



# IT TAKES EFFORT TO LOOK THIS GOOD

Towards best practice in a snail trail-free exterior architectural paint. By Pierre Leger, Dow Silicones Belgium, Ashley Gong and Alan Piwowar, Dow Chemical USA.

**Snail trail, also referred to as surfactant leaching, is a complicated matter for architectural paint formulators. These coatings demand a high-quality visual appearance but weather conditions and water-soluble ingredients can cause unexpected failures. This article discusses the three main causes of snail trail and suggests ways to optimise paint formulations and improve drying speed and film formation to limit this issue.**

**A**rchitectural coatings provide improved aesthetics and critical substrate protection. They are formulated to meet many key coatings properties such as opacity, stain and dirt pickup resistance, washability, weatherability, adhesion or cracking resistance, to name a few. Unfortunately, despite optimising the paint for these and other variables, unexpected failures may still occur after paint application, drying and aging. The 'snail trail' phenomenon is one such failure, which we discuss in detail in this article.

## WHAT IS SNAIL TRAIL?

Snail trail is often described as a change of appearance that happens over the first days or weeks of exposure to exterior environment. This

manifests as a difference in gloss, colour, or light-scattering patterns that often resemble vertical lines and it appears in specific climatic conditions, typically low temperature and high humidity. Snail trail is also known by other names such as water staining, water streaking, or surfactant leaching. Surfactant leaching denotes the importance of water-soluble species present in a paint formulation, thought to be the main source of snail trail [1]. All latex paints are made with some water-soluble ingredients, such as dispersants, surfactants, wetting agents or thickeners, which can exude from a paint film over time. Weather conditions have a direct influence on the proportion of water-soluble ingredients that rise to the surface as the paint dries, or shortly thereafter. Dew or light rain soon after painting can extract water-soluble elements from the painted surface, leading to snail trail. Water concentrates the leachate and redistributes the material into lines (on a vertical surface), typically producing shiny streaks.

## DRYING SPEED AND PAINT COMPOSITION INFLUENCE SURFACTANT LEACHING

Many factors may influence the apparition or the severity of surfactant leaching. We can divide these into two groups: those linked to the en-

## RESULTS AT A GLANCE

- Snail trail is a name given to shiny streaks typically produced on a newly painted surface after exposure, for example to high humidity and low temperatures.
- Three causes of snail trail are pooling in discrete locations, crystal formation, and colour change.
- Solutions are formulation specific – optimising paint formulations can limit the visual effects of surfactant leaching.
- Suggested solutions include reducing water-soluble species, a careful additive selection, and promoting rapid and full film formation to limit void spaces and water migration channels.

environment or weather conditions during or after film application and those linked to the paint formulation itself, as shown in *Figure 1*.

The drying speed of a paint based on water-borne latex, typically acrylic, depends strongly on the temperature, humidity and the air flow conditions in which the paint is applied. Drying will slow down in cold, humid and low air flow conditions. In this case, the paint coating film will take more time to coalesce and fully dry, becoming more susceptible to adverse weather conditions such as rain or surface water condensation. The paint composition itself is an additional factor that will strongly influence surfactant leaching [2]. Certain water-soluble species contained in paint ingredients such as the binder, the dispersant, the rheology modifier or the tint can explain the sensitivity of certain paints to surfactant leaching [3].

### THREE MECHANISMS DETERMINE CHANGE IN APPEARANCE

When defining surfactant leaching we often refer to migration. It is not only migration that is critical, but what the materials do visually at the paint surface. In the introduction, we defined snail trail as a change in appearance. This change follows at least three different mechanisms: crystal formation, pooling of organic materials in discrete locations and colour change.

### CRYSTAL FORMATION

Surfactant-leaching crystals that develop on the surface of a paint may have different compositions but commonly contain sodium and sulfur, although organic crystals are also possible. Crystals impart a visual change at a paint surface by scattering light and are therefore most pronounced on deep shade paints as shown in *Figure 2*. The left image shows snail trails from a white paint on a black substrate and the right image presents two different types of crystal formation. The probability of salt crystal formation depends on the types of cationic




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ons and anions present and their solubility. Drying temperature and humidity can impact their precipitation speed, leading to varying crystal sizes, which can influence the extent of visual change at the surface. In some cases, water-soluble species at the surface can interact with carbon dioxide in the atmosphere, forming less soluble carbonates, which can be more challenging to remove.

