

Identifying and Prioritising Industrial Challenges and Potential Solutions for the Prevention, Detection, Management and Engineering of Biofilms

Workshop Report.

York, 27th February 2018



Executive Summary

Biofilms are created by microbial communities for a range of reasons, with a fundamental focus on the survival, maintenance and growth of the members of the community themselves. Biofilms are often seen as problems and are thus viewed negatively. However, their creation and maintenance can equally provide benefits such as the removal of pollutants, the potential production of pharmaceuticals and the production of biofuels on an industrial scale. In addition, biofilms on plant roots produced by micro organisms can help to preserve and unlock vital nutrients. And their role in the stabilization of microbial communities is ecologically important.

Investigation into the manipulation, control and exploitation of biofilms has gained momentum and seen an increase in research activity and funding in the UK in the last 3 years. Although the cost of detrimental biofilm creation is estimated to be tens of billions annually, significant market opportunities have also been identified.

Previous workshops in 2015 to look at research challenges for biofilms established two key needs:

- Detectable and quantifiable biofilm removal or prevention;
- Increased capability to manipulate, 'live with' and benefit from biofilms when removal is not possible and/or their presence is advantageous

This led to the funding of an Innovation Knowledge Centre – The National Biofilms Innovation Centre – which was designed to create networks, transform research and stimulate economic growth.

The purpose of the workshop in February 2018 was to build on these previous initiatives and engage widely across a range of industrial and research sectors to capture key priorities within each sector with a view to identifying generic challenges and needs which were sector agnostic. Experts in the following industries were involved:

- Medical/clinical and health
- Agri-food
- Biotechnology
- Oil & gas
- Water, marine & coatings

The following ranked needs were identified:

- 1 The effective detection and characterisation of biofilms.
- 2 Robust models to give greater predictability of properties and behaviour that can be implemented cross sectorally were seen as essential.
- 3 Water and the implication of detrimental biofilms, as well as those used for the treatment of water was seen as a common area to all the industries looked at in the workshop and therefore an area where common goals and projects could readily be developed
- 4 Exploiting biofilms – including for applications not yet anticipated – is something to be continuously considered

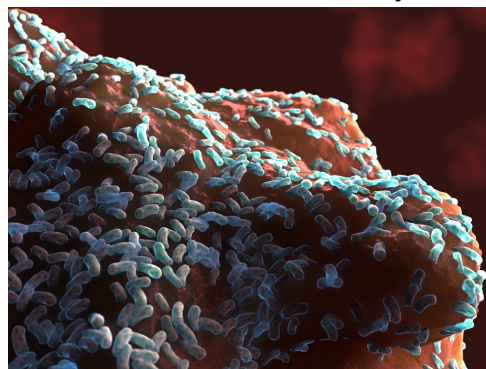
Additionally, the development of new materials and/or coatings was raised in several sectors as an opportunity area for future investigation.

Biofilms can inevitably act as a protective haven for pathogens, a cost for any moving parts (ships, machinery etc.) and a source of legislation and regulation, they also have the potential to provide a range of benefits. The key to making use of biofilms is their management, manipulation and control so that they become

part of the toolkit for medical science, biotechnology, energy and manufacturing industries. Just as synthetic chemistry has enabled us to manipulate and create individual molecules and molecular genetic techniques, including synthetic biology has made possible the creation of new biological molecules and systems. So a deeper understanding of biofilms will enable us to understand better microbial communities and their manipulation, to remove unwanted biofilms, to optimise beneficial biofilms and ultimately to create designer biofilm systems for specific uses. These represent major proactive challenges, which will best be met by integrative discussions between sectors, science systems and society.

Background

Biofilms are created by microbial communities for a range of reasons, with a fundamental focus on the survival, maintenance and growth of the members of the community themselves. The route to exploiting biofilms, in areas such as antibiotic production, is the management and control of the biofilms such that their production is of benefit to our commercial endpoints and of socio-economic advantage. At one extreme this may mean preventing their formation but it could also mean ensuring that beneficial or neutral biofilms are prevalent. Biofilms are a critical factor in the field of antimicrobial resistance and are a mechanism by which bacteria can evade antimicrobials and immunological response from the host. They also play a critical role in microbial influenced corrosion of pipes and equipment in the marine, oil and gas, food and water sectors. Biofilms may also form the basis of bioremediation processes, such as water treatment. Biofilms represent both a huge problem and an opportunity for exploitation, and better understanding of biofilms is likely to yield benefits beyond those we can currently anticipate.



