of VOC).
- Of the 38 categories with sufficient information, 24 categories showed increases in OFP per pound of VOC ranging from 1.6% to 88.5%
- In total, all 38 categories analyzed showed an increase of 7.7% OFP per pound VOC (equates to missed opportunity)

ARB Survey Data: 2004 versus 2000

Categories showing increased OFP per pound of VOC emitted.

2004 versus 2000 ARB Architectural Coatings VOC and Reactivity Data

					All VOC levels		
	Emissions, lb/day		TOFP, lb/day		Ratio, lb TOFP/lb VOC		% Change
AIM Coating Category	2000	2004	2000	2004	2000	2004	OFP/lb
Floor	1,742	1,655	7440	13320	4.27	8.05	88.5%
Bond Breakers	137	340	340	1540	2.48	4.53	82.6%
Traffic Marking	6,071	3,337	8680	8480	1.43	2.54	77.7%
Mastic Texture	1,359	1,145	1820	2260	1.34	1.97	47.3%
Bituminous Roof	8,652	1,288	14400	3100	1.66	2.41	44.6%
Form release Compounds	1,222	1,600	1420	2640	1.16	1.65	42.0%
Quick Dry Primer/Sealer/UC	12,970	2,126	14980	3380	1.15	1.59	37.6%
Stains - Opaque	2,729	953	5880	2740	2.15	2.87	33.4%
Primer, Sealer, Undercoater	17,096	13,090	38220	36760	2.24	2.81	25.6%
Waterproofing Masonry Sealers	2,597	4,707	7380	16700	2.84	3.55	24.9%
Dry Fog	2,192	1,633	3720	3440	1.70	2.11	24.1%
Nonflat LG	8,104	13,288	18720	37180	2.31	2.80	21.1%
Faux Finishing	433	685	1020	1940	2.36	2.83	20.2%
Roof	1,145	800	2840	2380	2.48	2.98	20.0%
Flat	31,195	27,605	69680	73440	2.23	2.66	19.1%
Pretreatment Wash Primer	197	22	460	60	2.33	2.74	17.4%
Industrial Maintenance	30,888	8,449	92780	29740	3.00	3.52	17.2%
Nonflat HG	7,299	2,674	17760	7620	2.43	2.85	17.1%
Nonflat MG	31,156	23,468	69540	59280	2.23	2.53	13.2%
High Temperature	164	99	420	280	2.56	2.84	11.1%
Swimming Pool	110	38	520	200	4.75	5.21	9.9%
Bituminous Roof Primer	729	482	1400	1000	1.92	2.07	8.0%
Sanding Sealers	274	482	580	1060	2.12	2.20	3.8%
Other	44	49	140	160	3.19	3.24	1.6%
Total	216,597	186,285	489,760	454,220	2.26	2.44	7.8%

Example: Non-Flat Medium Gloss

- Year 2000: 69,540 ppd ozone/ 31,156 ppd VOC = 2.23# ozone per # VOC
- Year 2004: 59,280 ppd ozone/ 23,468 ppd VOC = 2.53# ozone per # VOC
- Implies 7000 ppd lost opportunity in ozone reduction.

Have Coatings Compliant with AQMD 2008 Limits Yielded the Expected Ozone Benefit?

- Compared the OFP per pound of VOC for 2000 & 2004 coatings with the subset of 2004 coatings compliant with AQMD 2008 limits.
- 11 categories in 2004 had OFP/pound of VOC that was higher for the subset of AQMD 2008 compliant coatings.
- Another 5 categories in 2004 were higher than the 2000 average for the AQMD 2008 compliant coatings.
- For those 16 categories, ozone reduction opportunities were missed between 2000 and 2004 and probably continue to be missed.

OFP Per Pound VOC @ VOC ≤ AQMD 2008 Limits

2004 versus 2000 ARB Architectural Coatings VOC and Reactivity Data

	All VOC levels				2004 @ ≤ AQMD Limits		
	Ratio, lb TOFP/lb VOC		% Change	SCAQMD	tpd	tpd	Ratio[6] @
AIM Coating Category	2000	2004	OFP/lb	VOC Lim.[7]	Emiss[6]	OFP[6]	≤ Limit
Bond Breakers	2.48	4.53	82.6%	350	0.16	0.64	4.0
Traffic Marking	1.43	2.54	77.7%	100	1.12	1.73	1.5
Mastic Texture	1.34	1.97	47.3%	300	0.33	1.08	3.3
Primer, Sealer, Undercoater	2.24	2.81	25.6%	100	1.08	2.7	2.5
Waterproofing Masonry Sealers	2.84	3.55	24.9%	100	0.14	0.7	5.0
Dry Fog	1.70	2.11	24.1%	150	0.05	0.11	2.2
Nonflat LG	2.31	2.80	21.1%	50	0.04	0.13	3.3
Faux Finishing	2.36	2.83	20.2%	350	0.22	0.65	3.0
Roof	2.48	2.98	20.0%	100	0.27	0.67	2.5
Flat	2.23	2.66	19.1%	50	0.39	0.93	2.4
Nonflat HG	2.43	2.85	17.1%	50	0.01	0.03	3.0
Nonflat MG	2.23	2.53	13.2%	50	0.09	0.25	2.8
Bituminous Roof Primer	1.92	2.07	8.0%	350	0.18	0.4	2.2
Lacquers	2.73	2.55	-6.9%	275	0.38	1.17	3.1
Wood Preservatives	1.74	1.55	-11.1%	350	0.61	0.95	1.6
Waterproofing Sealers	2.30	1.95	-15.2%	100	0.07	0.19	2.7
Total	2.26	2.44	7.8%				

Example: Non-Flat Medium Gloss

- For 2004, coatings @ ≤ 50 g/L VOC:
  OFP = 0.25 tpd
  VOC = 0.09 tpd

- OFP per pound VOC = 0.25/0.9 = 2.8

- 2004 Average for all NF MG coatings = 2.53

- 2000 Average for all NF MG coatings = 2.23

How much possible ozone reduction has been and will continue to be missed?

