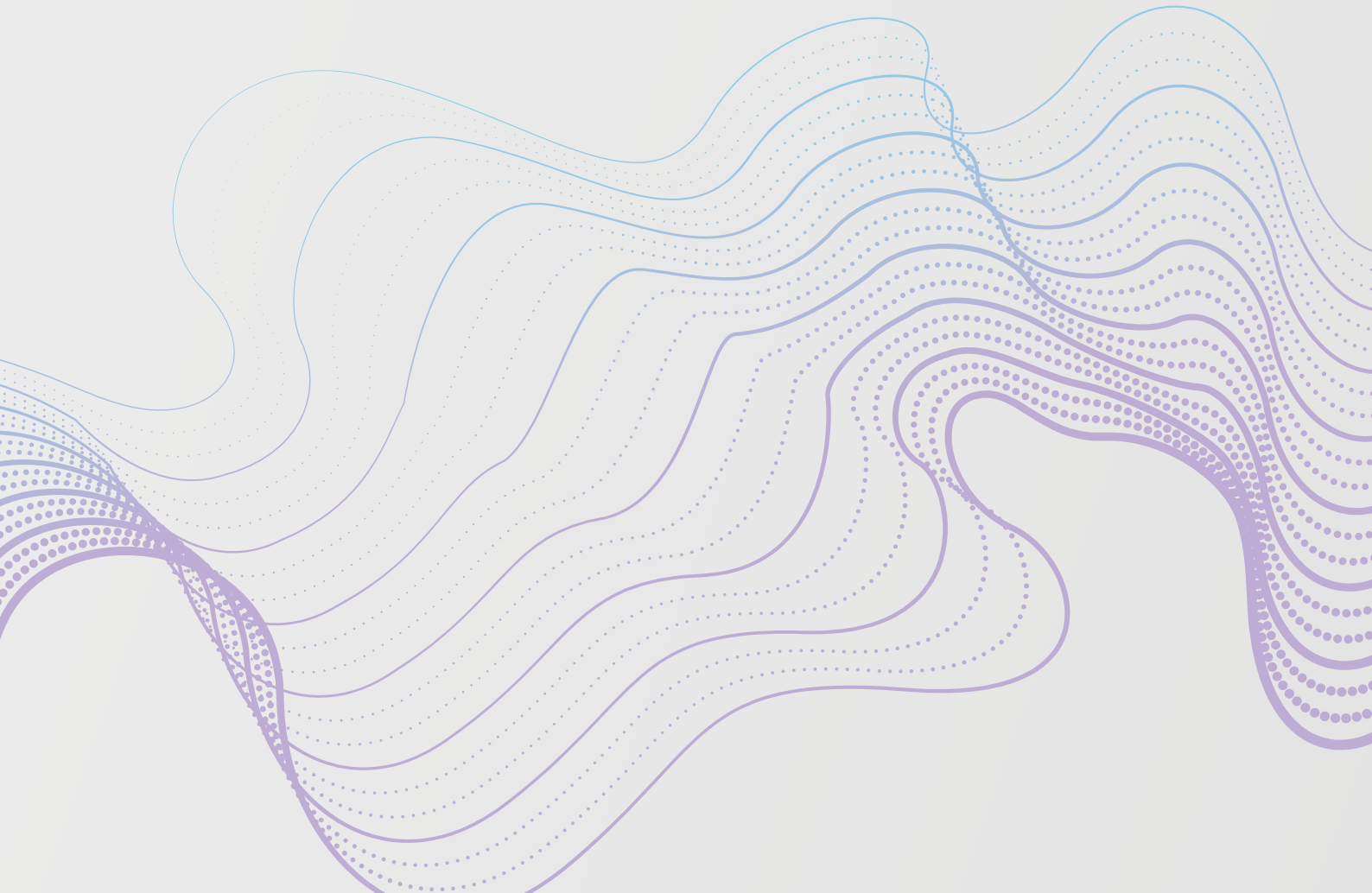
National Biofilms Innovation Centre

Biofilm Management

WORKSHOP REPORT

FEBRUARY 2020 – NOTTINGHAM UK



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NBIC WORKSHOP

Executive Summary

This workshop was aimed at exploring unmet industrial needs and resulting research questions in the field of Biofilm Management.

NBIC partner organisations shared their unmet needs and the 65 attendees (34 from industry) worked in syndicates to discuss the key challenges and ways to overcome them.