In 2012/13 BBSRC invested over £18m in biofilms and directly related underpinning technology research (<https://bbsrc.ukri.org/documents/biofilms-strategic-opportunity-pdf/>). When combined with other significant advances in fundamental biosciences research and other applicable adjacent and tangential fields, this represents investment in a huge body of world-class science on which the UK can build and capitalise.

Indeed, investigation into the manipulation, control and exploitation of biofilms has gained momentum and seen an increase in research activity and funding in the UK in the last 3 years. Although the cost of detrimental biofilm creation is estimated to be tens of billions annually, significant market opportunities have also been identified.

(<https://bbsrc.ukri.org/documents/biofilms-strategic-opportunity-pdf/> ref)

Some specific examples of the costs of biofilm control include:

- Biofilm infection in hospitals - potential savings in orthopaedic cases. €100,000 saving per 100 treated patients if infection is prevented (http://www.bjjprocs.boneandjoint.org.uk/content/98-B/SUPP_23/33 2016)
- IFF (internal fracture fixation) devices infection costs. 3% of all implants become infected with biofilm associated infections. Cost of treating infection estimated to be \$1.5bn annually (BALI (BioFilm Alliance) consortium (<http://www.bali-consortium.eu/index.php/infection/biofilms>)

- Biofouling in plants in contact with water, cost estimated to be \$200bn in US (<http://www.cisuvc.com/applications/environmental-sensing/biofilm-biofouling>)
- The overall cost associated with hull fouling for the US Navy's present coating, cleaning, and fouling level is estimated to be \$56M per year for the entire DDG- 51 class of ships or \$1B over 15 years (Biofouling. 2011 Jan;27(1):87-98. doi: 10.1080/08927014.2010.542809. Economic impact of biofouling on a naval surface ship. Schultz MP1, Bendick JA, Holm ER, Hertel WM.)

As previously noted, the UK is a global leader in bioscience research and the launch of a new [National Biofilms Innovation Centre \(NBIC\)](#) in November 2017 to foster academic-industry collaborations, create new technologies and expedite those already developed into commercial benefit will aid this. The multi-site NBIC has received £16M funding from BBSRC and Innovate UK, with additional support from universities and industry. The NBIC is part of the UK Biofilms Programme launched in March 2015 will support businesses and academia in the exploitation and advancement of biofilm science and technology. The initial areas the programme is likely to focus on are:

- To support development of biofilm management technologies through translational proof of concept funding
- Deepening the scientific understanding of the prevention, detection, management and engineering of biofilms

The programme will consist of a number of different funding opportunities across the research and innovation pipeline and will develop a coherent multidisciplinary, multi-sectoral community across Industry and academia.

Previous workshops convened by BBSRC and Innovate UK in 2014: horizon scanning and cross sector industry scoping identified a number of pre-competitive and commercial areas that presented industrial challenges and explored potential solutions. The outputs identified three clear groups: those that needed to remove or prevent formation of biofilms; those that need biofilms and underpinning solutions/technology provision. Two key needs arose:

- Detectable and quantifiable biofilm removal or prevention;
- Increased capability to manipulate and 'live with' and benefit from biofilms when removal is not possible and/or is advantageous

This was followed by a collaborative R&D competition, jointly funded by Innovate UK and BBSRC in 2015, which funded 21 projects in areas including:

- Healthcare
- Manufacturing
- Consumer goods
- Food and drink
- Water treatment
- Marine industries



Workshop Objective

The purpose of the workshop hosted in February 2018 by Knowledge Transfer Network and funded by Innovate UK, was to build on these previous initiatives and engage widely with industrial and research sectors to capture common industrial challenges and needs, helping to further shape the short-term and long-term strategy for industrial pre- and post-competitive research in biofilms. The workshop was supported (non-financially) by the NBIC and it is expected the results will provide useful themes and specific tangible areas of focus. A secondary output of the workshop was to provide a forum for ideas and information exchange and the development of nascent collaborations and projects.

