Relationship between Secchi depth and the diffuse light attenuation coefficient in Danish estuaries

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Photograph: Peter Bondo
Aim

Our aim was to quantify the relationship between the light attenuation coefficient ($K_d$) and Secchi depth (SD) and analyse the variability in time and space.
Background

- Light attenuation is a key parameter in coastal ecosystems.
- Governs the growth and distribution of underwater vegetation.
- Responds to changes in nutrient loadings.
- Correct representation of light attenuation is essential in coastal ecosystem models.
Background

- Current monitoring programs often use direct light measurements, allowing a calculation of the light attenuation coefficient ($K_d$).
- Some older data is found as Secchi depth (SD) observations.
- Validation of models back in time therefore requires quantification of the factor $K_d \times SD$.
- This factor also represents the percentage of surface light remaining at the Secchi depth.
**K\textsubscript{d}.SD**

Beer’s law

\[ I = I_0 e^{-kz} \]

\[
\ln \left( \frac{I}{I_0} \right) = -k \cdot z
\]

\[-\ln \left( \frac{I_{\text{Secchi}}}{I_0} \right) = k \cdot SD\]

For example

\[
\frac{I_{\text{Secchi}}}{I_0} = 15\%
\]

\[ k_d \cdot SD = -\ln(0.15) = 1.89 \]
Methods

› Observations from the Danish national monitoring program.
› 174 stations.
› Temporal coverage 1985-2011
› $K_d$ was obtained by regression of light intensity profiles.
› $K_d \cdot SD$ was calculated for coinciding observations of SD and light intensity profile.
› 37049 light profile / Secchi observations.
Methods

› Annual variation in $K_d$, SD and $K_d \times SD$ was analysed.
› Variation in $K_d \times SD$ was analysed by regression on parameters:
  › salinity
  › chlorophyll-a
  › total suspended solids (TSS)
› Average of $K_d \times SD$ at each station was compared with depth for all stations.
› (20 stations had TSS observations)
Results

- mean $K_d^\times SD$ is 2.00
- significant annual variability
- lowest values during summer (1.86)
- highest values in late autumn and early winter (2.15)
- Low $K_d^\times SD$-values during summer are likely due to higher concentrations of phytoplankton and detritus.
Results by station

› There is variation from station to station.
› Eutrophic station.
› Station showing effects of resuspension.
Results - TSS

› Chl effect is significant but negligibly small
› TSS is the most important factor in explaining the variation in $K_d*SD$
› Accounts for 23% of the variation seen in annual mean $K_d*SD$ (subset of 20 stations)
Results - TSS

- Particle type?
- Organic / inorganic?
- Effect of loss-on-ignition was significant
- Size of data set including loss-on-ignition was even smaller
Results - Depth

- Station depth was considered as a proxy for TSS
- The shallower stations are subject to a greater resuspension
- Therefore TSS decreases with increasing depth.
- Non-linear regression used (Michaelis-Menten)
Results - Depth

› Attempt to include some component related to absorption – DON?
› Some correlation between DON and salinity
› Model expanded to include Salinity
› Residuals were then analysed by month
Empirical Model

\[ K_d \times SD = \frac{Depth}{a + b \times Depth} + c \times Salinity + d(Month) \]

› \( a = 0.2544 \) m
› \( b = 0.4498 \)
› \( c = -0.006626 \) PSU\(^{-1} \)

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Room for improvement

\[ R^2 = 0.9847 \quad K_d = 2.51 \]

\[ R^2 = 0.9942 \quad K_d = 1.98 \]
Conclusions

› The mean value for $K_d \times SD$ at 174 stations (37049 observations) is 2.00.

› There is a significant annual variability with the lowest values during summer and the highest values in late autumn and early winter.

› The direct negative effect of phytoplankton is statistically significant but too small to be quantitatively important.

› The most important effect is a decrease in $K_d \times SD$ with increasing particle concentrations, causing a maximum in $K_d \times SD$ in late summer due to accumulation of detritus during the growth season.

› An empirical model is given for $K_d \times SD$ as a function of depth, salinity and month.
Thank you

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