The main needs which emerged were:

Improved models and methods for characterisation, visualisation and detection of biofilms: these should be relevant (real world context), standardised and accessible to industry and academia.

Improved cross-disciplinary collaboration (industry to academia but also with regulators and between sectors of industry): through workshops, partner searches and in the development and execution of project proposals and models.

Clarification of pathways from industry regulators for solutions, and an enhanced understanding of time frames and associated costs. Support is required in easing the ability to navigate the pathways and influence the standards development. NBIC has a leading role to play here.

Understanding biofilm behaviour and control: there remains a need for further effort in terms of fundamental research on understanding biofilm behaviour and control to give us new leads and insights.

Data centralisation and management: Large amounts of data are produced using contemporary techniques and the collation, arrangement and interpretation of this and existing data sets via bioinformatics is a compelling need.

A range of strategies for addressing these needs were proposed and it was highlighted that NBIC needs to aim to widen its engagement and influence, to develop a broader shared concrete understanding of the problems and the optimum route to solutions. For example, this could include specific lobbying/outreach in areas such as identifying funding that could be released for fundamental research, creating an appropriate regulatory framework and greater public awareness of needs and opportunities.

Background: National Biofilms Innovation Centre (NBIC)

The NBIC was formed in December 2017 as an Innovation Knowledge Centre (IKC) funded by BBSRC, Innovate UK and the Hartree Centre.

NBIC 's mission is to harness the UK's industrial and academic strength in biofilms.

NBIC aims to be the recognised UK hub for accessing biofilm expertise, capability, science and innovation capacity. We exist to catalyse the growth in the UK's scientific, technological and industrial expertise in biofilms with the goal of delivering:

- World class science and scientists
- Breakthrough innovations
- Economic and societal value.

It has created a network and community of researchers and industrial/commercial partners across the UK and internationally to progress all these elements.

NBIC's Industrial and Academic Engagement Strategy

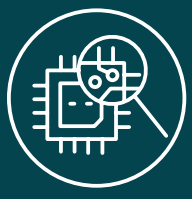
A primary element of the engagement strategy of NBIC, with its industrial and academic community, is the exploration of the current unmet industrial, scientific and societal needs in relation to biofilms. Be this the challenges they create or the opportunities they open up. It is NBIC's intent to explore these needs across each industry sector, context and market in order to define the current state of scientific and technological knowledge in relation to addressing these needs. These could be, for example, as diverse as identifying methods for either preventing or removing biofilms from the hulls of ships to the search for hand held systems for detecting biofilms in a high volume food manufacturing plant (as identified in our Biofilm Detection Workshop[1]). Many of these needs will be shared across industrial sectors and others may be unique to a particular context.

Developing this understanding allows NBIC to better direct its research and translational strategy, as well as facilitating and sharpening its industrial and academic engagement. NBIC will continue to hold workshops and scientific fora around these 4 themes as well as on specific subject fields. These will deepen the overall understanding and consensus around each theme and influence future scientific and translational activity and funding. In addition, NBIC in collaboration with our community have developed a Biofilm Ontology to build a common language.

This workshop and its predecessors on Biofilm Detection[1] and Biofilm Engineering[2] are a key dimension in achieving these goals and are intended to create a forum whereby academic experts and industrial practitioners can meet to explore solving unmet needs.

PREVENT

Knowledge-based design of surfaces, interfaces and materials



DETECT

Innovative sensing, tracking and diagnostic technologies

MANAGE

Kill, remove or control established biofilms from exploiting their life cycle dynamics

ENGINEER

Control and direct complex microbial communities in process applications

Biofilms in Context

It is well understood that microbial biofilms and communities collectively represent the largest biomass and activity centre on the planet playing a major role in the biology of the environment (both natural and engineered) and in maintaining public health. Therefore, the understanding of biofilms is key to discovering, controlling and directing the behaviour of microbial communities to support a sustainable environmental, different areas of engineering, public health and medical applications.

Biofilms are central to some of the most urgent global challenges and exert considerable economic impact across industry sectors. Biofilm management is essential to deliver clean and globally sustainable drinking water and food safety and security. Contamination, fouling, and energy losses by biofilms impact on the £70 billion UK foods industry, the $2.8 trillion US consumer products sector, and $117 billion global coatings industry. They are also a leading cause of antimicrobial resistance (AMR). As well as these challenges, it is also clear that harnessing biofilms for economic and societal benefits offers significant potential as shown in the 'Market Need for Biofilm Control Technologies' report[2].