The outputs of the workshop are being provided to Innovate UK and BBSRC to provide both industry and academic challenges to help inform their future funding scopes for this area as appropriate, as well as to the NBIC as further community evidence gathering on focus areas.

Methodology

Specific companies were identified based upon information obtained from previous biofilm initiatives and collated by the KTN. Other participants including academics, solution providers and representatives from the NBIC were also invited. The industrial attendees were recruited to represent different sector interests and were then split into the following broad sector areas and interests based on awareness of the biofilms area:

- Medical/clinical and health
- Agri-food
- Biotechnology
- Oil & gas
- Water, marine & coatings

Approximately 55 attendees from a broad range of backgrounds participated (see Appendix 2 for attendees) and, despite the challenging weather conditions, there were only a small number (5 or 6) non-attendees.

Each working group was tasked with the development of a list of challenges based on four thematic areas previously identified by Innovate UK and BBSRC: Prevention, Detection, Management and Engineering. Each theme was examined in a facilitated 'world café' format. Each group was asked to consider:



Opportunities and targets to include benefits

- Scientific
- Commercial
- Societal
- Environmental

What needs to be done?

- Identify challenges
- Science and technology solutions
- Expertise and skills
- Commercial realisation - Industry responsibilities (eg commercial pipeline development, engagement, setting challenges, ambassadorial responsibilities)
- Other?

Who can/needs to do it?

- Scientists
- Funders
- Industry
- Other?

Why the UK?

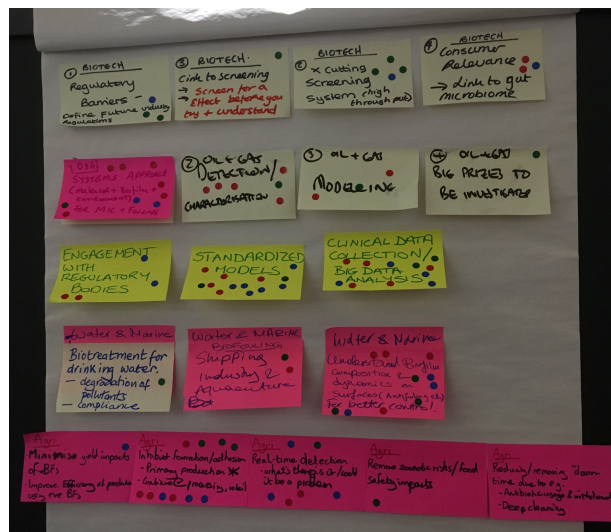
- Expertise
- Capabilities
- Gas

The aim was to identify key priorities within each sector, with a view to identifying generic challenges and needs which were sector agnostic. Participants circulated between the five themes with one person and a KTN facilitator staying with each theme throughout. In this way participants were able to provide insights in areas other than their own in a mixed sectoral format

Finally delegates chose their preferred sector and each was asked to carry out a 'reality check' on the conclusions from the joint session and to consider any potential solutions identified by the other groups. Each sector group prioritised their list of challenges (maximum of five).

The groups then reconvened in a single session and presented their prioritised list based upon the following criteria. All delegates voted for their top 3 challenges/opportunities across all sectors, which were then ranked (see Tables 1 and 2 below).

During the workshop, a number of delegates were able to give 3 minute 'elevator' pitches of their technology offerings in particular after the first round of challenge identification, to stimulate the afternoon discussion on priorities and potential solutions.



Outputs and discussion

The meeting started with the knowledge that workshops to identify key areas for biofilms research and innovation, particularly to inform the funding of a knowledge innovation centre had already taken place 2 years ago. Thus, the aim was to look specifically for cross-sectoral challenges and areas where real traction and critical mass to solve the challenges was needed, with ideas about what resource and technology could be required in order to deliver solutions. Delegates were actively encouraged to offer their personal and organisations expertise, not only to their own sector discussions, but more broadly as comparison and ultimately requirements and solutions for adjacent and entirely different sectors.

Lively and enthusiastic discussions were noted for every industry sector and it was gratifying to note discussions on potential future collaborations taking place. The collated suggestions from each of the sector groups are shown in Appendix 1 for reference.

The top priorities derived from each sector are shown in Table 1. The ranked priorities across all sectors are shown in Table 2.

