Chlorophyll and other naturally occurring tracer dyes for laser-induced fluorescence in liquid flow applications

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Tracers commonly used in experimental flow studies are mostly nocuous to the environment and human health. Particularly in large flow installations this can become a problem. Naturally occurring non-harmful substances are an alternative that has been tested in this study. Chlorophyll, as well as vitamins, are examined here for their applicability as tracers in flow studies. Several of them turned out to be most promising and the dependency of their fluorescence intensity on parameters like concentration, laser energy, temperature and pH are determined for two commonly used laser excitation wavelengths (532nm, 355nm).

Experimental technique

Chlorophyll and the vitamins have been purchased as pure substances. All are dissolved in distilled water in different concentrations and filled into small transparent cuvettes. A frequency doubled or tripled Nd:YAG laser is used for excitation and the laser light sheet is passed through the center of the cuvette. The fluorescence light from the cuvette is focalized to the entrance slit of a spectrometer. The spectra are then recorded by an ICCD-camera.

The temperature dependency of fluorescence has been determined by heating up the solutions to about 50°C. The pH-dependency has been obtained by changing the pH of the original solution by the addition of HCl or NaOH.

Results

Chlorophyll: Excitation wavelength 355nm

The concentration and laser energy dependencies of Chlorophyll fluorescence at excitation wavelength 355nm are represented in figure 1. Growing concentration and laser energy leads, as expected, to increasing fluorescence intensity. The increase of maximum intensity (around 660nm) is, in the considered range, linear with laser energy, but not with concentration.

![Fig. 1](image1.png)

**Fig. 1** Fluorescence of Chlorophyll: excitation at 355nm, influence of concentration (left) and laser energy (right).

The temperature dependency of Chlorophyll fluorescence exists, but is not very strong in the considered range (fig. 2, left). The maximum intensity was attained at 50°C and a linear increase can be observed. Also, the wavelength of the fluorescence maximum changes slightly, but linearly with temperature (right).

![Fig. 2](image2.png)

**Fig. 2** Chlorophyll fluorescence: influence of temperature.

Chlorophyll: Excitation wavelength 532nm

Corresponding measurements have been completed at an excitation wavelength of 532nm. The resulting figures show a rather similar behavior and are shown in the paper.

Parameter study for Vitamins:

Several water soluble vitamins have also been examined for their capability of replacing currently used tracer dyes in flow studies. The results of this study (Zähringer, 2014) showed a special suitability of vitamins B, and B, for the use in fluid mechanical applications (Fig. 3).

First applications of Vitamin B in a static mixer showed the good applicability of this tracer (Fig. 4).

![Fig. 3](image3.png)

**Fig. 3** vitamins at excit. wavelength 355nm

![Fig. 4](image4.png)

**Fig. 4** Vitamin B. (at 532nm) as tracer in a static mixer

Conclusions

Naturally occurring dyes like Chlorophyll and vitamins are examined here for their suitability to replace currently used, often harmful tracer dyes for flow studies. The temperature and pH dependency of their fluorescence intensity and maximum wavelength are analyzed, as well as the concentration and laser energy influences. First applications show the excellent possibilities of these very cheap and non-harmful dyes. Especially in big flow installations and if tracer is released to the surroundings (spray, wind-tunnel, etc.) they may show big advantages compared to common tracer dyes.

Literature