In trying to both tackle and utilise biofilms the industrial and research communities (led by BBSRC and Innovate UK) have defined 4 key interventional strategies:

- **Prevent:** To limit or prevent the early stage microbial adhesion and colonisation events at surfaces. This could employ the use of advanced techniques to create the knowledge-based design of next-generation surfaces.
- **Detect:** To deliver a step change in the ability to detect biofilms directly, in situ, at the point-of-use in field-based contexts and close-to-patient care through accurate and quantitative biofilm detection and metrology across multiple scales.
- **Manage:** To destroy, remove or control established biofilms by understanding and exploiting their life cycle dynamics and development across a range of environments and levels of complexity. Also, to accelerate the development of successful treatments, which target the biofilm life cycle-dynamics and intricate structure, through the creation and use of biofilm models resembling real environments.
- **Engineer:** To harness the benefits of complex microbial consortia from knowledge of their composition, function, ecology and evolution. This exploits understanding at the interface with engineering and process applications. It includes improving engineered platforms and solutions e.g. wastewater, biotechnology, resource recovery from wastewater, microbial fuel cells, aerobic and anaerobic biorefinery. The scope for this theme also includes precision tools for microbial community engineering using synthetic biology.

Innovate UK's network partner, the Knowledge Transfer Network (KTN) held a workshop in 2018 soon after NBIC was formed entitled 'Identifying and Prioritising Industrial Challenges and Potential Solutions for the Prevention, Detection, Management and Engineering of Biofilms'. In this report[4] it is very clear that participants saw it as vital that NBIC should apply attention to the creation of a balanced view of biofilms, whereby they should be addressing not only the problems that biofilms present but the opportunities which they offer. We aimed to begin addressing this in our workshop and report on Biofilm Engineering[3].

This present report covers a workshop held on the subject of Biofilm Management. This relates to destroying, removing or controlling established biofilms by understanding and exploiting their life cycle dynamics. In many commercial fields this is the primary need for companies and the purpose of their products (and of course health care providers in relation to human health). The question we are often asked is around the best approaches to remove or attenuate as biofilm. This leads to a range of unmet or poorly met needs:

- Biofilm models to evaluate new treatments in the lab (e.g. oral biofilms to assess dental hygiene products, chronic wound models to accelerate commercialization of new treatments and models including pipework and pumps to imitate production systems). There is also the need from industry and investigators to incorporate higher complexity, using mixed dynamic bacterial/fungi biofilms into these models, in order to improve their relevance to the real context.
- How to interfere with microbial signalling to manage/disperse biofilms (e.g. lactam technology in marine fouling and nitric oxide in wounds).
- Creating novel delivery systems in the management of biofilms to better penetrate them with active agents (e.g. smart nanoparticle or liposome formulations and novel dressings).
- Developing innovative physical, chemical and biological treatments aiming to better destroy or remove the biofilm community alone or in combination (e.g. plasma technology, blue light, activated bubbles, bioelectrical technologies, novel antimicrobials and enzymes).

Biofilm Management Workshop

1.1 SETTING AIMS AND PROCESS

The workshop was held in Nottingham on 25 February 2020 starting at 10:00am and finishing at 4:00pm.

The stated goals of the workshop were:

- To identify the unmet needs in relation to Biofilm Management across a range of sectors including commercial, industrial and clinical.
- To understand the problems with current approaches.
- To explore possible solutions and the way forward.

The intended outputs of the day were:

