ANGUS®
CHEMICAL COMPANY

IMPROVING INDOOR AIR QUALITY WITH AMINO ALCOHOLS

MARK LANGILLE
ANGUS Chemical Company
1500 E. Lake Cook Rd., Buffalo Grove, IL 60089, United States

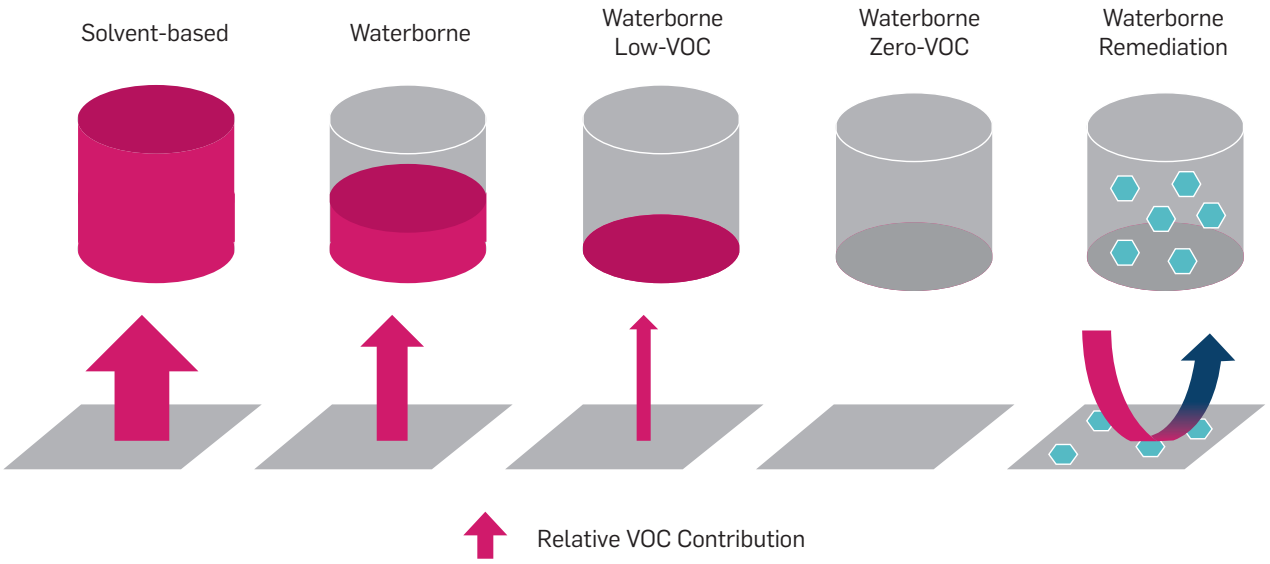
ROMAIN SEVERAC
ANGUS Chemical Company
6 Avenue du Marais, Argenteuil, 95100, France

ABSTRACT

Amino alcohols based on ANGUS chemistry can assist formulators in creating more environmentally friendly paints and coatings. Multifunctional additives from ANGUS can be used to create low- and zero-VOC waterborne formulations, as well as low emissive coatings that qualify for green label certification programs. Amino alcohols are also highly effective formaldehyde scavengers that can be used to create functional coatings that improve indoor air quality. The level of hazardous air pollutants can be five times higher in indoor air than outdoor air. Chronic exposure to these invisible toxins, such as formaldehyde, can create long-term health problems. An attractive solution to reducing indoor formaldehyde levels is through a chemical remediation or scavenging system. One of the emerging trends for the effective removal of indoor air contaminants is the use of functional coatings. We demonstrate how the unique functionality of amino alcohols can help improve indoor air quality by providing high-efficiency formaldehyde scavenging performance when used in waterborne architectural paints. Amino alcohol additives are highly effective at low dosages and do not require major reformulation work, enabling the creation of functional coatings to improve indoor air quality.

