EGU2017-1068

Experimental investigations of diatomaceous biofilm behaviour and sediment stabilising capacity

Wietse I. van de Lageweg, Stuart McLelland and Daniel Parsons

Department of Geography & Geology, School of Environmental Sciences, University of Hull, UK

Biofilm | Flow | Saline | Sediment | Experiment

Biostability | EPS | Erodibility | Shear stress

@WietseLageweg

W.Van-de-Lageweg@hull.ac.uk

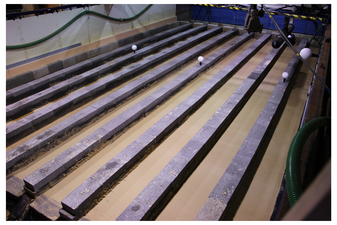
Motivation

Microbial assemblages ('**biofilms**') preferentially develop at water-sediment interfaces and are known to have a considerable influence on **sediment stability** and **erodibility.** There is potential for significant impacts on sediment transport and morphodynamics and, hence, on the longer-term evolution of coastal and fluvial environments. But the **biostabilisation** effects remain poorly understood and quantified due to the inherent complexity of biofilms and the large **spatial** and **temporal** (i.e. seasonality) **variations** involved. Specifically, we aim to:

i) explore biofilm colonisation, growth and sediment stabilisation for a range of sediment substrates.

ii) systematically quantify the effect of biofilm colonisation on sediment stability over time for a range of sediment substrates.

iii) develop protocols to replicate natural biofilm behaviour across a range of spatial and temporal scales.



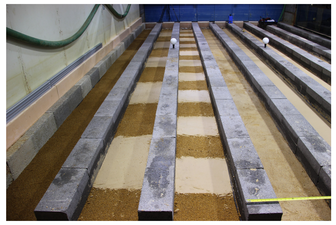


Figure 1. Setup for biofilm growth experiment in Total Environment Simulator (@TotEnvSim) at the University of Hull. The left panel shows a top view of nine parallel channels with substrates ranging from fine sand to gravel. The left panel shows a detail of four channels with (from left to right) coarse substate, 1 m patches of coarse and fine substrate, 0.5 m patches of coarse and fine substrate, and a 50/50 substate mixture of the fine and coarse sediment.

Experimental setup

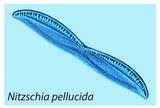
+ Nine (9) parallel channels (9 m long; 0.48 m wide) **recirculating saline water** with typical u ≈ 1 cm/s during base flow but up to 0.5 m/s during weekly sediment entrainment tests.

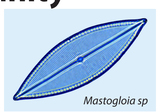
+ Five (5) channels with fine sand (110 µm) substrate used to measure shear strength for different growth periods [**Figure 1**, **left panel**].

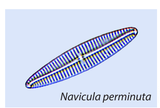
+ Four (4) channels with different substrate mixtures and spatial structures of fine sand and gravel (1 mm) to explore interaction between substrates and biofilm behaviour [**Figure 1, right panel**].

+ Measurements include **Cohesive Strength Meter** (CSM) tests for sediment stability, **Acoustic Doppler Velocimetry** (ADV) for flow characterisation, **Terrestrial Laser Scanner** for digitial elevation models, **spectrometer** for spectral characterisation, **extracellular polymeric substances** (EPS) soil sampling and **microscope** investigations.

Biofilm community







Source: http://www.diatomloir.eu

+ **Species ecology** confirms that the water is saline, being dominated by **halophilous diatoms** which are common in **coastal zones**. Many of the found species are **obligate** and cannot tolerate fresh water.

+ All taxa are **benthic** rather than planktonic, as expected in flowing water. Some are attached, others float around the substrate. **Ciliates** were present and presumably eating diatoms.

