Quality Control of Industrial Dye Products Using Absorbance Spectroscopy

Key Words

NanoDrop Spectrophotometer, Absorbance, Industrial Dyes, Quality Control (QC), Uranine

Introduction

Quality control of industrial dye additives is imperative to ensure the reproducibility of dye color and appearance in the colorant's final application. The Thermo Scientific™ NanoDrop™ 2000 UV-Vis spectrophotometer offers a rapid, fully customizable method for checking batch quality for proper pigment concentration prior to distribution to the product's end user. The concentrations of most aqueous dyes and pigments can be assessed using the full ultraviolet and visible spectrum capabilities of the NanoDrop 2000 spectrophotometer.

The NanoDrop 2000 spectrophotometer utilizes auto-ranging pathlengths to quantify dye samples across a much broader concentration range than is possible using a conventional cuvette-based spectrophotometer. By optimizing the pathlength based on dye absorbance (ranging from 1.0 mm to 0.05 mm) the NanoDrop 2000 spectrophotometer can accurately measure the absorbance of a sample across a concentration range nearly 200 fold greater than that of a cuvette-based system.

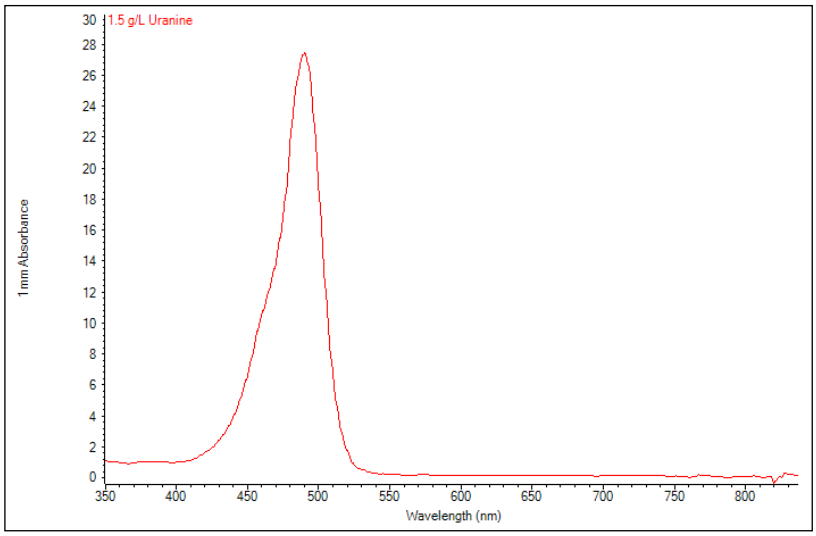

Figure 1: Absorbance spectrum of 1.5 g/L uranine. Absorbance maximum at 490 nm was used for subsequent analysis.

In this study, the visible absorbance spectrum of uranine, the disodium salt of fluorescein, was assessed using a NanoDrop 2000 spectrophotometer across a broad concentration range. Uranine is commonly used in oil and gas industries to detect leaks in containment vessels and pipelines. It is also used as a colorant in military, medical, and cosmetic applications. Both linear dynamic range and precision (reproducibility) were assessed.

Experimental Procedures

The absorbance of uranine test samples was measured at 490 nm. A custom method was developed in the NanoDrop 2000 software that allowed for ideal lamp integration times for analysis of the peak of interest (Figure 1), while avoiding additional peaks in the UV region of the spectrum.

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A 1.5 g/L stock solution was prepared by dissolving 1.5 g uranine powder in 20 mL of 1 N sodium hydroxide. Volume was adjusted to 1 L in a volumetric flask using deionized water. Linear dynamic range was tested by measuring a serial dilution of this stock solution. Absorbance of five, 2.0 µL aliquots of each dilution were measured at 490 nm using a custom method developed using the Method Editor in the NanoDrop 2000 software.

Results

A linear relationship between absorbance and dye concentration was observed throughout the concentration range measured (Figure 2).

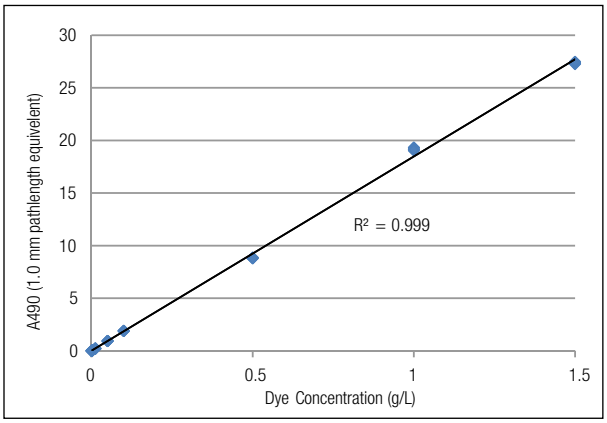

Figure 2: Uranine absorbance vs. concentration at 490 nm. Strong linear response observed through the entire dilution range.

Reported absorbances at 490 nm ranged from 0.02 A at the lowest concentration (0.0015 g/L) to over 27 A for the highest (1.5 g/L) concentration solution at a 1.0 mm pathlength equivalent.

Reproducibility across replicate aliquots was very good; CV values of 1% or less were observed in samples above 0.003 g/L, with excellent standard deviations in all cases (Table 1). This data indicates a linear, reproducible measurement range nearly 200 times broader than a traditional spectrophotometer utilizing a 1 cm cuvette.

Table 1: Average, standard deviation, and % CV of replicate aliquots (n = 5) of a serial dilution of uranine dye.

Concentration (g/L)	Average A490	SD	% CV
0	0.000	0.001	
0.0015	0.021	0.001	
0.003	0.046	0.002	
0.012	0.220	0.002	1.045
0.050	0.936	0.005	0.507
0.100	1.895	0.007	0.389
0.500	8.832	0.033	0.370
1.000	19.185	0.124	0.648
1.500	27.367	0.091	0.333

Conclusion

The use of UV-Visible spectrophotometers for the quality control of dyes and pigments has been a standard practice for decades. However, the detection limitations of a fixed-pathlength, cuvette-based spectrophotometer require that a pigment sample be heavily diluted prior to measurement. These dilutions introduce a potential source of error in the quality control process. The NanoDrop 2000 UV-Vis spectrophotometer can be employed to provide a rapid and accurate verification of dye concentration without the need for significant dilutions. The custom method capabilities of the NanoDrop 2000 software can be used to develop specific applications for various dyes and pigment quality processes, allowing data capture and analysis to be performed automatically. The polished stainless steel and quartz construction of the measurement pedestal is highly resistant to sample carryover or staining, even when exposed to extremely concentrated dyes. In addition, the instrument's short measurement cycle, lack of a warm-up period, and general ease of use greatly increases the rate at which samples can be processed.

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