INTRODUCTION

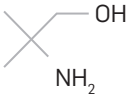
Driven by environmental, health, and safety concerns, coating technologies have undergone a dramatic shift in the past few decades. Most of this movement has been driven by the reduction of VOCs and other hazardous materials in coating formulations. The continuous development and improvement of waterborne technologies has enabled many solvent-based systems to be replaced with waterborne chemistries that contain significantly lower VOC content than their solvent-based counterparts. VOC levels have been pushed even lower by the development of low-VOC and zero-VOC water-based formulations. A continuation of this trend emerging in the global coatings industry has been focused on the development of functional coatings that not only limit emissions of VOCs into the environment but extract and remove VOCs that have originated from other sources. A functional coating with VOC remediation capability could improve indoor air quality and provide a means to scavenge VOC emissions from sources that have proven to be more challenging to address.



Scheme depicting the evolution of more environmentally friendly paints and the emergence of VOC remediation technologies.

ANGUS PRODUCTS FOR IMPROVING INDOOR AIR QUALITY

ANGUS offers a unique set of materials that can assist formulators in creating paints and coatings that improve indoor air quality. These include multifunctional additives that can be used to create zero-VOC waterborne formulations and formulations that have low emissions that can qualify for green labeling programs. These additives can also be used to create functional coatings that scavenge airborne formaldehyde from indoor environments.



AMP-95™
2-Amino-2-methyl-1-propanol

AEPD™ VOX 1000
2-Amino-2-ethyl-1, 3-propanediol

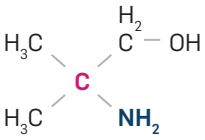
TRIS AMINO™
Tris (hydroxymethyl) aminomethane

Material	Molecular Weight (g/mol)	pKa	pH of 1% Amine Solution	Boiling Point (°C)	Melting Point (°C)	Flash Point (°C)	Vapor Pressure (Pa)	Density, 20°C (g/mL)
AMP-95	89.1	9.7	11.7	165	-11	86	10.7	0.93
AEPD VOX 1000	119.2	8.8	11.0	283	-24	>100	0.27	1.08
TRIS AMINO	121.1	8.1	10.4	>300	170	>100	0.0003	1.35

ADDITIVES FOR ZERO-VOC COATINGS

AMP-95 can be used in the United States and Canada to formulate zero-VOC waterborne coatings, while AEPD VOX 1000 can be used in Europe and China to meet zero-VOC regulations.

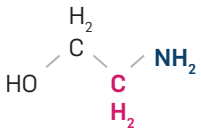
AMP is the only organic amine to have a VOC exemption status from the U.S. Environmental Protection Agency (EPA) and the Government of Canada. The EPA wrote in their direct final rule that "AMP's performance as a multifunctional neutralizer, combined with its reduced ozone potential and favorable toxicity data, makes this product a preferred one compared to more toxic chemicals used for the same purpose."



AMP

(2-amino-2-methyl-1-propanol)

Carbon atom bonded to the nitrogen is not bonded to any hydrogen atoms



MEA

(monoethanolamine)

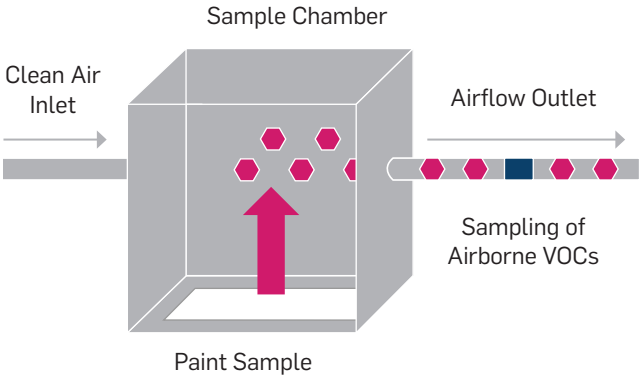
Carbon atom bonded to the nitrogen is also bonded to **two abstractable hydrogens**

AMP, as well as AEPD and TRIS AMINO, lack abstractable hydrogens in their molecular structure. The absence of an abstractable hydrogen leads to exceptional photochemical stability. In the case of AMP, this limits the generation of peroxy radicals, which in turn limits the generation of ground level ozone and smog. This chemical feature was an important contributing factor in the decision to exempt AMP from VOC status. The photostability of these materials also imparts excellent non-yellowing characteristics that can be beneficial for color stability in paint formulations.