+ **Diverse flora** with **dominant species** being: *Nitzschia pellucida* (early colonisers)
Nitzschia sigma (early colonisers)
Mastogloia sp
Navicula perminuta
Amphora pediculus

Biofilm colonisation & behaviour

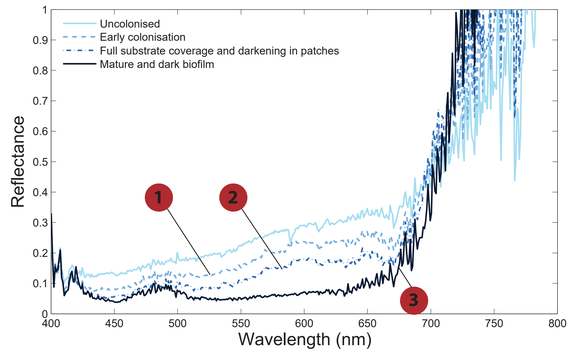


Figure 2. Reflectance signals resulting from different degrees of biofilm colonisation [**Figure 3**]. The normalised difference vegetation index (NDVI) is used as an indication of chlorophyll conc.:

$NDVI = R_{750} - R_{673} / R_{750} + R_{673}$

NDVI 1 = 0.61

NDVI 2 = 0.71

NDVI 3 = 0.82

NDVI = 0.43 [uncolonised]

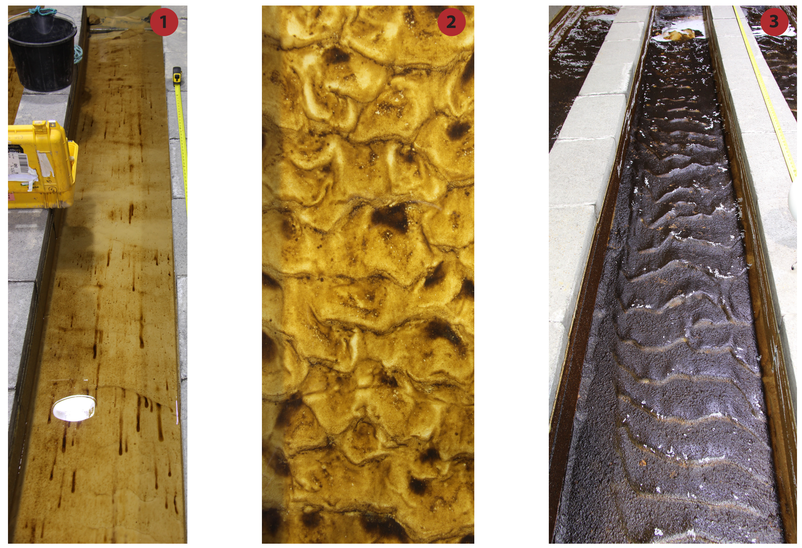


Figure 3. Colonisation of diatomaceous biofilm during experiment showing (1) early onset of biofilm groth in isolated patches, (2) biofilm growth over bedforms with enhanced growth in lee of bedforms, and (3) mature and dark biofilm after 6 weeks.

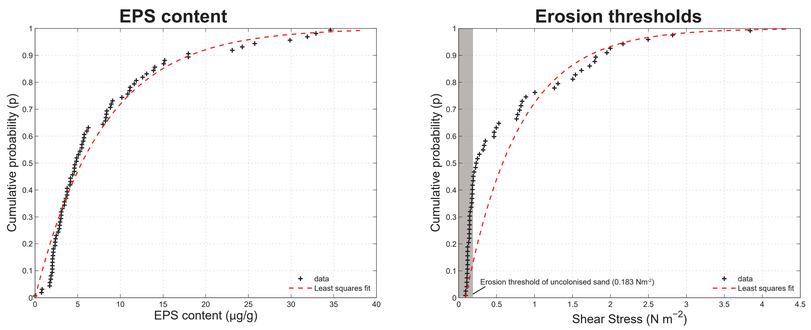


Figure 4. Extracellular polymeric substance (EPS) contents (left) and sediment erosion thresholds measured with CSM erosion device (right) during 6 weeks biofilm growth experiment. The EPS measurements (n = 80) are best described by a least squares exponential fit with a mean parameter µ of 7.88. The erosion threshold measurements (n = 61) are best described by a least squares exponential fit with a mean parameter µ of 0.71. Note that 42% of the measurements shows no increased sediment stability compared to the uncolonised sand.

