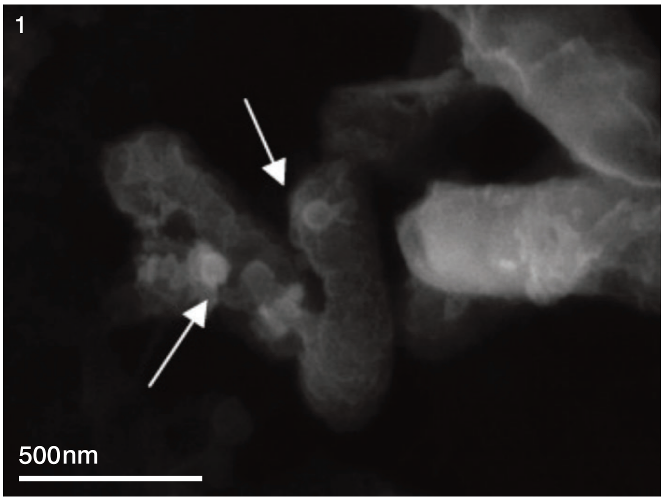
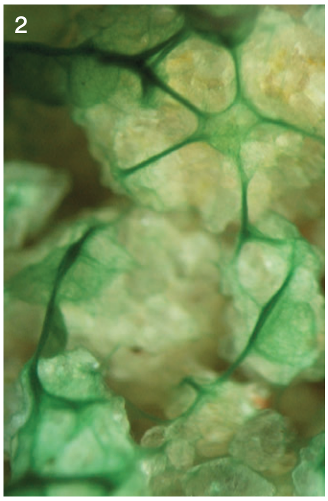
Biofilms: A Major Scourge

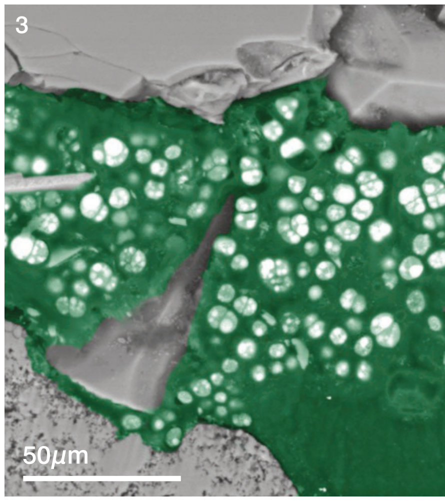
Biofilms Cost to Society

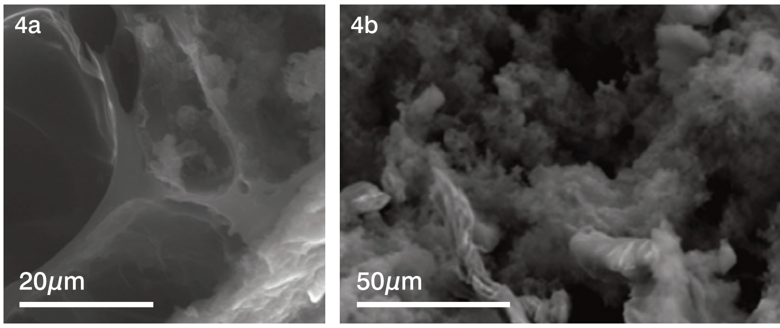
Biofilms are the dominant mode of life for bacteria. They form when bacteria adhere to surfaces in moist environments by excreting a slimy, glue-like substance. The term biofouling implies their accumulation. Biofilms cost the UK billions of pounds every year in energy losses, product contamination, equipment damage, and medical infections. The costs from energy losses alone are staggering. For example, fuel consumption of large ships, whose hulls are contaminated by colonies of micro-organisms, is 18% higher than that of ships with clean hulls. As fuel prices rise, the cost impact of biofilms increases. In addition, approximately 5% of the UK's CO_2 emissions come from shipping, so greater fuel usage, because of biofilms, has an environmental price as well.