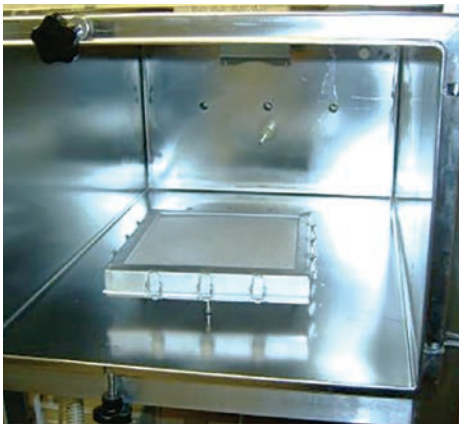
AEPD VOX 1000 is considered a low-VOC additive in the U.S., but with a boiling point > 250°C it is not considered a VOC in Europe or China and can be used to formulate zero-VOC paints and coatings in those regions. AEPD VOX 1000 also has an extremely low odor, making it an ideal choice for odorless paints in any region.

LOW VOLATILE EMISSIONS AND GREEN LABEL CERTIFICATIONS

Green certifications are increasingly looking at measured emissions from coatings to assess qualification. Products like AMP-95 and AEPD VOX 1000 can be used to formulate low-emissive coatings.



Schematic of a small-scale emissions testing chamber.



Region	Standard	AEPD VOX 1000	AMP-95
United States/Canada	CDPH/EHLB/Standard Method V1.2 (Sect. 01350)	Below detection limit	Below detection limit
Europe	ISO 16000-6	Below detection limit	Trace levels detected
China	JG/T 481-2015	Below detection limit	Not evaluated

Formulations containing AEPD VOX 1000 and AMP-95 were evaluated for volatile emissions. Following regional emissions testing protocols from the United States/Canada, Europe, and China, representative architectural paint formulations from each region were prepared and evaluated.

AEPD VOX 1000

- Always found to be below detection limits
- Did not contribute to total VOC emissions

AMP-95

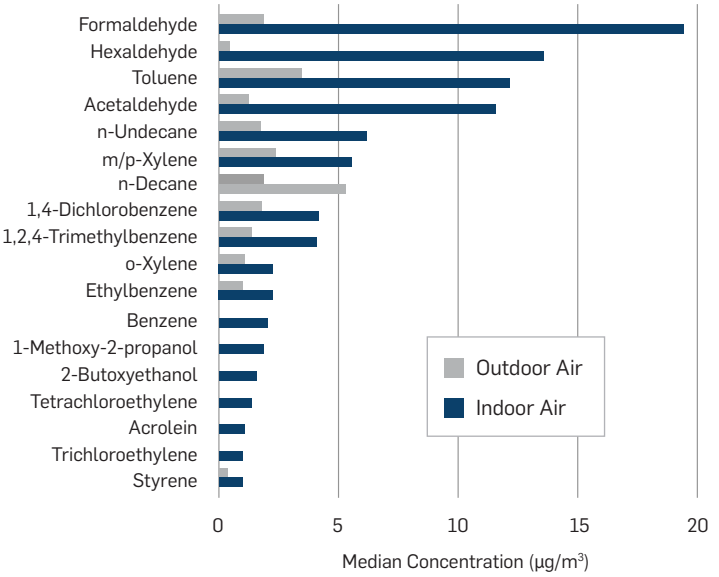
- Ability to detect depends on test method and/or formulation
- When detectible, the emissions were low and did not greatly contribute to the total volatile emissions from the coating

Results from this type of emission testing are often needed for coatings to qualify for various green label certifications, such as Greenguard or LEED. The paints formulated in this study for the United States/Canada test method with either AEPD VOX 1000 or AMP-95 would have qualified for such labels based on their emission testing results.