**POOLING OF MATERIALS**

In addition to crystal formation, pooling of organic material such as surfactant or other water-soluble species is another form of snail trail. Interestingly, if these materials form a continuous, homogenous coating at the paint surface, they are not visually identifiable. However, if solubilised and redistributed by a water droplet, material can begin to accumulate or pool into isolated regions, leading to a visual change as shown in Figure 3. Essentially, water or dew interacting with the water-soluble species concentrates material to the edge of water droplets during evaporation. This will typically translate into gloss change, or tackiness in some cases once it is dry. This concentration of leaching materials can be observed with analytical techniques such as SEM or TOF-SIMS, as indicated in Figure 3.

**COLOUR CHANGE**

The last mechanism observed in the change of appearance is due to colour change (Figure 4). Colour change is typically linked to a migration of leachates to the paint surface that either produce colour or change colour upon exposure to the atmosphere (e.g. oxidation) or light (e.g. UV degradation). Identification of this source of change requires an accurate diagnosis of each raw material present in the paint.

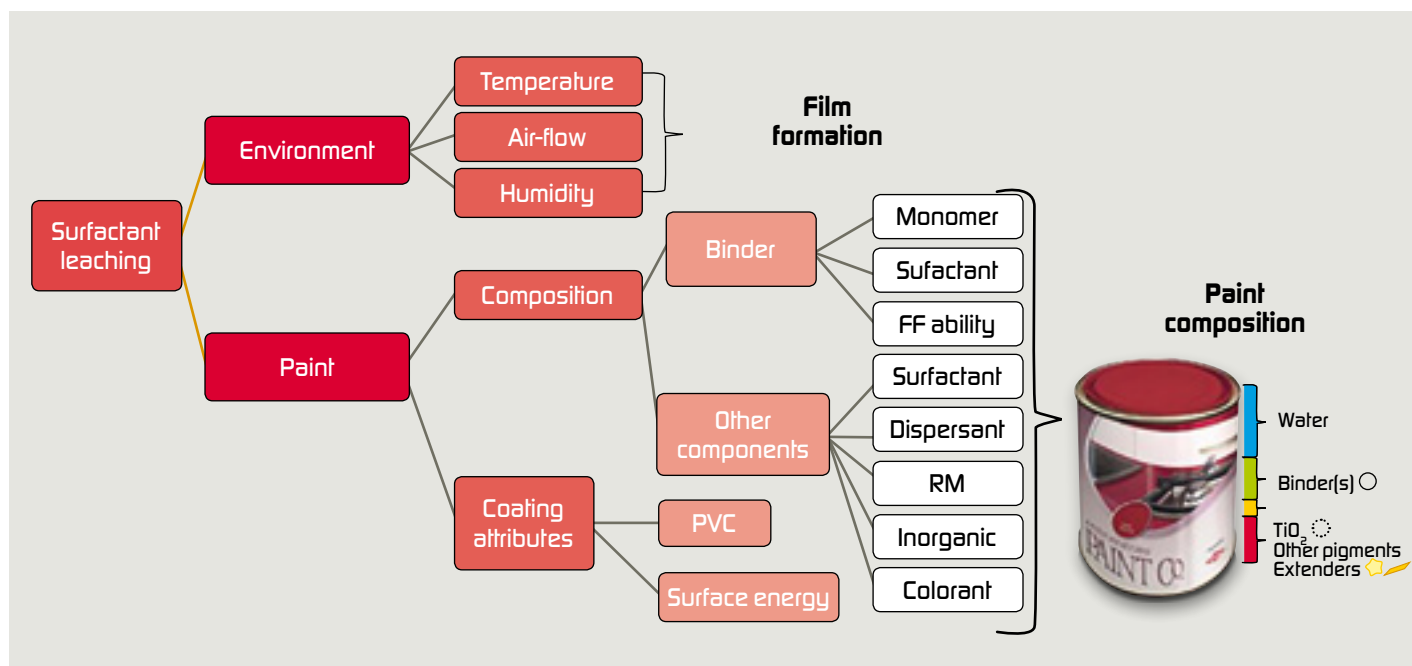
**COMPOSITION OF EXUDATE**

It may be necessary to know the composition of the exudate to understand the source of surfactant leaching. We can either consider what is leaching in the water placed on the paint surface or try to find a correlation between the quantity of water-soluble species in a paint composition and the visual modification of the surface. From various analyses, we have observed that surfactants, dispersants, salts, oligomer, rheology modifiers and other small molecules can migrate to the water droplets placed on the surface of a dried paint and that more leaching often corresponds to a greater visual difference, as indicated in Table 1.

