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Key Points



Figure 1. Visualisation of decontamination process using ionic liquids.

- Previously demonstrated the benefits of coloured ionic liquids to monitor the decontamination process. These are only suitable to visualise drop removal and the effluent from the process (Figure 1)
- Ionic liquids do not penetrate the paint surrogate surfaces (Silicones and Polyurethanes) at a quick enough rate to be useful in evaluating surface interactions.
- Incorporation of a solvatochromic dye into the test material affords the ability to monitor surface interactions with traditional simulants e.g. Methyl salicylate (Figure 2).
- Objective is to visually monitor the decontamination process by having a contaminant (colour simulant) on a surface where it is possible to observe both contaminant- surface and decontaminant- surface interactions (Figure 3).

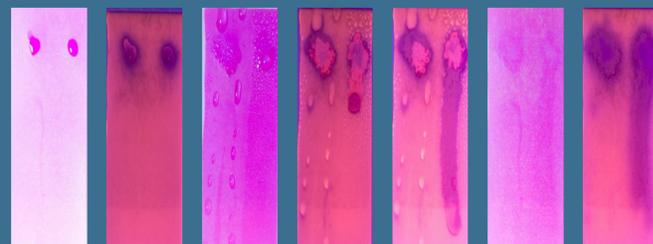


Figure 2. Sub-surface contamination after decontamination of Methyl Salicylate droplets on silicone impregnated with Nile Red.

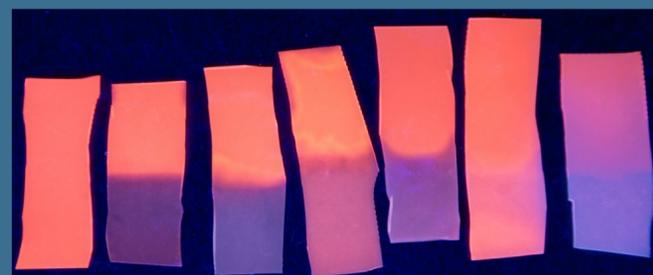


Figure 3. Nile Red impregnated into silicone after immersion in solvents. Left to Right: Water, 1:1 Acetone:Water, Acetone, Ethanol, Toluene, Hexane & Methyl salicylate

Background

We want to develop decontamination processes that minimise the volume of decontaminant needed without compromising efficiency. This requires determining residual contamination as a function of spray time at different delivery flow rates.

Using traditional solvent extraction methods to determine residual contamination, it is not practical to produce graphs with more than 6 points: equivalent to one point per hour of experimental time.

Ionic Liquids

By using a single component coloured liquid we can accurately follow the course of the decontamination process. We are able to visually monitor the decontamination process affords the ability to acquire:

- Surface interactions properties
- Flow rate effects
- Solvent/ chemical effects
- Large data sets

However, this is only part of the challenge. We have previously demonstrated that the act of decontamination may complicate the problem by spreading contamination not only over uncontaminated surfaces, but also into the surface.

Dye incorporation to substrates

Exploiting the properties of solvatochromic dyes by incorporating them into test materials; in our case surrogates for painted surfaces (silicone and polyurethanes) it should be possible to monitor not only when the contaminant has penetrated the surface of the material but also the decontaminant.

We have chosen Nile Red as this not only gives a large bathochromic shift, but is readily available. It has been reported¹ that analogues of Prodan (FR-0) have a much stronger fluorescence solvatochromism and warrant further study.

Incorporation of the dye into a substrate is achieved by:

- For Polyurethane- addition as a solution (in a suitable solvent) to the two part resin during the casting process.
- For Silicones – soaking in a solution of Tetraethyl Orthosilicate (TEOS) containing the dye.

References/Acknowledgments

1. Oleksandr A. Kucharak, Pascal Didier, Yves Mely, and Andrey S. Klymchenko, Fluorene Analogues of Prodan with Superior Fluorescence Brightness and Solvatochromism J. Phys. Chem. Lett. 2010, 1, 616–620.
2. Christian Reichardt, Solvatochromic Dyes as Solvent Polarity Indicators, Chem. Rev 1994, 94, 2319-2358
3. P Greenspan; E. P. Mayer & S. D. Fowler (1985). "Nile Red, A Selective Fluorescent Stain for Intracellular Lipid Droplets". Journal of Cell Biology. 100 (1): 965

Contamination under UV light

It has proved possible by using UV photography to monitor contamination spread within a material. When a contaminant fluoresces under ultra-violet light detection is simple. However, during the decontamination process removal of the contaminant can make this more difficult to visualise as shown in Figure 4.

With use of a UV camera† it has proved possible to visualise residual contamination with a test material after the decontamination process. This process affords a contrast image. The darker the contaminant appears the greater the contamination density (Figure 5).

The additional benefit to this technique is that it does not require the contaminant to fluoresce under UV light or for the substrate to contain a dye.

The downside with this technique is that it can only be used to evaluate the substrate post-decontamination and requires the surface to be blotted dry and any residual surface liquid adversely affects the quality of the image obtained.

† DSLR with sensor conversion, UV lens and bandpass filter.

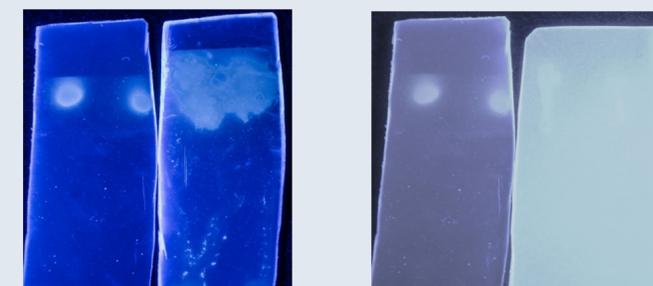


Figure 4. Left - Methyl salicylate drops under UV light (303 nm) on clear polyurethane before and after decontamination with water. Right- Methyl salicylate drops on clear polyurethane before and after decontamination with water containing SDS at the critical micelle concentration.

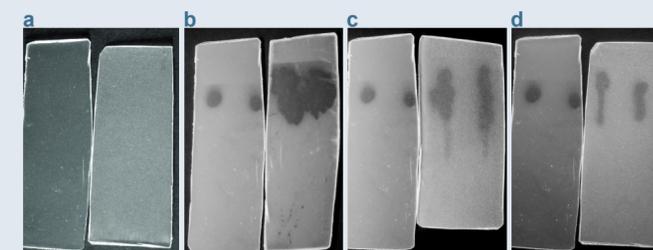


Figure 5. Methyl salicylate drops on under UV light (303 nm) clear polyurethane before and after decontamination with a: water (under white light) b: water c: water containing SDS at the half the critical micelle concentration d: water containing SDS at the critical micelle concentration



Figure 6. Nile Red in Common Solvents (Left to Right: Water, 1:1 Acetone:Water, Acetone, Ethanol, Dichloromethane, Toluene, Hexane, Methyl salicylate, Triethyl phosphate, Diethyl succinate. a: under white light b: under UV light (303 nm)

Solvatochromic Properties of Nile Red

Solvatochromism is defined as the ability of a chemical substance to change its colour by changing the solvent polarity.

The solvatochromism observed depends on the chemical structure and physical properties of the chromophore and the solvent molecules, which, for their part, determine the strength of the intermolecular solute/solvent interactions in the equilibrium ground state and the Franck-Condon excited state.¹

Nile Red is widely used as a highly sensitive lipophilic stain and polarity sensitive probe fluorescent probe.² This suggest it would be a good choice for incorporation into polymers.

Figure 6 shows the solvatochromic and fluorescent nature of this dye in decreasing solvent polarity.