Similarly, biofouling can reduce hydropower turbine efficiency by 40% and clog up pipes and membranes, significantly increasing the pumping costs incurred in the water and petroleum industries. However, these costs are small in comparison to those expended in medical and domestic settings in a continuous battle against biofilms. For organisations working to preserve the nation's heritage, biofilms also cause significant erosion of structural materials, in particular to the porous sandstones used in many historic buildings. Thus, managing biofilms is big business, and companies with a deeper understanding of biofilms' interactions with surfaces and their impact on fluid flow will have a competitive advantage in developing products and biofilm management strategies tailored to specific environments and materials.









Responding to the Challenge of Removing and Preventing Biofilms

The challenge of removing biofilms and preventing biofouling requires knowledge of the behaviour of bacteria on surfaces at a micro or even nano scale. To demonstrate the efficacy of a particular biocide, new surface chemistry, or biofilm management strategy, researchers must be able to image and quantify the distribution and activity of bacteria on surfaces. This may be further complicated as bacteria on surfaces often reside below a layer of extracellular polymers. To achieve this bacterial quantification, a suite of highly specialised equipment is needed. The University of Glasgow's School of Engineering is actively researching the effects of biofouling on water systems and potential treatments. Essential metrology and analytical support is provided by the Imaging Spectroscopy and Analysis Centre (ISAAC), based in the University's School of Geographical and Earth Sciences (GES).

Analysing Biofilms in Water Supply Systems with Electron Microscopy

The use of specific nanoparticles, such as silver, on desalination membranes to prevent biofouling is one research area. Once a bacteria cell absorbs a nanoparticle it will die. ISAAC's high resolution field-emission environmental scanning electron microscope (ESEM) can show cell walls absorbing silver nanoparticles, which pit the walls and ultimately lead to bacteria cell death. This research has led to scientists achieving success in limiting biofouling by attaching silver nanoparticles to desalination membranes.

In drinking water supply systems, another area of research at the University of Glasgow, the ability of bacteria to survive disinfection is directly linked to their ability to exist within biofilms. For example, identifying bacteria that are able to colonize drinking water filters or water distribution pipes in the form of biofilms is critical to ensuring safe drinking water. In a recent study, Glasgow researchers showed that the biofilms attaching to the activated carbon particles in water filters have the potential to seed bacteria into the drinking water supply system, which are then distributed throughout the network. Further, the growth of microbial biofilms and associated extra-polymeric substances can result in (1) greater head loss during filtration, by clogging the filters and the under-drains, and (2) corroded drinking water distribution pipes due to microbial activity. All of these factors not only drive up the cost of potable water production, but can also affect water safety. Once more, ISAAC's ESEM can show biofilms in a drinking water supply filter and distribution pipe section, helping to confirm that the biofilms will reside in areas of low and high fluid shear stress.

Managing Biofilms for Constructive Applications

While biofilms cause a diverse array of problems, they can be used to advantage as well. Biofilms are often applied in waste water treatment to convert organic matter into CO_2, as a key ingredient in the production of some biochemicals, for eliminating petroleum from contaminated oceans or marine systems, in microbial fuel cells for generation of electricity, and to help bind unconsolidated materials, such as river gravels, to limit erosion.

The University of Glasgow's Expertise and Scientific Analysis Advances Biofilm Research

The University of Glasgow's expertise in the School of Engineering, combined with the state-of-the-art scientific analysis available through ISAAC, enables it to address many of the major challenges involved in the study and treatment of biofilms. ISAAC has an array of instruments, particularly ESEM and Raman microscopy, able to characterise bacterial distribution and surfaces. Through such analysis, the effectiveness of biocides, nanoparticles, surface chemistry solutions, and other treatment systems on biofilms can be proven.

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Images

1. *ESEM image with arrows pointing to silver nano particles absorbed onto nitrifying bacteria cells (Chio et al 2006), which once contaminated ultimately die*
2. *Image of cyano-bacterial biofilm binding river gravel*
3. *SEM image of algal biofilm (green) within pore spaces of quartz building stone mineral grains (grey)*
4. *ESEM images of biofilms growing in activated carbon filters (4a) and drinking water supply pipes (4b)*