Investigating Biofilm Growth on Polymer Surfaces in Wastewater Systems

Student: **Michael Urwin**
Email address: m.urwin1@newcastle.ac.uk
Supervisors: Sam Charlton, Dr Jinju (Vicky) Chen
Email addresses: s.charlton2@newcastle.ac.uk, jinju.chen@newcastle.ac.uk
School of Mechanical & Systems Engineering
Newcastle University

Design smart polymer surfaces to promote efficiency of trickling filter wastewater treatment

Background

Biofilms are thin layers of microorganisms which stick to surfaces in natural, industrial and hospital settings. Biofilms are mostly undesirable, especially in medical situations like in catheters, as they can spread infection. However, biofilms are utilised in wastewater treatment.

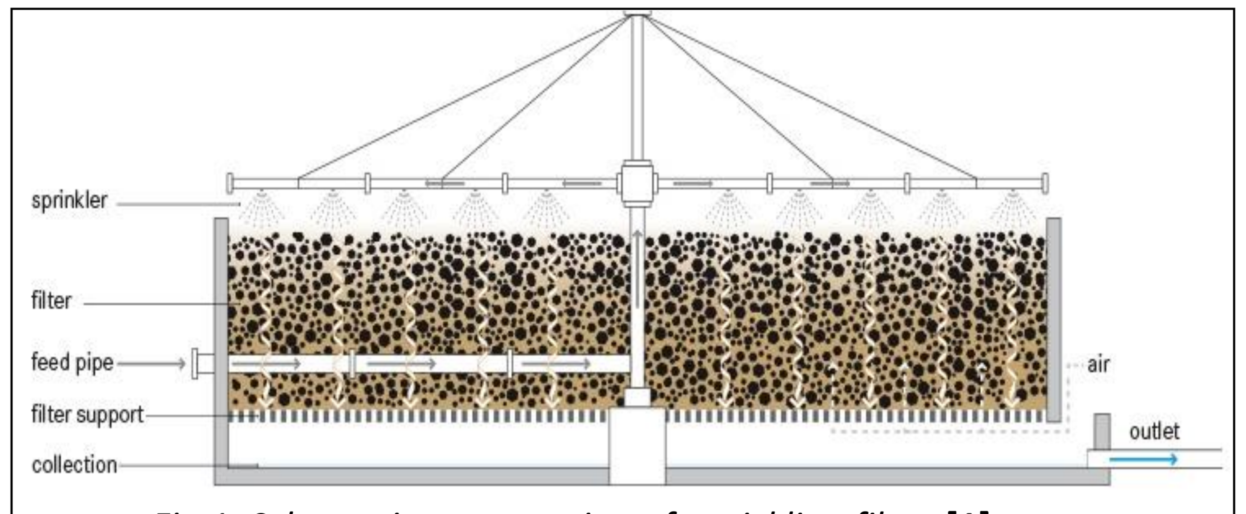

Fig 1: Schematic cross section of a trickling filter. **[1]**

A trickling filter is a form of (fixed film) wastewater treatment consisting of a large bed of filter media e.g. rocks, plastic..etc. on which biofilms form as wastewater is passed over the media. The biofilm is then used to remove organic components thus improving water quality. The issue that engineers are facing is how to design a plastic material which most efficiently promotes biofilm growth, ultimately improving the efficiency of these trickling filters.

Several material surface properties, which are illustrated below, affect microbe-surface interactions. In this project, some of these properties were investigated in an attempt to help us understand how we can design plastics which best promote formation and growth of biofilms.