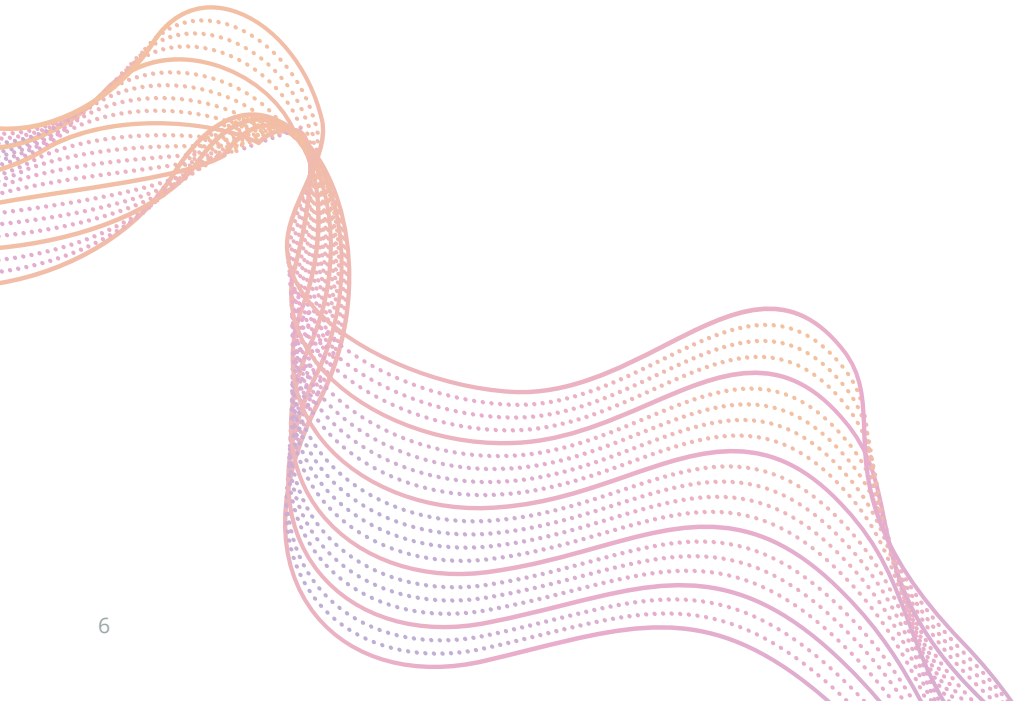
- Generate a report for all attendees and for wider dissemination.
- Establish the translational priorities which could influence funding calls and regulators.
- Identify gaps in current research to address industry needs.
- Determine whether there are existing solutions available to addressable challenges.
- Identify collaboration opportunities.

The meeting was open to all NBIC industry partners and affiliated research institutions, with 65 attendees in total comprising of 34 from industry representing 18 companies, and 31 attendees from research institutions representing 15 organisations. A list of participating organisations is available in Appendix 4.

To provide inputs to the meeting, those who had registered to attend were asked to consider four questions in advance and submit these online, by email or by hand. Submissions were accepted before, during or after the meeting (Appendix 1). We received a total of 33 submissions ahead of the meeting.

1. What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms? What are the problems with current approaches available to you?
2. In your view what should be done to address these needs/problems?
3. What do you think it would take to close these gap(s)? For example, in duration of time, level of expertise, specific capabilities and level of effort (e.g. in £/$ or people in full time equivalents)? Is this basic research, applied research, cross industry action?
4. Do you have any other thoughts, contacts, opportunities, ideas or proposals?

There was an initial plenary session led by NBIC (Professor Miguel Cámara, University of Nottingham) summarising and discussing an outline scope of the needs, problems and opportunities in Biofilm Management.



1.2 SYNDICATE OUTPUT

For the rest of the day there then followed industry/ academia syndicate sessions (with mixes of sectors and expertise) discussing the four questions and aiming to reach clear thoughts and recommendations.

This output was captured on a flipchart (collated in Appendix 2) and each member also had the chance to create individual feedback on the sheet shown below before, during or after the meeting (collated in Appendix 1).

The groups were then rotated to a new groups with new people.

Finally, all outputs were posted on the walls and all delegates had a chance to post input to problems they had not yet had the chance to review and to allocate 5 votes in total across areas they saw as being the most critical.

The NBIC team collected and organised all the output and reviewed and ordered the rankings/ votes from the syndicates (Appendix 3).

1.3 PARTICIPANT POLLING

During the meeting an online tool called Mentimeter, accessible via PC or smartphone, was used to allow attendees to give immediate thoughts and feedback on key questions relating to biofilms. The output of this is shown in Appendix 6.

1.4 PITCHES

All attendees were given the chance to give a quick pitch of an idea, opportunity or need. Details of these pitches from Fourth State Medicine, IOCyte - a spinout of Xiros Ltd, Freedom Hygiene and Dr Sepideh Khodaparast, School of Mechanical Engineering, University of Leeds are provided in Appendix 5.