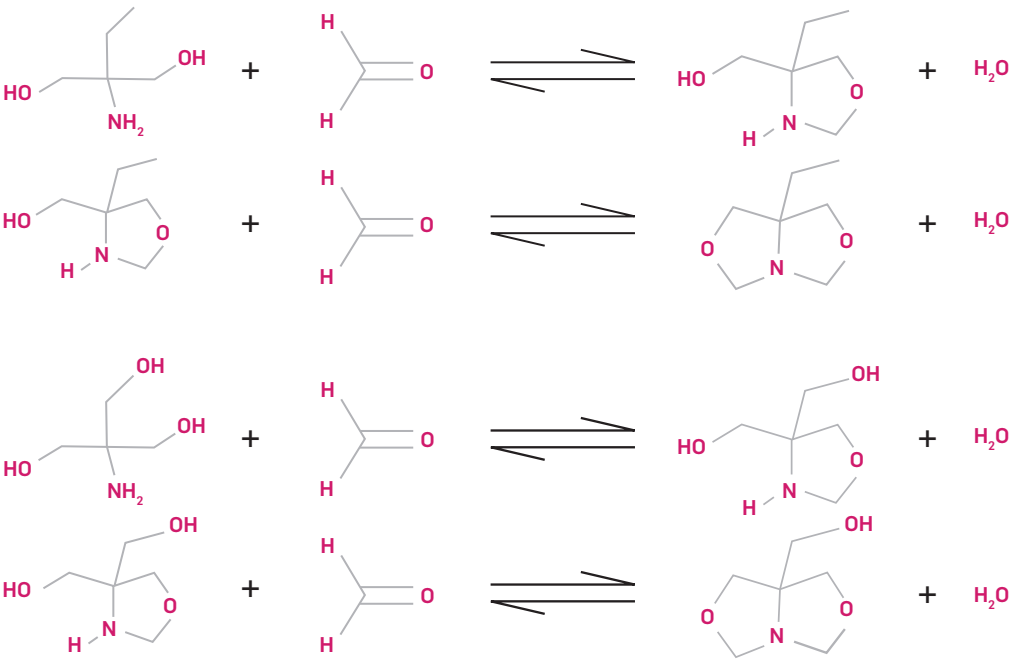
FORMALDEHYDE SCAVENGING

ANGUS amino alcohols such as AEPD VOX 1000 and TRIS AMINO can be used to create functional coatings that scavenge formaldehyde from indoor environments.

Concentrations of pollutants are found to be significantly higher in indoor air than outdoor air.[1] Furthermore, among the most prevalent VOCs found in indoor air, aldehydes account for three of the four found at highest concentrations, with formaldehyde being the most prevalent.[2] Formaldehyde poses serious health risks associated with respiratory issues, asthma symptoms, and carcinogenicity.[3] The U.S. EPA considers formaldehyde a probable human carcinogen[4] while the U.S. National Toxicology Program (NTP) lists formaldehyde as known to be a human carcinogen.[5] Sources of formaldehyde are numerous and include furniture, cabinetry, flooring, carpets, electronics, household cleaning products, and open stoves and heaters. Approaches to reduce formaldehyde levels by targeting reductions from each individual source of formaldehyde presents a significant challenge. A more attractive solution would be to engineer remediation technologies into existing building materials that are commonly used within indoor environments.

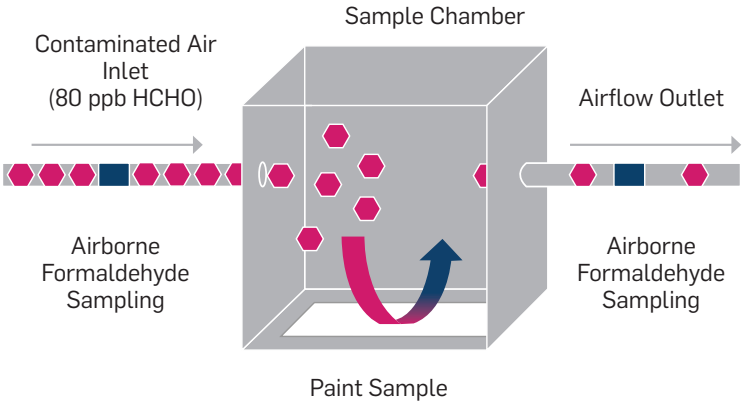


Median concentration of indoor and outdoor air pollutants from a study of French households, adapted from Reference 2.



Reaction of AEPD with two equivalents of formaldehyde to yield a bisoxazolidine.

Reaction of TRIS AMINO with two equivalents of formaldehyde to yield a bisoxazolidine.