Table 1 Challenge/Opportunity Priorities Per Industry Sector

Sector	Identified Priority Need	No of votes
AgriFood	Inhibit formation/adhesion of biofilms for primary production and continue through processing	10
	Real time detection what is present is or could be a problem	6
	Minimise yield impacts of biofilms and improve efficiency of production using biofilms	1
	Remove zoonotic risks – food safety impacts	1
Biotechnology	Link to Screening – Screen for an effect before you try and understand it	6
	Cross cutting screening systems – high throughput	4
	Regulatory Barriers – Define future industry regulations	3
	Consumer relevance – link to gut microbiome	3
Health & Medtech	Standardised models	13
	Clinical data collection – big data analysis	10
	Engagement with regulatory bodies	4
Oil & Gas	Detection and characterisation	6
	Modelling	2
	Big prizes to be investigated	1
Water & Marine	Understand biofilms – composition and dynamics on surfaces (antifouling etc) for better control	10
	Fouling – shipping industry & aquaculture	2
	Biotreatment for drinking water – degradation of pollutants, compliance	1

Table 2: the top 3 grouped and ranked priorities across all sectors

Ranking	Priority Need
1	Standardised models
2	Inhibit formation/adhesion of biofilms
3	Data collection – big data analysis
3	Real time detection what is present or could be a problem

Key themes that came up across many areas as expected were the need to identify cross-sectoral activities and work collectively on them to solve the generic, pre-competitive challenges together to help cement and strengthen the already significant UK capabilities and to allow better productivity and efficiency in the industries that biofilms have an impact on, whether they are positive or negative.

Across all the challenges, the need for cross-disciplinary approaches was identified requiring engineers, physical and computational scientists, as well as modellers to work alongside bio and life science professionals. Equally the need for academia to work closely with industry, healthcare providers and other key stakeholders is key to accelerate innovation to drive economic value.

The biggest need identified via voting - also raised in the previously held workshops - was the effective detection and characterisation of biofilms.

Developing tools to aid the characterisation, particularly sampling, is often difficult from potentially extreme and hard to reach environments (eg oil and gas, human and animals and food and water industry). It is seen as a major challenge that is needed first to enable representative and more importantly 'real time' information - both snap shots and in-line monitoring. It is recognised that irrespective of sector, the ability to understand not only the microbial community constitution, but also the structure and functionality of the consortium is fundamental in order to give a greater ability to control what is occurring if confidence in the measurements can be assured. The need to better understand the structure-function nexus was seen as essential in all areas. This includes, but is not specific to, identification of species present in biofilms and their interactions in the biofilm.

Robust models to give greater predictability of properties and behaviour that can be implemented cross sectorally were seen as essential.

Models of biofilms are already available, but it was noted that these are evidently not working effectively enough and it is pointless doing the same things when they are not effective. Thus, the number one priority was seen as the development of *standardised* models. This could in turn make the development of regulations protocols for the management of biofilms easier for all industries if a 'gold standard' standard method of testing is available. Making use of tools such as bioinformatics, proteomics and metabolomics will undoubtedly help in achieving a greater understanding of the microbial make up, what different microbes do under different conditions and the impact of external influences on the microbial consortium which can be modelled to provide areas of control and engineering.

Water and the implication of detrimental biofilms, as well as those use for the treatment of water was seen as a common area to all the industries looked at in the workshop and therefore an area where common goals and projects could readily be developed.

Biofilms are frequently thought of only in negative terms. The swell of activity and cohort building that the workshop encouraged will therefore be a positive move in building a more balanced and complete picture. Not just in understanding the

functionality but also in terms of communicating both the impact and the benefits - actual and potential, of biofilms beyond the scientific community. The provision of case studies and positive stories about what a biofilm is and why the public should care, especially as it applies to public health, was viewed as an important aspect that needs addressing.

Exploiting biofilms – including for applications not yet anticipated – is something to be continuously considered.

Examples given by workshop participants included plant protection; food and other waste treatment; corrosion prevention and engineering of microbiomes for specific properties and outcomes.