1.5 DISCUSSION AND CONCLUSIONS

The subject of Biofilm Management provoked intense discussion and engagement across the attendees and is demonstrably an area of ongoing industrial and academic attention as evidenced by our own project calls, where for example, across our first two calls in 2018 and 2019, 42% of the applications addressed biofilm management in some way[5]. Underpinning the discussions at the meeting was a plea to consider industry problems. There was a request that academic focus needs to be addressing the real industry problem and need. It is clear there is a lack of joint understanding and definition of industry problems in each field and that NBIC has a role to play in bridging this gap.

Prior to the meeting attendees were asked to think about the four questions referred to in Section 1.1 around what they see as the key problems and ways forward and nearly half of them pre-submitted their thoughts (Appendix 1). These then formed the heart of the syndicate discussions which mixed industry, academic institution and business sector.

The outputs from the discussions are highlighted in Table 1 and in detail in Appendices 2 and 3 the latter of which shows the key priorities of the attendees at the end of the day based on their collated individual votes (each had up to 5 votes to make using a dot system).

Models and methods for characterisation, visualisation and detection: Relevant (environmental context e.g. factory), standardised and accessible to industry and academia	91
Cross-disciplinary (industry-academia, with regulators and between sectors of industry) engagement including workshops, partner searches and in the development/execution of project proposals and models	39
Clarifying and improving regulatory pathways from regulators for solutions, time frames and associated costs	28
Understanding biofilm behaviour and control from definition to formation. Collapse, host response, control vs. kill and characterisation including agent penetration	22
Data Centralisation and Management: Including collating of existing data. Bioinformatics and statistical modelling	11

Table 1- **Main themes arising from the group answering these questions: What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms? What needs to be done to address these problems? What would it take to move this forward (type of activity, skills, time and cost (£)?**

This is viewed from the attendees perspective (academic/industry sector) in terms of the importance and the compelling need for it to be addressed. Whilst accepting the inevitable limitations with such a system of setting priorities we should note that these are 60 of the people in the UK most actively interested as true practitioners in this area. They had also discussed deeply during the day the issues with others who shared this interest. Therefore, these overall conclusions are vital to understanding the current priorities and needs in the UK.

- The strongest emerging theme from the syndicate sessions and pre submissions was the need for the creation of *improved real life models and methods* for the *characterisation, visualisation, detection and removal/management of biofilms*. Importantly these models need to be in a relevant context (eg. factory, human, environmental) and ideally *standardised* and accessible to both industry and academia.
- Building on this need for standard models is the requirement for truly cross-disciplinary 'all party' engagement (access, buy-in and funding) for collaborations at a cross-industry level and also with the regulators in creating and validating these models. This will allow products to be approved, claims to be made and the science to move forward in a way relevant to industry needs. In particular, there was a strong resounding call from the community for improving both the clarity and ease of navigating for the regulatory environment. The view was that the regulatory environment should be more science-led and responsive to requirements changing and knowledge progressing. An example of this gap between standards and the science would be the standard for testing hard surface antiseptics and disinfectants which makes no reference or acknowledgment of the presence of biofilms in the environments where these products need to work[6]. NBIC has a role to play in bridging the various groups needed to move this forward
- It was perhaps surprising that the need for better interventional strategies was viewed as less important than better models and an improved regulatory environment. This suggests that industry see the bottlenecks are in these areas rather than novel interventions.
- The groups clearly thought that there is still effort required in terms of fundamental research on understanding biofilm behaviour and control to give us new leads and insights (e.g. areas such formation, collapse, host response in man and animals, achieving control vs kill, enhancing agent penetration).
- Additionally, the need for best practice when working with data was highlighted. Huge amounts of data are produced using contemporary techniques and the collation, arrangement and interpretation of this via bioinformatics is a compelling need. This includes the training of more bioinformatics professionals for this field.
- Other areas also were raised by some attendees as important including the need for new strategies for biofilm management and also the use of combination approaches and therapies. Enhanced education about and ease of access to markets for the whole community was also cited, as was the creation of PhD studentships with a real world focus and placements/KTP with realistic timescales for achieving their goals. Finally, there was also some frustration at the time and costs associated with early investigative work and product testing.

What are the possible strategies for moving these areas forward and what is NBICs role in delivering these?