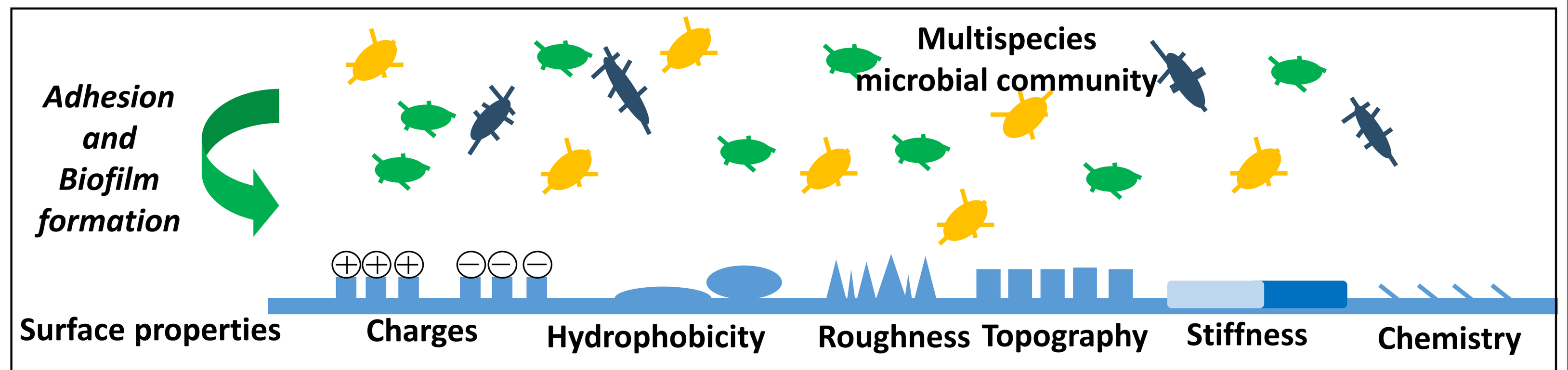

Fig 2: Schematic illustration of the interaction between bacteria and a surface depending on several surface properties. **[2]**

Aims

- Prepare and characterise nylon coupon samples.
- Examine how these nylon samples of different surface roughnesses affects biofilm formation.
- Design a lighting rig with four separate channels to fit a Polydimethylsiloxane (PDMS) flow cell in which plastic samples will sit to test the biofilms mechanical properties.

Experiments

Preparing the samples

- Ground the surfaces of 60 samples on a surface grinder into five different roughness categories (Ra's):
  - Control (surface not ground at all)
  - 0.1-0.2µm
  - 0.5µm
  - 1µm
  - 2µm
- Used a probing profilometer to measure the average roughnesses (Ra's) of these samples. Any outliers were discarded.

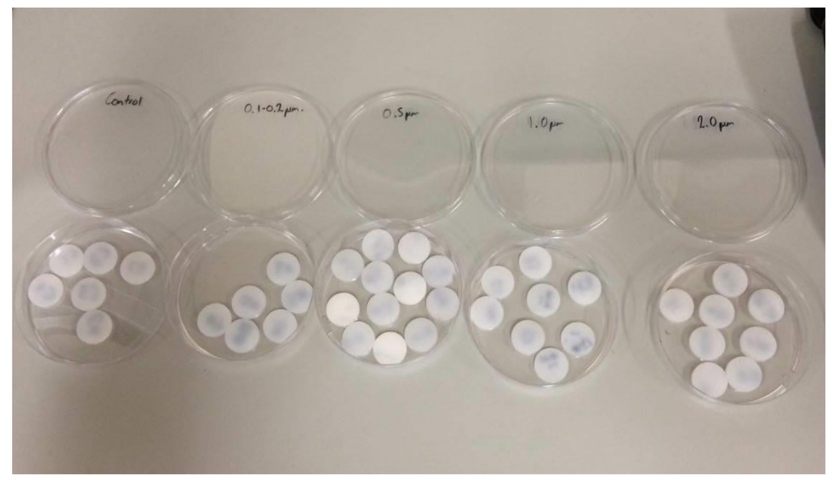

Fig 3: Nylon samples of five different roughness categories in petri dishes accordingly.

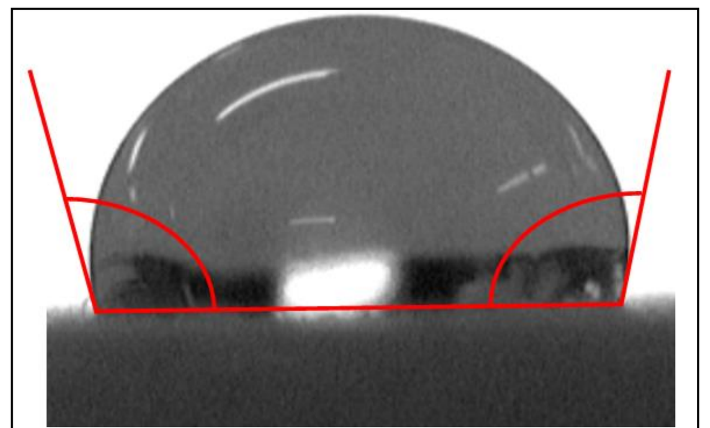

Fig 4: Image taken from the goniometer software illustrating the contact angle between a droplet and surface.

- Measured contact angles of water, glycerol and diiodomethane on each of the samples using a pipette and a goniometer. Contact angles were collected and used to determine the hydrophobicity of the samples.
- Used an optical profilometer to obtain 3D images of each sample, which were then used to obtain six parameters used for characterising the surface topography.
- Attached the samples to small plastic holders with silicon adhesive which were then left in a real trickling filter for 28 days to allow for biofilm growth and formation.