The creation and implementation of NBIC as a multi-disciplinary, multiple stakeholder innovation centre that is designed in part to support industrial needs is of course seen as a positive step to tackling some of the generic challenges. It will also have a role to play in terms of pulling in additional expertise, identifying knowledge and infrastructure gaps and promoting UK capability more widely.

Areas of interest other than the understanding, control and exploitation of the microbial communities

The development of new materials and/or coatings was raised in several sectors as an opportunity area of future investigation.

Costs of fouling in marine environments are huge and this, as well as the importance of hospital acquired infections led to the suggestion that cross-learning could be obtained from medtech as to appropriate materials and coatings and their properties, for use in the marine environment and vice versa. This could also be true for other processing equipment in other areas. Stainless steel is used for a lot of equipment and is designed to prevent the formation of potentially hard to clean areas. However, future equipment could perhaps be designed to have specialist microbially resistant coatings or new materials to prevent microbial colonization. For example self-healing materials, which are already under investigation in academic groups in the UK could be tested in this application. Synthetic biology approaches could be used to generate new materials, using the knowledge of microbial composition and function to engineer them for specific purposes rather than just a generic 'non-stick' property.

Conclusion and next steps

There are some common themes that run over all of the sectors and which can provide the basis of recommendations for further thematic (and perhaps deeper dive) workshops to explore solutions more explicitly; the basis of specific cross-sector pre-competitive projects; feedback to funders and legislators and how best to convey what is developed to help reduce down time from removal or control of biofilms and increase productivity.

- Understanding biofilms not just in terms of their constituent microbes but also the dynamics of formation, structure, function, maintenance and resistance to perturbation.
- Developing better model systems for biofilms that are testable – particularly in environments where direct inspection is difficult – and which have a high degree of predictive power across a range of biofilm environments. The fact that biofilms form in such a wide range of places

suggests that some characteristics are likely to be common and information about these should be amenable to 'big data' analysis.

- Making sure legislation (national and international) is consistent and is underpinned by good and robust science.
- Are there uses for beneficial biofilms to prevent the growth of unwanted organisms or of biofilms with deleterious properties?
- Understanding what is already out there in terms of data and how different collections of data can be interpreted and contribute.
- The use of small molecules (e.g. quorum sensing and others) for the specific control or elimination of biofilms is an attractive option. This could be by direct application of such molecules (or analogues) or manipulation of their production by microbial biosynthetic pathways.
- Depending on where you are coming from, complete elimination of biofilms is either the ultimate aim or neither a good or achievable ambition. Solutions must be tailored to circumstance and need.
- Contextualised communication material for a variety of stakeholders on both the benefits and problems of biofilms including what they are with good case studies exemplifying UK capability.

Undoubtedly unwanted biofilms cost industry huge amounts annually as well as the associated health issues. Thus the coming together of different sectors from industry to work with academic excellence including the launch of an innovation centre was clearly seen as a very positive move in order to capitalise on what the UK already has in terms of capability and infrastructure, but there is still a need to identify gaps in both and articulate them.

Biofilms are an inevitable consequence of multi-microbial communities. While they can act as a protective haven for pathogens, a cost for any moving parts (ships, machinery etc.) and a source of legislation and regulation, they also have the potential to provide a range of benefits. The key to making use of biofilms is their management, manipulation and control so that they become part of the toolkit for medical science, biotechnology, energy and manufacturing industries. Just as synthetic chemistry has enabled us to manipulate and create individual molecules and molecular genetic techniques, including synthetic biology has made possible the creation of new biological molecules and systems. So a deeper understanding of biofilms will enable us to remove unwanted biofilms, to optimise beneficial biofilms and ultimately to create designer biofilm systems for specific uses. These represent major proactive challenges, which will best be met by integrative discussions between sectors, science systems and society.

The outputs from each sector are given in Appendix 1

The participants in the workshop are given in Appendix 2

Appendix 1

The outputs from the five industry sectors are given below.