The primary need is for improved collaboration to work across all these areas and this should be multidisciplinary, cross sectorial and national in order to facilitate communication and to bridge the gap between academia and industry. There should be more forums for interdisciplinary discussions. Biofilms are a global challenge, it is a task for NBIC to agree common themes/goals.

Approaches to tackle this should be:

a) Raising public awareness of importance of biofilms and raising academic/industry awareness of biofilm problems.

b) Development of early partnerships with better integration and links between industry and academia to address key questions. There should be a clear visibility of needs. Such partnerships should be academia lead but industry relevant, multidisciplinary large collaborative 'NBIC' Consortium projects.

c) Cross-disciplinary teams and Joint activities and workshops (academics, regulators and industry). These should address the lack of integration and meeting points and provide an interface to allow coordination between experts. There should be an enforcement of complexity and rigour in academic engagement and not just a search for faster/cheaper solutions.

d) Better signposting for grant funding and partnering, particularly co-developed (academic/industry) grants for relevant, translational research.

e) NBIC academic and industrial facilities map. Provision of forums where the members can offer testing facility/capabilities e.g. early stage validation testing.

f) Regulatory workshops to make this area less hard to navigate - NBIC as an independent body can facilitate definition of credible tests/standards that could be published as an 'NBIC SOP'. Influencing regulators.

There is a strong need for better models

This includes - *in vitro, in vivo* and *in silico* – these should be relevant/representative, real world (larger scale), robust models including environmental, factory setting or a clinical context.

Approaches to tackle the areas of models should be:

a) Recognising these models would be different for each sector e.g. oral, wound, catheters – and fit within the industry/regulatory authority accepted criteria and definitions. Models should be developed with international remit and endorsed by an independent body (NBIC).

b) Simple or multifactorial models as appropriate should be developed and validated with other industry protocols. They should have different levels of complexity for different purposes eg. screening versus predictive efficacy. Some may be somewhat generic to be used in the oil and gas/water treatment (piped model for example). In all cases, the models should be based on industrial needs.

c) Coordinated development and validation of new models e.g. (for early detection of anti-biofilm efficacy) is recommended. Current evidence and data should be collated eg. carrying out a systematic review and then collaborate to agree on best standards/unified models in terms of purpose and application/translation. NBIC should progress optimisation and development of models. Once developed then industry, who don't have academic level expertise in models could then access for testing. Ideally, a 'central hub' is needed for testing. This should be accessible, affordable and agile. This would then provide an overview of models used across NBIC (a catalogue of models) and also provide consensus about the criteria/methods for screening new models. Ideally this would then arrive at a unified and standardised model with the need for limited diagnostics/easy biofilm measurements/assays, visualisation of biofilm growth, viability and vitality.

Regulatory clarity and enhanced ease of navigation of pathways is critical for industry

There is a need, not only for standardisation of models, testing methods/platforms, that are relevant to each industry and approved by regulatory authorities, as described above, but a need for NBIC to support and lead the influencing of regulatory agencies.

Approaches to tackle this should be:

a) The Influencing of policy needs to be tackled and NBIC should aim to lead the conversation on creating a clear regulatory framework. NBIC could advise and educate the regulatory authorities and also increase academic understanding of regulatory pathways for a product/service at the start of a project. The industry are challenged to make claims which will be accepted by regulators with no standard tests at present, as standards lag behind technology development. There is a need to act and for e.g. a European steering group to govern a set of ISO standards meetings (as in the water industry regulated by the government) where all industry members participate. A standardised approach and systematic analysis are required. NBIC regulatory influence is paramount - the regulatory body notification is a time consuming and ill-informed process at present. Some standards are not suitable for testing with new products/methods of management. It is important to understand regulatory pathways for different solutions and their associated costs, timescales and restrictions for each field of research and specific markets (e.g. regulatory guidance such as for biofilm disruptors on hard surfaces in the USA). Note: The Center for Biofilm Engineering (Montana, US) has a track record of influencing regulators and NBIC is working with them and the Singapore National Biofilms Consortium in an international task force to move this area forward.

b) The creation of an NBIC database for guidelines on regulatory criteria on biofilm management technologies. This would be appreciated and valued by partners (e.g. Product type, EU (European Chemical Agency/UK/US regulations). Workshops to educate and inform should also be carried out.

Novel approaches to funding are needed to progress these activities

Joint industry projects would reduce financial risk, increases the chances of successful solution and reduce project lead times.