Table 1: Leachate in water analysis (HPLC-ELSD) and surfactant leaching ratings.

Liquid chromatography analysis	Visual surfactant leaching rating (1-5, 5 the best)	Surfactant ppm	Thickener ppm	Oligomers ppm
binder 2 hrs	1	285.5	ND	570
binder 24 hrs	5	3.9	ND	420
paint 2 hrs	1.5	150.1	426.4	600
paint 24 hrs	3.5	80.3	175.4	350

Figure 1: Factors influencing snail trail.



On the other hand, it has been very difficult to establish a correlation between the total amount of water-soluble ingredients in a paint formulation or latex and the observed leaching appearance. This seems to indicate that the overall quantity is a factor but the conditions in which some of the water-soluble materials are able to migrate are also important.

**IMPORTANCE OF FILM FORMATION**

To understand the fate of water-soluble species during film formation and how they interact with the water in contact with the paint surface, two factors are important to examine: the accessibility of water-soluble substances in a dried paint coating and the different mobility factors that influence their speed of migration. It is expected that leaching solutes localise at interstitial spaces between latex particles. *Figure 5* shows 2D AFM phase maps of a paint's surface at three different time periods. In this figure, the bright regions show water-soluble or inorganic material such as pigment and the darker regions corre-

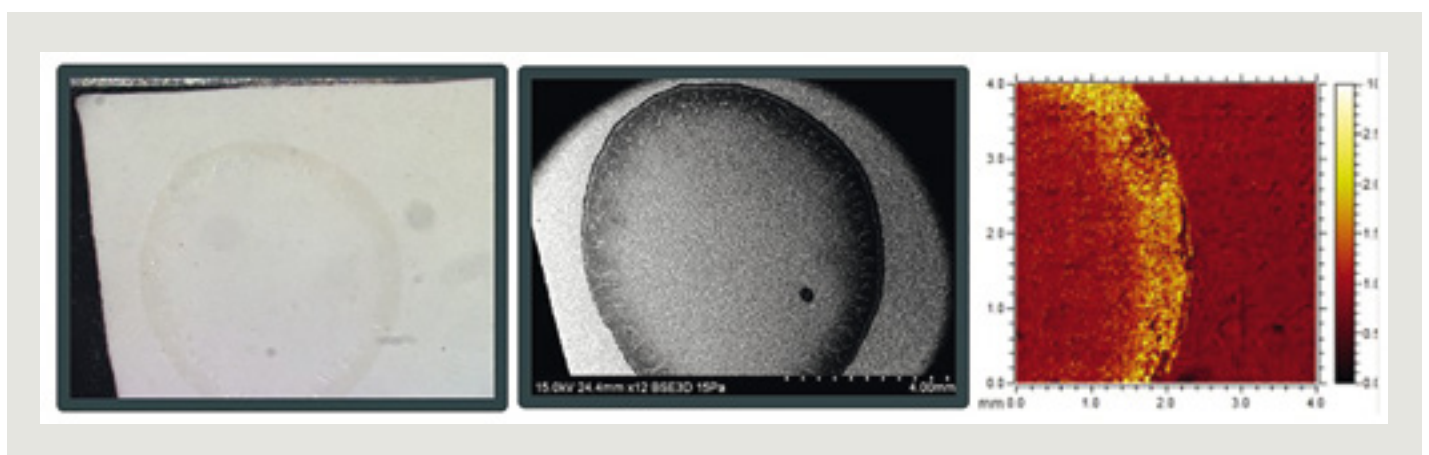
spond to latex polymer. Water-soluble components at the surface are usually accessible to water but the accessibility of those in the bulk of a coating depends on the pathways left after film coalescence or channels between film forming and non-film forming materials. In addition to the physical channels or pathways, migration might depend upon other mobility factors such as polymer compatibility, affinities or interactions.

From multiple experiments, we have learned that shorter drying times often lead to greater snail trail. Drying time is correlated with latex film formation, with a short drying time likely representing poorer film formation. AFM images shown in *Figure 5* indicate a time-dependent localisation of water-soluble materials, with more water-soluble material observed at 8 hours of drying than 24 or 144 hours of drying. Another way of viewing surfactant leading is to examine the surface of the coating before and after water exposure as shown in *Figure 6*. Water placed on the dry paint surface may redistribute soluble exudates (left images in *Figure 6*), or extract material from the bulk of a coating, redistributing it at the surface as shown in the images on the right.