Oil and Gas

Key Opportunities and Targets

- New sampling methods and new markers for detection. Sampling is a challenge from extreme environments (cf med and food).
- Real time methods are needed for monitoring biofilms at depth and pressure. Note monitoring and detection are key to all areas and sectors.
- Understanding which microbial communities are most important. Why and how does biocorrosion work? What is the biocommunity and which are the problematic microbes?
- Why does nitrate injection work?
- Fouling on membrane, especially bioprocesses and water clean up
- Where does the engineered biofilm end up. If it is removed needs complete removal.
- Planktonic vs. Sessile Monitoring: Monitoring - Good sensors and second degree indicators needed for early biofilm detection.
- A clear need for new and accurate model systems.
- Developing solutions – chemical and physical. Need a better understanding of why some solutions appear to work.
- Is there an opportunity to use biofilms to prevent corrosion? Is it possible to engineer biofilms for benefit?
- Engineer biofilm coatings
- Prevent contamination of oil
- Cost reduction of pipe maintenance would be a benefit of biofilm control
- Safety implementation needed due to biofilms
- Are there opportunities to make use of self-repairing materials?
- Corrosion inside pipes can be 100-1000mm. Velocity in pipes is 1-20 m/s.
- Cost of interventions is an issue but needs doing.

What Needs to be Done?

- Education of industry, regulators, population in general on biofilms
- Cross sector conversation and funding is required.
- Physical means of biofilm manipulation
- Better models.
- Identify engineering problems vs biological problems.
- Exploit biofilms
- Real time detection and sampling techniques

Who Needs to Act?

- Industry and academics need to talk to each other
- Specific funding needed.
- All three (industry-academic-funders) need to be part of the solution.
- Regulatory involvement with new solutions is important.

Why the UK?

- It is a global problem and the UK needs to stay at the cutting edge
- There is a large UK industry base in oil and gas
- There are some (3 or 4) biofilm centres in the world
- There is an opportunity for the UK to be leaders.

Priorities

Detection and characterisation (6)

Modelling (2)
Big prizes to be investigated (1)

Agri-Food

Key Opportunities and Targets

- Use of biofilms for water treatment including desalination
- Positive use of biofilms to help in bioremediation e.g. run offs, effluent etc.
- Biofilms to help with food waste processing
- Biofilms for plant protection
- Diagnostic labelling- indicates 'off' products better.
- Bacteria are an issue – Salmonella, Campylobacter, Listeria, Pseudomonas, E coli. Also issue with spoilage and shelf life reduction.
- Treatment options for biofilms – hypochlorite, propionic acid, enzymes, polymers, small molecules, competitive organisms
- Potato pink rot
- Antimicrobial resistance is an issue and an opportunity. Persistence vs resistance.
- Destruction of biofilms in food processing equipment.
- Biofilms for use in degrading plastics/packaging?

What Needs to be Done?

- A better understanding of what is acceptable in the regulation vs retailer standards.
- Might phage control be an option?
- Can we retrofit the system or does it need a new build?
- A better understanding of how to control biofilms so as to get the required status.
- Is the use of biocides acceptable? And their disposal.
- Management across the supply chain.
- What impact will the use of control methods have on the biofilms organic status?
- Can we have improved biofilm clearing through non-antimicrobial approaches? Probiotic cleaning to exclude problematic bacteria?
- Can we control viruses in biofilms as they are a big source of food poisoning.

Who Needs to Act?

- Diagnostics are needed to detect the presence and problem causing microbes.
- Retailers - understand the presence of organisms in foods.
- Processors and producers and the animal and plant health community need to be involved.
- Animal/plant health community.
- Monitoring needs have to be determined – ongoing or with what frequency?
- Legislators and regulators for food safety considerations.
- The science base.
- Producers/processors.
- Development of new materials..

Why the UK?

- Intensive food industry.
- Supermarket influences can make big changes in industry wide quickly.
- Large industry can work pre-competitively.
- Co-ordinated collaborative approach.

- Risk appetite is low -

Priority Needs

- Real time detection.
- Identify if what is there could be a problem
- Inhibition of formation/adhesion in primary production and processing plants
- Education regarding actual risks and positives and negatives of biofilms and establish what is acceptable
- Reliable competitive products for livestock

Commercial needs

- Improving FCR/productivity
- Food safety impacts
- Biofilm removal causes yield impacts
- Zoonotic risks

Societal benefits

- Improving public health
- Preventing illness
- Shelf life extension
- Improve productivity/efficiency
- Price of goods

Priorities

Inhibit formation/adhesion of biofilms for primary production and continue through processing (10)

Real time detection what is present is or could be a problem (6)

Minimise yield impacts of biofilms and improve efficiency of production using biofilms (1)

Remove zoonotic risks – food safety impacts (1)

Reducing/removing down time due to, for example, antibiotic usage, & withdrawal and deep cleaning (0).