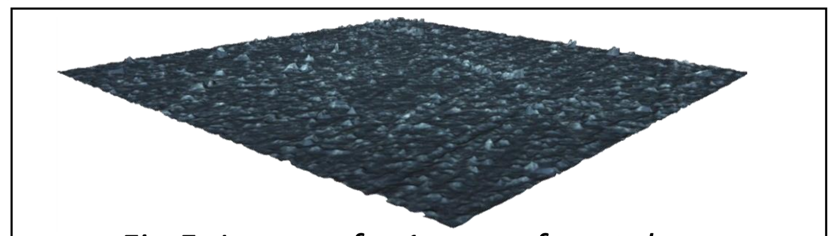

Fig 5: Image of a 1µm surface taken from the optical profilometer.

Analysing the samples

- Collected the nylon samples from the trickling filter after 28 days of biofilm growth and used confocal laser scanning microscopy (CLSM) to obtain images of the biofilms on each coupon.

Lighting rig

- Used Autodesk Inventor (CAD) to design a roof to fit on top of a PDMS flow cell with four channels.

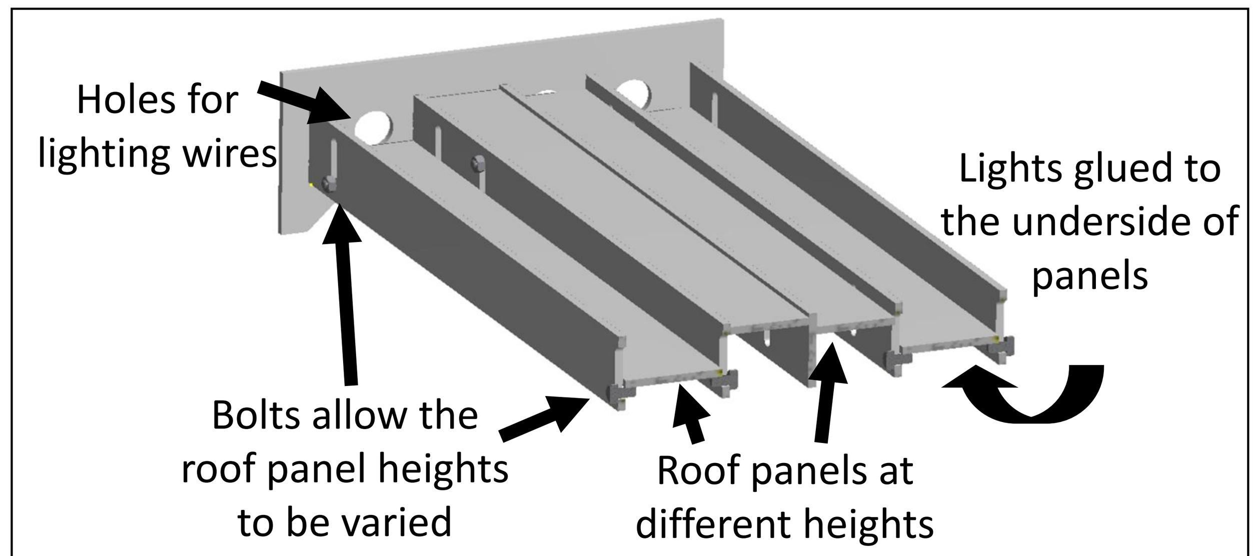

Fig 6: Cross section of the lighting rig on Inventor.

Results and discussion

Profilometer results

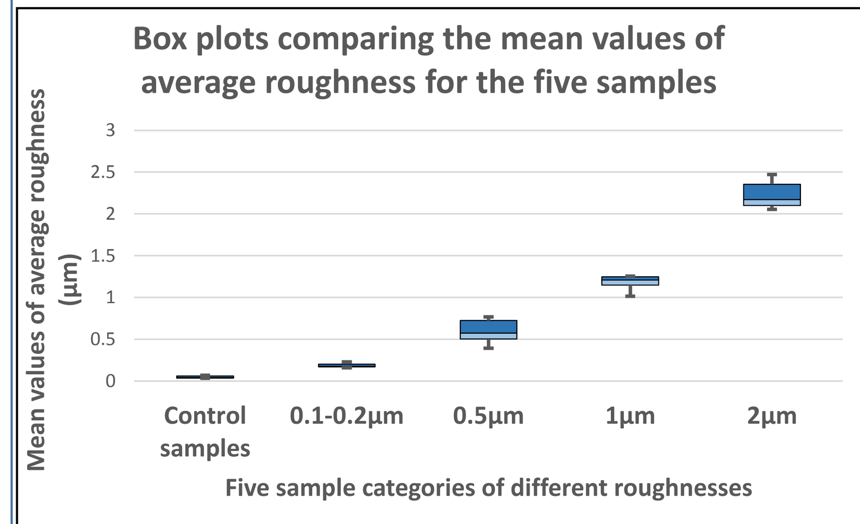

Fig 7: Results from the probe profilometer.