Figure 2: Left: optical image showing snail trails from a white paint onto a black substrate. Right: Scanning electron micrographs showing two different types of crystal formation.



Figure 3: Left: Optical image of a paint surface after a drop of water evaporated. Middle: Scanning electron micrograph of the optical image highlighting a concentration of organic material (dark regions) near the edge of the droplet. Right: A 2D molecular representation of the droplet by ToF-SIMS showcasing an enrichment of exudate at the edge of the droplet.



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- AFM data suggests that if water-soluble materials 'coat' the surface of a paint following drying and if water or dew hits the surface, a re-solubilisation occurs. If this happens on a vertical surface, water would run down the surface redistributing the soluble species and forming snail trail.

### POSSIBLE ROUTES TO LIMIT SNAIL TRAIL

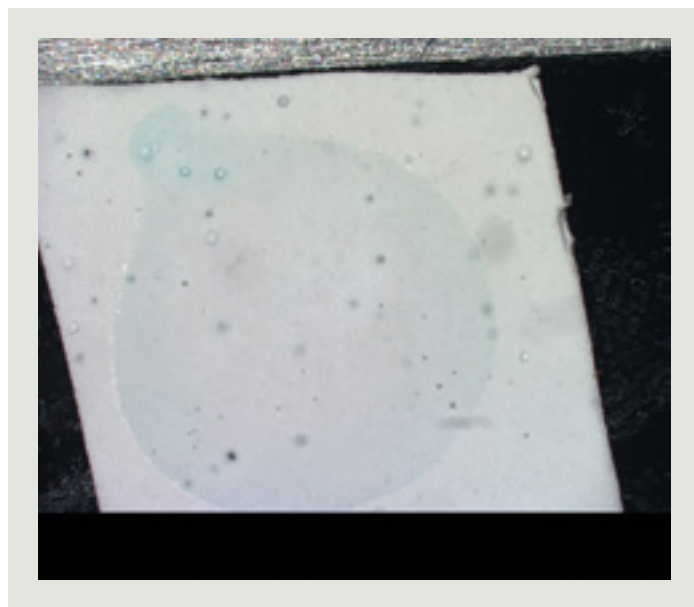
The ideal strategy is to promote fast and full film formation to limit voids spaces and migration channels [4].

Film formation is the ability of a binder to coalesce, which minimises channels that enable the diffusion of water-soluble species. As already discussed, optimising the drying conditions positively impacts film formation. Other ways to improve film formation include the choice of a suitable binder. Packing ability, morphology, composition and leachate content are all important parameters to keep in mind when selecting a binder. Binder suppliers can make recommendations based on these factors or specific technologies. The ASTM 7190 standard can also help to make a pre-selection by evaluating poor film formation or potential indicators of excess water-soluble substances migration such as water whitening, surface hydrophilicity, width of streaking water lines or high value of water absorption using a simplified water adsorption test. When possible, adding a coalescent will further improve the level of film formation and snail trail resistance even if the binder does not necessarily require it based on guidance on the technical data sheet.

Pigment volume concentration and volume solids are both important formulation parameters when trying to limit surfactant leaching. Lower PVC and corresponding higher amount of binder will provide better film integrity, while higher volume solids will reduce evaporation time with corresponding lower transport of water-soluble substances to the paint surface.

Of course, traditional paints ingredients such as surfactants and dispersants need to be chosen with the most care. Often, the ionic or non-ionic nature of a surfactant or dispersant and their hydrophilic and hydrophobic balance are enough to explain part of their resistance to snail trail [5].

Figure 4: Optical image showing a colour change in a paint coating after exposure to a drop of water.



Thickeners may also present a source of surfactant leaching and we have seen that increased levels of rheology modifier will make snail trail worse. Testing different types and looking for more efficient rheology modifiers to limit their addition level might be another appropriate way to reduce surfactant leaching.

Finally, adding a hydrophobic material that will reduce water absorption or decrease the contact area between the water and the paint surface could also further decrease the surfactant leaching potential of architectural exterior paints.

