WATER QUALITY

Specifying the colour of natural waters

Rob Davies-Colley

John Nagels

Natural water occurs in a surprising range of colours, but specifying exactly what colour is not that easy. A system developed at NIWA in Hamilton promises to take the guesswork out of water colour specification.

COLOUR IS ONE of the most immediately apparent features of natural waters. Together with other visual attributes such as visibility (visual clarity), colour strongly influences aesthetic perception and recreational use of water (Smith *et al.* 1991; 1995). Colour also influences aquatic habitat inasmuch as this depends on the wavelength distribution of sunlight in waters (Davies-Colley *et al.* 1993). Despite its importance, water colour is not a widely understood concept and simple methods for its specification in field work have been lacking.

The concept of colour applied to water

Colour is the sensation produced by light. Particular colours have a characteristic wavelength distribution of light. Colour of natural waters, as viewed from above their surface, is associated with the light upwelling within the water volume. This upward-directed light is sunlight that has been *backscattered* by small particles suspended in the water volume as well as by molecules of water itself (Davies-Colley et al. 1993). Colour of water is therefore associated with the spectral *reflectance*, the ratio of the upward-directed light to incident light from the sun in water.

There are three main dimensions of colour (Anon. 1966): *hue*, relating to how the colour sensation is described ("blue" or "red" for example); *saturation* or colour purity, which is the opposite of greyness and depends, like hue, on the distribution of wavelengths in the spectrum; and *brightness*, which depends on the amount of light reaching the eye. Hue and saturation of a water body depend only on the shape of its reflectance spectrum (i.e., the distribution of light energy with wavelength) whereas brightness depends on the *magnitude* of its reflectance.

The term "colour" is sometimes, rather misleadingly, applied to laboratory measurements of the "yellowness" of water samples as quantified by visual comparison or with a spectrophotometer. However, for a variety of reasons, such measurements do not relate closely to water colour as observed in the field. For example, the yellowness of water samples is a useful index of the concentration of dissolved aquatic humic substances but, as the humic content of initially pure water increases, its hue changes from blue-green to green, green-yellow, yellow and, ultimately, to orange.

Colour is difficult to measure because this involves analysing the wavelength-distribution or "spectral quality" of light. An instrument called a spectroradiometer can be used to record light spectra for the calculation of colour. NIWA owns a submersible spectroradiometer which has been used for the purpose of measuring water colour. But such instruments are research tools and not suited to routine work.

However, although colours are difficult to *measure*, people can accurately *match* colours viewed simultaneously, and this was the approach taken in the present study. What we require then, is a simple method for specifying water colour by matching to colour standards, thus avoiding complex spectral measurements and colour computation.

Colour standards

Several systems of colour standards are available. Probably the most widely known and certainly the most scientifically well-characterised is the Munsell System, which is useful for specifying colour of, for example, paints or textiles. In the "Munsell Book of Color" each of 40 pages has a different hue (denoted H) at 2.5 hue unit intervals on a scale of 0–100 (Anon. 1966). The Munsell value (V) measures the apparent brightness of the colour and ranges from 0 (black) to 10 (white), moving vertically on each page. The Munsell chroma (C) is a measure of the colour saturation or colour purity and extends from 0 for neutral greys to 20 or more for spectral colours, moving across each hue page. Colours are specified in the Munsell system as H V/C (Anon. 1966). For example, a typical rather dark and greyish water colour of 45 hue units in the green hue range might be denoted 5G 2/4.

The main requirement for specifying a colour by matching to Munsell standards is to position the sample and standard so that they can be observed simultaneously. This presents no difficulty with a sample of textile for example, which is simply placed on the "Munsell Book of Color" for comparison with the standard colour patches. However the colour of water cannot be manipulated so easily. Perhaps the biggest problem is that the intrinsic colour of water as viewed from above its surface is partially obscured by surface reflection of skylight.