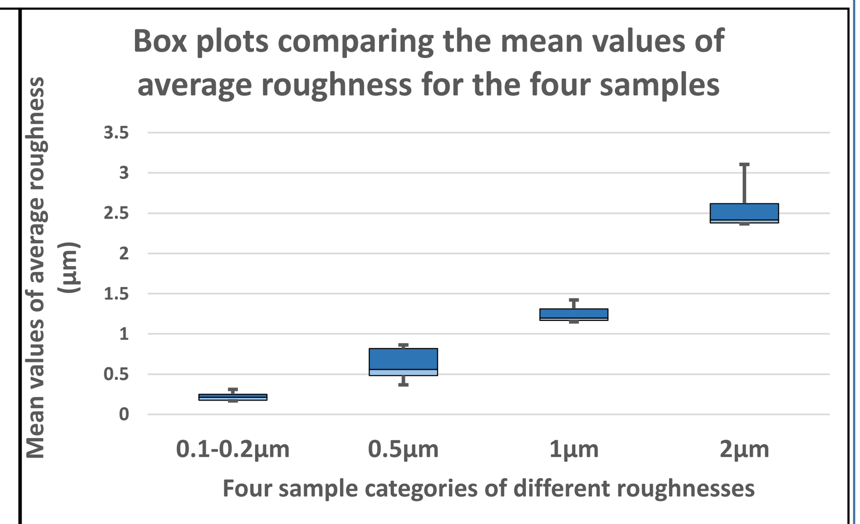

Fig 8: Results from the optical profilometer.

- Both graphs verify that the samples used were within range with no outliers.
- The optical profilometer shows slightly more spread in average roughness.

CLSM Images

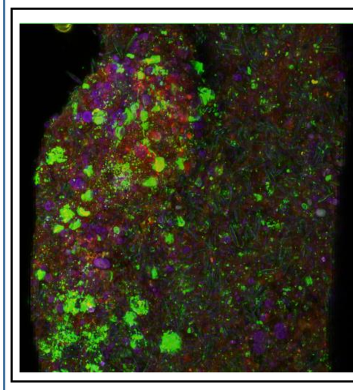

Fig 9: 3D image of biofilm growth on a 2µm nylon sample. Each fluoresced colour represents different members of this particular biological community.

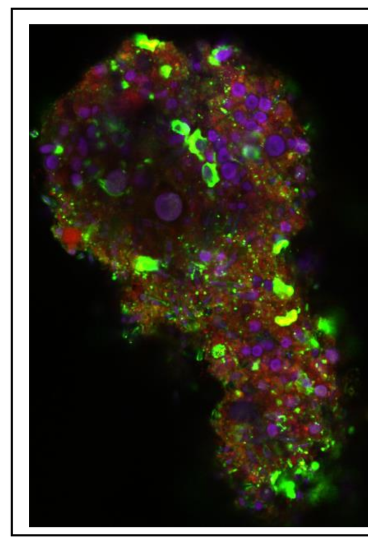

Fig 10: 2D image of biofilm growth on a 2µm nylon sample.

Conclusion

- More biofilm growth and formation was observed for higher surface roughnesses of these nylon samples using CLSM; all aims were achieved.
- This preliminary work therefore validates a full scale investigation into how polymer surface roughnesses relate to biofilm formation and growth. Further research in this field could help contribute to a world with cleaner, safer water.

Acknowledgements

Funding source: Newcastle University
Special thanks to the School of Mechanical & Systems Engineering technicians, Sam Charlton, Dr Matt German, Dr Alex Laude and Dr Jinju Chen.

References

[1] Tilley, E.; Ulrich, L.; Luethi, C.; Reymond, P.; Zurbruegg, C (2014): Compendium of Sanitation Systems and Technologies. 2nd Revised Edition. Duebendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag).

[2] Song, F. K., H ; Ren, D (2015). "Effects of Material Properties on Bacterial Adhesion and Biofilm Formation." Journal of Dental Research **Vol.94(8)**: pp.1027-1034.