Biotechnology

Key opportunities and Targets

- Define what a biofilm is
- Health care infection control
- Segway to microbiome. Look at skin and oral microbiomes
- Killing/sterilisation is not an effective way to treat biofilms
- When is a biofilm not a biofilm? Characterisation important to define the biofilm.
- Common goals in different sectors leading to cross industry initiatives such as screening.
- Manipulation of the biofilm to put it to good use. Could use a biofilm as a biological binder.

What Needs to be Done?

- Regulatory challenge – it depends on what you claim the purpose is
- Nasty biofilms outnumber good biofilms and both need to be defined and differences determined.
- Need to understand better the structure/function relationship of biofilms
- Identify cross-sectoral activities for greatest impact
- Positive and negative strategic risk assessment is needed
- What is the risk of proactively using biofilms?

- Biofilms are not as we would like reproducible for a single screening system. New model systems needed.
- Current chemistry is insufficient – we need new solutions.
- There is a challenge: Exploit Synbio / Marketing : DNA exchange happens naturally in the gut. How to use biofilms in a positive way.
- Message to public: Relate the biofilm message to the gut microbiome. This is what they understand and feel comfortable with.
- Biofilms are generally seen as a bad thing – can't mention the biofilm!

Who Needs to Act?

- Development of high throughput screening system. Signalling. Material modification. Trigger a response or small molecule attack.
- AMR – an issue with anti microbial resistance
- Novel biofilm disruption technology needed.
- The challenges need to be mapped – a road map can be prepared.

Why the UK?

- Lots of good work already being done in the UK
- Consumer materials - North England has the largest network of companies in the world
- Strong critical mass, cleaning material north England: large concentration of cleaning materials in North England
- Activity already in oil and gas where bacteria are injected into the ground to break down components
- Bioscience can have solutions to deal with fouling and biofilms. UK is strong in bioscience

Priorities

Link to Screening – Screen for an effect before you try and understand it (6)

Cross cutting screening systems – high throughput (4)

Regulatory Barriers – Define future industry regulations (3)

Consumer relevance – link to gut microbiome (3).

Water and Marine

Key opportunities and targets

- Hospital effluent is a big issue and therefore opportunity. Public health is priority for water industry.
- Development of non-stick surfaces – an opportunity for other sectors? Medtech materials could be useful for marine environment.
- Need good models to understand biofilms – quorum sensing models
- Pre-competitive cross sectorial fundamental understanding of communities needs funding
- Education on effluent needed to see what happens
- Constantly changing systems need to lead to clean drinking water
- There are models but they need to be improved because currently we are just reinventing the wheel. It needs a joined up approach.

What Needs to be Done?

- Different microbes have different mechanisms associated with them and we need to understand these
- What are the current solutions – we need to understand these.
- Optimisation of the sewage process. Growing population/infrastructure is resulting in antibiotics being present leading to AMR.
- Marine is not just microbes – includes mini animals as well.

- Need to develop monitoring, analytics, to develop the right microbial communities.
- Can graphene maintain growth as a possible material?
- Biomimicry to produce better surfaces.
- Are there sensor systems for small and large scale systems. Design materials for new coatings for ships and/or prime the hulls . Probiotics for ships?

Who can/needs to do it?

- Need good models to understand biofilm and quorum sensing models. Models re there but need to be better as currently not effective enough. Need joined up approach across sectors
- Constantly changing system. But goal in water is clean drinking water.
- Pre-competitive cross sectoral fundamental understanding of communities needs funding
- Environmental and biocide regulation new biofouling solutions
- Education on effluent needed. Eg what happens to it
-

Why the UK?

- Bio-corrosion is a real problem
- Risks from biofilms in distribution systems
- Bio-treatment for drinking water: degradation of pollutants: compliance
- Needs: Odour reduction - sulphates: Resistance (AMR): Public Health:
- Need to understand surface properties and how cells adhere, can then mitigate
- Characterising EPS. What are anchoring systems chemistries used then design solutions
- How do we get the 'right' biofilm to deliver the right functionality?