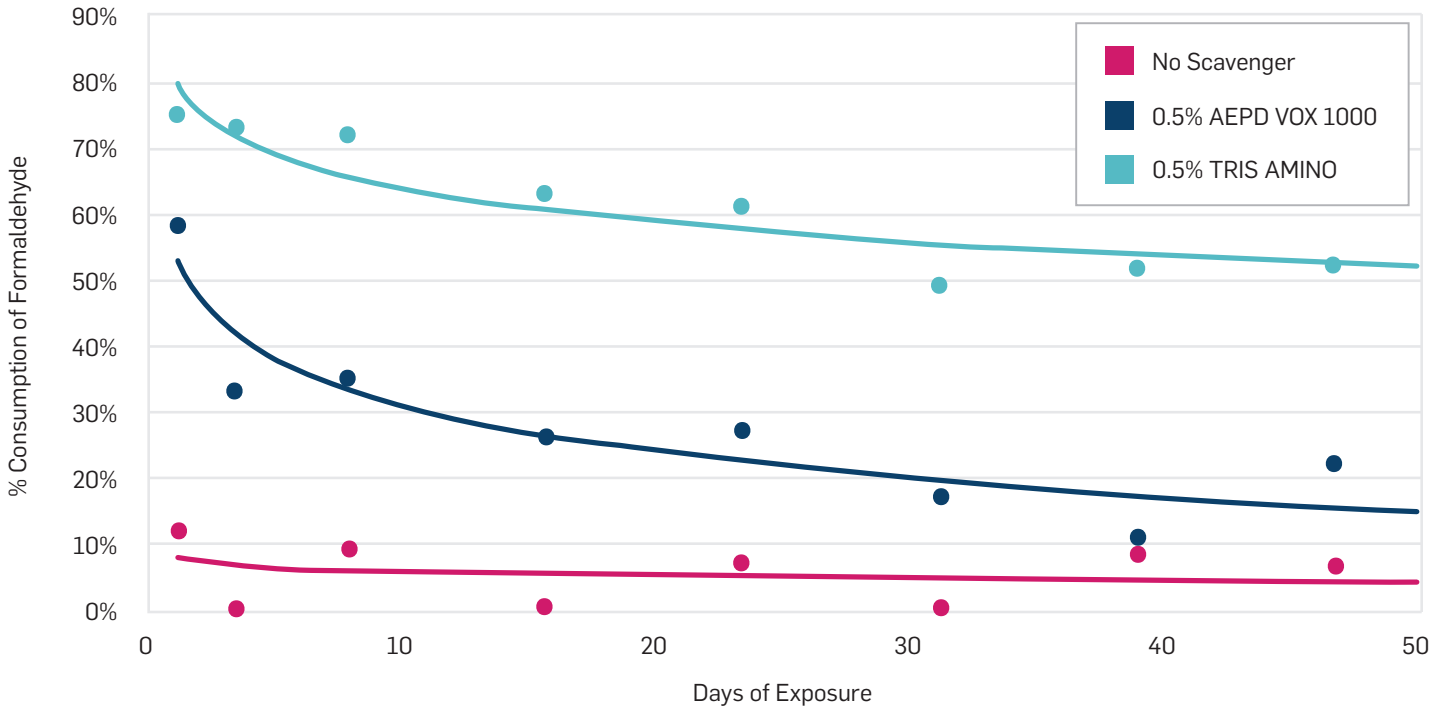
Schematic of a small-scale testing chamber to monitor formaldehyde scavenging performance of a coating.

Three coating samples were prepared:

- 0.5% AEPD VOX 1000 on total formulation weight
- 0.5% TRIS AMINO on total formulation weight
- A control paint with the pH adjusted with NaOH

AEPD VOX 1000 was added as supplied and a 40% weight TRIS AMINO solution in deionized water was first prepared prior to addition to the paint

Material	Amount (g)
Grind	
Water	17.18
Defoamer	0.14
Cellulosic Thickener	0.36
Dispersant	0.10
Biocide	0.10
Titanium Dioxide	17.00
Calcium Carbonate	8.50
Talc	1.00
Let Down	
Acrylic Resin	44.0
Defoamer	0.06
Associative High Shear Thickener	0.70
Associative Low Shear Thickener	2.75
Formaldehyde Scavenger	Variable
Water	8.11
Total	**100.00**



Results from the ISO 16000-23 test method are reported as a percent consumption of formaldehyde versus days of exposure in the chamber. Air containing 100 µg/m^3 (80 ppb) formaldehyde is continually introduced to the chamber for the duration of the test at a rate of 0.5 chamber volumes per hour. These results provide strong evidence that amino alcohols like AEPD VOX 1000 and TRIS AMINO are chemically active toward formaldehyde even when formulated into a waterborne coating.