- Assume SCAQMD accounts for 45% of the volume in each category.
- 45% of volume x Overall MIR (pounds ozone per gallon) = predicted OFP
- Use % change in OFP/pound of VOC starting in 2000 to calculate pounds of ozone produced each year as a result of the change.
- Implies 1.4 million pounds ozone reduction has been or will be missed with mass-based regulations.

Calculation of Missed Opportunity

Based on SCAQMD VOC Limits and Coating Volumes

AIM Coating Category	45% of Reported Volume gpy	Overall MIR @ ≤ limit # O^3/gallon [8]	OFP (OMIR* 45% Vol)	% ratio @ ≤ Limit Increased	Missed Ozone Oppty, ppy
Bond Breakers	84,503	Not Shown		38.0%	
Traffic Marking	996,503	0.21	209,266	7.4%	15,573
Mastic Texture	365,676	0.1	36,568	59.1%	21,603
Primer, Sealer, Undercoater	4,682,569	0.22	1,030,165	10.6%	108,940
Waterproofing Masonry Sealers	685,560	0.21	143,968	43.2%	62,152
Dry Fog	169,968	0.23	39,093	22.9%	8,934
Nonflat LG	5,414,354	0.25	1,353,589	28.9%	391,525
Faux Finishing	136,715	0.15	20,507	20.2%	4,152
Roof	639,318	0.28	179,009	0.1%	114
Flat	16,771,806	0.28	4,696,106	6.3%	297,152
Nonflat HG	767,545	0.33	253,290	18.9%	47,844
Nonflat MG	9,056,547	0.24	2,173,571	19.6%	427,077
Bituminous Roof Primer	30,641	Not Shown		13.6%	
Lacquers	583,345	0.24	140,003	11.2%	15,708
Wood Preservatives	78,231	Not Shown			
Waterproofing Sealers	731,990	0.07	51,239	15.4%	7,867
Total					1,408,640

Example: Non-Flat Medium Gloss

- 2004 volume = 20.1 million gallons
  45% = 9.1 million gallons
- Overall MIR at VOC ≤ 50 g/L = 0.24 # O3 per gallon
- TOFP = 0.24 #/gallon * 9.1 M gallons = 2.17 M# ozone
- OFP/pound VOC increased 19.6% v 2000
- 0.196 * 2.17 M# O3 = 427K # O3 missed opportunity.

Architectural Flat Coatings
2004 vs 2000 ARB Data

- Volume of coating sales increased 7%
- SWA* VOC decreased from 96 to 82 g/l
- Total emissions (mass) decreased 11%
- SWA MIR was constant at 0.06 #/#
- Total OFP** increased 5.4% (1.88 tpd)

- ***Sales-weighted average**
- ****Ozone-forming potential**

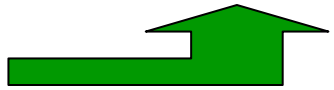
We Can Do Better

- Lower-reactivity formulation options exist.
- Could produce significant reductions in OFP for solvent-based and water-based coatings.
- Mass-based regulations provide no incentive to achieve those greater gains

Architectural Flat Coatings
Some Reformulation Options

Category	Ingredient	Ingred. MIR	Qty, t/d	Max OFP, t/d	Probable Substitute	MIR	OFP
Flat	Ethylene Glycol	3.63	3.48	12.65	Propylene Glycol	2.75	9.57
	2,2,4-Trimethyl-1,3-Pentanediol monoisobutyrate	0.89	6.46	5.75			5.75
	Propylene Glycol	2.75	1.84	5.05			5.06
	Total		11.78	23.45			20.38
Potential OFP Reduction, tpd							3.07

13% Reduction



Assumes full replacement of EG with PG, both at the same mass.

Solvent-Based Coatings Formulation Options

- The 2005 ARB AIM survey report indicates 4.09 tpd of aromatic hydrocarbon VOC emitted.
- This yields 29.69 tpd of TOFP from these materials.
- Simple reformulation choices exist using aliphatic and oxygenated alternatives that could reduce the use of high-reactivity aromatics and lead to significant OFP reduction.
- If replacements had avg MIR ≈ 2.25, we calculate an ozone potential reduction of 20 tpd

Conclusion

- Mass-based regulations are not achieving the ozone reductions predicted.
- Increased and more certain ozone reductions are possible with reactivity-based regulations.
- Product performance compromises would be less likely to occur.
- We stand ready to help.

Data Sources

- 1: ARB 2005 Architectural Coatings Survey Report, Table 11-2, pg. 11-3 to 11-4.
- 2: 2001 ARB Architectural Coatings Reactivity Analysis, Table 2-2, pg. 2-6 to 2-8
- 3: 2005 ARB Architectural Coatings Reactivity Analysis, Table B-3, Appendix B, pg. B-7 to B-9.
- 4: 2001 ARB Architectural Coatings Reactivity Analysis, Table 2-6, pg 2-26 to 2-27
- 5. 2005 ARB Architectural Coatings Reactivity Analysis, Table 2-2, pg. 2-5 to 2-6
- 6: 2005 ARB Architectural Coatings Reactivity Analysis, Tables B-1 & B-2, Appendix B, pg. B-1 to B-6.
- 7. 2008 VOC limits from SCAQMD Rule 1113
- 8: 2005 ARB Architectural Coatings Reactivity Analysis, Table B-7, Appendix B, pg. B-17 to B-19.