Optical effects on aquatic ecosystems of fine suspended sediment, and optical methods for its monitoring and management.

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Introduction: The most visually obvious features of sediment-laden water are its low clarity, typically accompanied by 'muddy' colours. These visual features reflect light-attenuation, which is often among the most ecologically damaging properties of fine sediment. This paper reviews the optics of fine sediment and optical effects on aquatic ecosystems, and argues for wider application of optical technologies and methods in fine sediment monitoring and management.

Optical properties of fine sediment: The most important optical properties of waters are its light-absorbing and light-scattering [1,2]. Both are strongly influenced by fine sediment in sizes ranging from, say, 0.2-63 μm. Fine sediment scatters light intensely, and organic materials (phytoplankton, detritus, humic matter) absorb light strongly. Total light beam attenuation, symbol c (units: m^{-1}) is the sum of the light absorption coefficient (a) and scattering coefficient (b).

Light scattering by suspended particles is typically strongest in the forward direction, but backscattering (at angles >90°), typically of ~1.5% of total light, is important for generating the upwelling light signal that can potentially be remote-sensed. Light absorption is more variable than scattering across the UV to NIR spectrum, and the resulting upwelling light spectrum contains information about water quality.

Optical effects of fine sediment on aquatic ecosystems: 'Optical damages' of fine sediment include both 'top-down' impacts on the visual range of fish and birds (also the visual amenity of recreational water users) and 'bottom-up' impacts on the light climate of benthic plants.

Water clarity, is strongly affected by fine sediment, and has two distinct aspects: visual clarity and light penetration [2]. Visual clarity is traditionally indexed by the Secchi depth, but horizontal black disc visibility, y_{BD} is a better index – particularly for providing an estimate of light beam attenuation: $c = 4.8/y_{BD}$ [3,4]. Visual range of sighted aquatic animals is very similar to that of humans, so y_{BD} provides a valuable index of 'visual habitat' of waters. Light penetration is quantified by another optical property, the diffuse light attenuation coefficient, K_d, which is calculated from depth profiles of (diffuse) light in water. K_d controls the light climate of benthic plants, such as seagrasses in estuaries and coastal waters. Despite their similar name and identical units of measurement, K_d and c are numerically different and not immediately inter-convertible [5]

Discussion – application of optical methods to fine sediment management: Optical measurements are particularly relevant and valuable for monitoring and managing fine sediment in waters – both because of the important optical effects of fine sediment and because optical sensors can operate continuously [6]. Instruments for estimating light beam attenuation (beam transmissometers) and light penetration (irradiance sensor arrays) can, in principle, be operated continuously at fixed stations in waters. However, there are practical difficulties including vulnerability to bio-fouling and limited dynamic range. Therefore nephelometric turbidity sensors are usually more practical, with (local) calibration to beam attenuation (or, equivalently, visual clarity) and light penetration (e.g., when spatial variation of optical properties is being quantified by boat surveys). Optical characterization over both space and time is needed to provide 'water truthing' for remote sensing using satellite imagery. These optical applications will be illustrated with findings from three mutually-supporting optical measurement campaigns (fixed stations, boat surveys and remote-sensing) for defining the sediment and optical regimes of the Kaipara system (harbour and catchment) in northern New Zealand.

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