Coatings formulated with 0.5% TRIS AMINO and 0.5% AEPD VOX 1000 were also evaluated in the Chinese standard test method, JC/T 1074-2008. Both TRIS AMINO and AEPD VOX 1000 show excellent performance as formaldehyde scavengers in the Chinese standard test method.

- Efficiency and durability of both chemistries are far above the required limit
- TRIS AMINO demonstrates the highest performance efficiency

Scavenger	None	0.5% TRIS AMINO	0.5% AEPD VOX 1000
Efficiency	32.9%	97.9%	92.3%
Durability	21.1%	90.1%	86.4%

CONCLUSIONS

With the use of amino alcohols based on ANGUS chemistry, it is possible to create zero-VOC and low emissions coatings, as well as functional coatings that improve indoor air quality. Coatings can be formulated using either AMP-95 or AEPD VOX 1000 to meet zero-VOC requirements in the United States/Canada and Europe/China, respectively. These same products also have no or low emissions, which can enable coating formulations to qualify for green label programs. Amino alcohols, such as AEPD VOX 1000 and TRIS AMINO, are easily formulated into waterborne coatings and are highly effective at low use levels as scavengers of airborne formaldehyde. While TRIS AMINO has superior formaldehyde scavenging potential, AEPD VOX 1000 can offer additional functionality as it not only scavenges formaldehyde but can also adjust solution pH, disperse pigments, and develop a synergistic effect with registered biocides leading to extended shelf life. These chemistries provide an easily accessible pathway to advance the evolution of environmentally friendly coatings by creating functionality that improves indoor air quality within homes, schools, offices, and other buildings.

TEST METHODS

Formaldehyde Scavenging Test by ISO 16000-23

Dynamic airflow formaldehyde scavenging tests were performed by Eurofins Scientific according to the ISO 16000-23 test method, "Indoor air — Part 23: Performance test for evaluating the reduction of formaldehyde and other carbonyl compounds concentrations by sorptive building materials." Paint samples were first homogenized prior to brush application onto glass plate in two coats, each of a spread rate of 140 g/m^2 and dried for 8 hours between coats. The coated glass panels were then placed into individual 119-liter controlled temperature and humidity chambers. The airflow rate into the chamber yielded an air change rate of 50% chamber volumes per hour. The ratio between the coating surface and the chamber volume was set up at 1.4, corresponding to both walls and ceiling coating conditions. The air supplied to the chamber contained 100 µg/m^3 formaldehyde (equivalent to 80 ppb) at 23±1°C and 50±3% relative humidity. As a reference, the World Health Organization (WHO) considers an airborne formaldehyde concentration at or above 100 µg/m^3 to be unsafe,[6, 7] so the coatings in these studies were exposed to a continuous supply of airborne formaldehyde concentration just at the WHO recommended exposure threshold. To reach a steady state in the chamber, the protocol was extended from a maximum of 28 days to 42 days.

REFERENCES

[1] Salthammer, T., Mentese, S., Marutzky, R. Formaldehyde in the Indoor Environment. Chem. Rev. 2010, 110, 2536-2572.

[2] Kirchner, S., et al. Indoor Air Quality in French Dwellings. Air Infiltration and Ventilation Centre, AIVC-CR12. 2009.

[3] Golden, R. Identifying an Indoor Air Exposure Limit for Formaldehyde Considering Both Irritation and Cancer Hazards. Critical Reviews in Toxicology. 2011. 41(8), 672-721.

[4] United States Environmental Protection Agency – Formaldehyde. https://www.epa.gov/formaldehyde

[5] United States National Toxicology Program Report on Carcinogens, Fourteenth Edition – Formaldehyde. https://ntp.niehs.nih.gov/ntp/roc/content/profiles/formaldehyde.pdf

[6] WHO Guidelines for Indoor Air Quality: Selected Pollutants. https://www.who.int/publications/i/item/9789289002134

[7] Nielsen, G. D., Larsen, S. T., Wolkoff, P. Re-evaluation of the WHO (2010) Formaldehyde Indoor Air Quality Guideline for Cancer Risk Assessment. Arch. Toxicol. 2017, 91, 35-61.