Approaches to tackle this should:

a) Gain industry buy-in, in seeking translational funding though a lighter touch engagement via KTP/placements and real -world PhDs is also valued in knowledge transfer. Translational research has to be monitored closely. TRL translation via grant funding can stall due to grant time scales. NBIC assistance in writing grant applications would be appreciated, as well as fostering more reactive follow-up funding.

b) Recognise some solutions cannot be found with a short-term pressure from the industry. Early investigative (testing) costs have to be considered, and at the moment to get to this stage it's very expensive. Joint industry programmes may be one way forward.

NBIC needs to aim to widen its engagement and influence to develop broader concrete understanding of the problems and the route to solutions

Examples of these and actions needed are:

a) Clinical - NBIC has to engage and bring together the industry, clinician and academia, address the clinical community, to understand clinical impact and outcomes. In particular, in terms of the symptoms of infection related to biofilm research e.g. in wound healing where anti-biofilm claims are substantiated in models that don't compare in clinical studies.

b) Supply chain – It is important to bring together the 'right' people considering the supply chain for each industry and the bottlenecks and also the value chain.

c) NHS - Access to NHS and other healthcare professionals is still difficult. The supply chains of some sectors can be a problem e.g. in the NHS even once approved/proven, it is still difficult to sell products. How can be the research knowledge best transferred to customers/the NHS decision makers? In the health economics driven sector – what is the evidence needed to persuade the decision makers for e.g. catheters and would treatment (vs. cost of disposables).

d) End users - There is a lack of public and/or customer understanding of the terminology/ language: do they know what a biofilm is? There is a need for better education around biofilm including its limitations and its effect on each sector. There is a lack of consumer-friendly presentation for cosmetics and medical devices. Communication between the 'end user' and researcher is essential. For example, in the food industry, staff are ignorant of biofilms: methods of removal, not open to new technologies.

Novel technologies and interventions are needed but only if they address genuine unmet or poorly met needs

a) New strategies are required for biofilm management. However, workshop attendees did not see this as the overriding imperative relative to the points above.

b) The regulatory constraints lead to a need to boost or repurpose current chemical, physical and biological ingredients, and to aim for better delivery and use of existing actives in combinations.

c) Understanding of 'anti-biofilm' efficacy is key, using universally relevant research for antimicrobials to see whether an agent penetrates a biofilm. In terms of new technologies, there is a ban on preservatives with no new ingredients in the pipeline, therefore attention should be given to delivery, control release of compounds and formulation design.

d) In the industry, time to market is essential and if proof of concept has positive results, there is a need to move quickly to prototype. It is important to exploit commonality in sectors, e.g. surfaces and for industries to collaborate on pre-competitive problems.

e) A guided strategy for SMEs to access each sector would be of benefit, facilitating technology translation.

There is a perpetual need for a deeper understanding of the basic science of biofilms

This requires:

a) Fundamental, long-term published research on biofilm definition, identification and detection, including mechanisms of biofilm development is required.

b) Also required is application of research in a functional manner. Learning how nature deals with biofilms and transfer of this learning to applied research/products is the next step.

Bioinformatics and data analysis remain vital to utilising the data we have and that we will create.

a) Making data available and generating a source of trusted information is key, this is essential to avoid duplication. NBIC could serve as a data/knowledge hub with a database of compounds/interventions and also general data on biofilm research/resources.

b) It is important to identify what key data is required and what is minimum viable data. 'Brain drain' to industry is a problem in this area. Information technologists should be engaged as well as biofilm experts and mathematicians.

c) Publishing negative results should be acceptable, as is repurposing/retesting and gathering data across different industry areas e.g. skin and oral care.

References

1) NBIC Report on Biofilm Detection, October 2018

2) NBIC Report on Biofilm Engineering, April 2019

3) Market Need for Biofilm control technologies –Report Prepared by PHS Consulting for University of Edinburgh, May 2017

4) Identifying and Prioritising Industrial Challenges and Potential Solutions for the Prevention, Detection, Management and Engineering of Biofilms, May 2018

5) NBIC Annual Report, September 2019

6) EN 13697:2015+A1:2019. Chemical disinfectants and antiseptics, Quantitative non-porous surface test for the evaluation of bactericidal and/or fungicidal activity of chemical disinfectants used in food, industrial, domestic and institutional areas. Test method and requirements without mechanical action (phase 2, step 2) Published by BSI Standards Limited 2019