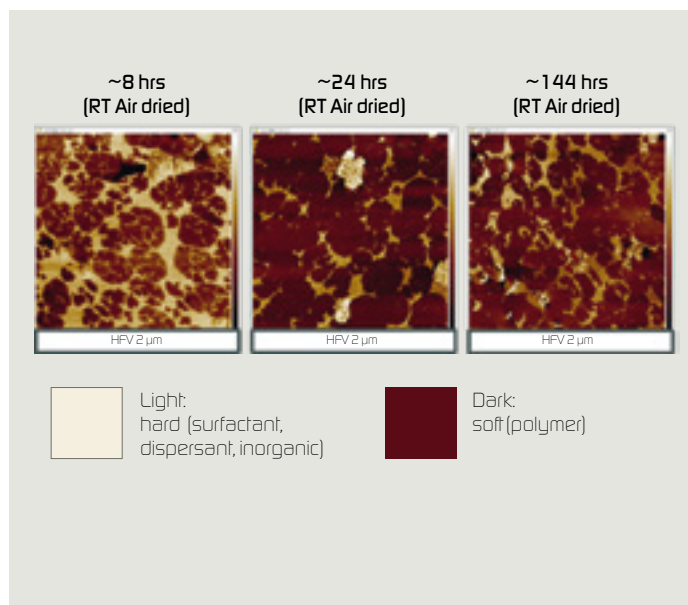
### TARGETED STRATEGIES TO REDUCE SNAIL TRAIL

Surfactant leaching depends on the formulation, drying conditions and film formation conditions. Solutions will be formulation specific. The critical issue is not just migration, but what the material does visually at the surface. We identified three causes for the visual detection of snail trail: pooling in discrete locations, crystal formation and colour change. Nevertheless, paint formulations can be optimised to limit the visual appearance of surfactant leaching. Solutions include promoting rapid and full film formation and limiting void spaces and water migration channels. We also need to reduce unnecessary water-soluble species and carefully select additives used in the paint formulation (i.e. dispersants, thickeners) that may be leached and hydrophobic additives. These are all strategies to limit snail trail in modern architectural paints.

### REFERENCES

- [1] The Rohm and Haas paint quality institute. Surfactant leaching. Exterior latex.
- [2] Progress in Organic Coatings, 2017, 105, p. 56-66
- [3] Progress in Organic Coatings 53, 2005, p. 112-118
- [4] Colloids and Surfaces A: Physicochem. Eng. Aspects 374, 2011, p. 58-68
- [5] J. Phys. Chem. B 2010, 114, p. 9135-9147

Figure 5. 2D atomic force microscopy phase maps of a paint surface dried at room temperature after 8 hrs (left), 24 hrs (middle), and 144 hrs (right).





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“Using an hydrophobic additive or a rheology modifier are some of the many solutions to limit staining.”

### 3 questions to Pierre Leger

**How high and how disturbing are snail trails in modern architectural coatings? How do you estimate the cost factor caused by snail trails?** Besides the climatic conditions during application, the presence of water-soluble materials in latex based paints and the decorative trend for deeper shades are the two main risks factors in modern water-borne architectural paint. Given that this aspect is perception-driven, certain owners are willing to tolerate the visible streaks if they appear while others will be very sensitive about it. The cost factor of regaining an appropriate painted surface appearance will strongly depend on the surface affected, the cost of cleaning the façade, or the cost of potentially repainting the affected areas, all factors being difficult to quantify.

**You mentioned that increased doses of rheology modifiers increase the occurrence of snail trails. At what concentration did you find increased snail trails?** The amount of rheology modifiers (HEUR) that we tested ranged from 0.5 to 1 % by weight. The impact is especially significant for smaller changes at lower loading levels and plateaued around 0.85 % by weight. Using a more efficient rheology modifier is just one of the many solutions to limit staining besides the careful selection of the binder and dispersant, or the use of an hydrophobic additive.

**Are there concrete recommendations for surfactants that keep snail trails low (e.g. HLB value)?** The common perception is that surfactants are the only cause of surfactant leaching, which is not the case as many other water-soluble materials may affect it. When testing the addition of different surfactants into a paint formulation, we found that in a rising HLB scale of the same surfactant chemistry, the major trend is that higher HLB values will cause more leaching. Nevertheless, even a surfactant having a medium HLB of 10 could cause staining in some cases. The type of surfactant should also be considered, as we also found that a higher HLB surfactant of one type could cause less leaching than a lower HLB surfactant of another type.

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