Priorities

Water and marine – understand biofilms – composition and dynamics on surfaces (antifouling etc) for better control (10)

Water and marine biofouling – shipping, industry, aquaculture (2)

Biotreatment for drinking water – degradation of pollutants, compliance (1)

Health and Med Tech

Key Opportunities and Targets

- Robust relevant models and biomarkers..
- Understand chronic infection, chronic wounds
- Opportunistic pathogens in hospitals, biofilms as reservoirs, transmission pathways – biofilm control, novel techniques
- Water systems and surfaces a problem
- Clinical link - biofilm contribution or what constituents
- Control: hospitals/PHE , clinicians , academics, industry
- Is AMR a Biofilm problem? Invariably
- Are all bacterial infections a biofilm problem?
- Engineering microbiome for different effect and results
- NHS costs to the public. Support HCP / NHS
- Improved patient outcomes
- Growth in an ageing population leads to more implants
- Define a "healthy" biofilm
- Preventative medicine (public health spending)

- Validation of models
- Functional activity test
- Detection systems for biofilms : Wounds, catheters, orthopaedic
- Healthy microbiomes.
- Solutions – incl new antibiotics, paints, endocytes

What needs to be done?

- Academia and industry to develop protocols.
- Simple diagnostic tests, standardised procedures.
- Characterisation of biological, physical and structural properties. What can be predicted from this
- What regulations are required and ensure regulator understanding. Future regulations – divergence or convergence?
- Robust models need to be developed.
- Sharing and common national/international terms.
- Standardisation needed.
- Make use of systems biology, functional genomics and bioinformatics to inform on microbial communities.
- Simple diagnostic tools to help identify biofilms
- Sharing of regulatory and microbial community models.
- Mixed population biofilm studies.
- Relationship between academia, industry, regulatory and the product
- Smart surfaces
- Consistency in national and international use of terms

Who needs to do it?

- Hygiene actives. Hurdles/combinations.
- Oral and gut health practitioners
- Role for researchers to develop models and work with regulators
- Funding: government funding BBSRC / EPSRC, Innovate UK / Industry. Make use of KTPs.
- Clinician led lobbying for support
- MHRA/KOL/PHE/ other regional equivalents to understand and work towards solutions
- NBIC/BBSRC – to ensure that the UK expertise in biofilms is well publicised both in and outside the UK.
- Need to understand how we stack up against our competitors
- IKC to develop models and work with regulators

Why the UK?

- World leading bioscience capability
- Innovative SMEs
- Global understanding

Priorities

- Can you predict what will be in a biofilm in any environment?
- Are biofilms ever stable?
- Models for wound care products that are good for proving the efficacy of wound care products *in vivo*.
- Defining biofilm functionality using 'omics approaches
- New anti biofilm agents for hospital-acquired infection prevention.
- Consensus in the medical community of what biofilm infections are and to produce standard models.

Standardised models (13)
Clinical data collection – big data analysis (10)
Engagement with regulatory bodies (4)

APPENDIX 2

Attending Organisations

ACTA
Innovate UK
BBSRC
WRc plc
GreenTech Corporation Ltd
5D Health Protection Group Ltd
OGIC - the Oil and Gas Innovation Centre
5D Health Protection Group Ltd
NBIC
Mars Inc
National Biofilms Innovation Centre, U. Southampton
3M United Kingdom plc
Medtrade Products Ltd
Unilever
Anglian Water
Clear water revival ltd
Smith & Nephew
Newcastle University
Black Kite Ltd.
Smith & Nephew
University of Nottingham
Bangor University, BioComposites Centre
Bangor University
AkzoNobel
Croda
JVS Products Ltd
Neem Biotech Ltd
Procter & Gamble Technical Centres Ltd
University of Southampton
Rawwater Engineering
Christeyns Food Hygiene
University of Glasgow
2 Sisters Food Group
University of Liverpool
BP
Vitacress
Devro (Scotland) Ltd
University of Edinburgh
University of Portsmouth
University of Nottingham
University of Birmingham
Edinburgh Complex Fluids Partnership/ University of
Edinburgh
Aqualution Systems Ltd
FOLIUM Science
Quadram Insitute Bioscience