Protocol development to replicate biofilm behaviour

Table 1. Relative biostabilisation for natural biofilm and Xanthan Gum and Carrageenan surrogates as measured in this study. Biostabilisation is defined relative to the erosion threshold of sand without EPS.

	Uncolonised	Median	Mean	Maximum
Biofilm	1	1.3	3.8	21.0

	1.25 g·kg^{-1}	2.5 g·kg^{-1}	5 g·kg^{-1}	10 g·kg^{-1}
Xanthan Gum	1.7	4.8	8.6	16.4
Carrageenan	0.6	1.5	3.5	7.4

	[PREPARATION PROCEDURE]		[ENVIRONMENTAL CONDITIONS]	
(10 g·kg^{-1})	Dry mix	Saline	pH = 10	T = 10° Celsius
Xanthan Gum	27.6	15.2	10.3	7.8
Carrageenan	9.8	4.7	2.2	1.6

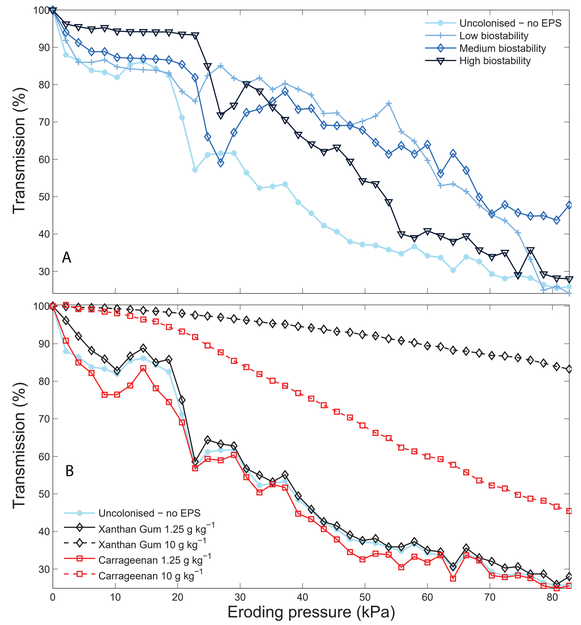


Figure 5. CSM erosion profiles for sediment with different degrees of biostability due to natural biofilm colonisation (A) and due to different Xanthan Gum and Carrageenan contents (B).

Note the difference in erosion behaviour between natural biofilms and Xanthan Gum and Carrageenan, particularly at higher concentrations.

The difference is likely caused by the mixing of the Xanthan Gum and Carrageen through the entire sediment column, while natural EPS predominantly occurs close to the surface and contents rapidly decrease with depth.

Application as a surface layer rather than mixing with the sediment may provide a better analogue to natural behaviour.

Conclusions

+ Spectrometer tests [**Figure 2**], soil sampling for extracellular polymeric substances (EPS) [**Figure 4**], and microscope investigations indicate that chlorophyll-a, EPS content, and the biofilm community are dynamic and spatially diverse.

+ The diatomaceous biofilm more rapidly colonises finer sand with an earlier onset for a flat-bed morphology compared to the bedform-dominated reaches [**Figure 3**].

+ Sediment entrainment tests show a higher sediment transport threshold for biostabilized beds in both fine as well as coarse substrates, which is confirmed by quantitative Cohesive Strength Meter (CSM) tests [**Figure 4**].

+ Chemical surrogate EPS such as Xanthan Gum and Carrageenan can be applied to introduce a similar added sediment stability in a fast and controlled manner compared to natural biofilms. Effectiveness of these surrogates depends on environmental factors such as salinity, pH and temperature and the application procedure [**Table 1**].

+ Although similar added sediment stabilities can be obtained by surrogates, complex biofilm behaviour can only be partly replicated as illustrated by the differences in erosion behaviour [**Figure 5**].

ACKNOWLEDGEMENTS: We would like to thank Jane Reed for help with the species ecology, Rodney Forster for help with spectrometer tests, and Brendan Murphy, Laura Jordan, Robert Houseago and Bas Bodewes for laboratory assistance.