Appendix 1: Pre-submitted input from attendees

Delegate	"What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms? What are the problems with current approaches available to you?"	"In your view what should be done to address these needs / problems?"	"What do you think it would take to close these gap(s)? For example time, expertise, capabilities and effort (£, FTE)? Is this basic research, applied research, cross industry action?"	"Do you have any other thoughts, contacts, opportunities, ideas or proposals?"
1	Biochemistry of bacteria and their biofilms has been addressed extensively, however, less is known about their physics and how they interact with the physical environments around them.	I believe we need to grow collaborations between physicists and engineers in areas of flow dynamics, colloidal science, soft matter and material science with microbiologist, biochemists, medical clinicians and representatives of health sectors.	I believe this will take a long time depending the steps taken today. The first step is to introduce support for interdisciplinary basic and applied research between the two distinct disciplines.	
2	Current antibiotics can not penetrate through the extracellular matrix of biofilms and can not prevent biofilm formation. There is a need for new antibiotics or repurposing antibiotics specifically targeted for biofilms. Antibiofouling surfaces need to be developed with better characterisation of these materials.	Early-stage biofilm formation should be understood at the cellular level in order to develop strategies to prevent biofilm formation. The dynamic fluxes and heterogeneities inside the biofilms should be elucidated more with imaging techniques and bioelectrochemical approaches. By exploiting these fluxes, more effective treatments for biofilms can be found. Antibiotics can be repurposed by using nanocarriers like liposomes, polymeric nanoparticles etc which can increase the penetration through the extracellular polymeric matrix.	Expertise is needed and collaboration between industry and academia is needed to prevent biofilms	I am currently in the Marie Curie ITN project "Break Biofilms" which is focusing on detection, understanding and inhibiting biofilms. I am going to develop a multifunctional electrochemical probe (scanning electrochemical probe microscopic techniques) to analyse and treat biofilms.
3	Our business is vascular access catheters where as you can imagine biofilm can provide major issues. From an industry perspective it is hard to find solutions that are being worked on by industry and academia. For our products we are looking to stop the build up of biofilms on the surface of catheters which could lead to infection and or removal and new catheter insertion.	I think NBIC makes great strides to bring two sides of a coin together. In our case many of the contacts made through NBIC have been spot on. Encouraging more industry and academic partners to come into the NBIC family would certainly be beneficial. Perhaps more easily accessible showcases by the owner of a technology, webinars that pitch the ideas, sort of an NBIC 'QVC'. Which ever way a greater presence, we only found out about NBIC by sheer chance.	To close the gaps I think a greater understanding of academic and industry from each party is required, perhaps academic establishments need to understand the real world issues of biofilm and industry need to recognise the work being done in institutes and the capabilities they have.	Whether or not it be NBIC, a co-operative formed by like minded industry companies to fund recognised lab testing at a reasonable price, many academic institutes could provide this, even if it were only proof of concept testing before more research were to take place. Testing a product to ISO10993 is a very expensive and in some circumstances very restrictive exercise and without it many products will never gain a CE mark.

Delegate	"What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms? What are the problems with current approaches available to you?"	"In your view what should be done to address these needs / problems?"	"What do you think it would take to close these gap(s)? For example time, expertise, capabilities and effort (£, FTE)? Is this basic research, applied research, cross industry action?"	"Do you have any other thoughts, contacts, opportunities, ideas or proposals?"
4	EU regulation is making it increasingly difficult to use biocides to control or eliminate biofilms through imposition of ill-considered residue limits for foods. Methods to control bacteria in biofilms on abiotic surfaces in the production and processing environment and on the surfaces of fresh leaf foods are however essential to maintaining a safe food supply.	Given the difficulties in securing approval for "chemical" disinfectants, we need to explore novel physical and "non-chemical" approaches to removing biofilms and hard to access bacterial populations.	"There is a need for applied research which might have common features with biofilm control in other industrial sectors. Companies able to manufacture the new technology/equipment need to be found, and should work with end-users to ensure user needs are taken into consideration in innovation work."	The food industry offers a very large market for suppliers, although it is one which is price sensitive. Mainstream companies are generally well-informed about products which are currently on the market from major suppliers, but less aware of novel products from smaller suppliers.
5	Delivery of biocidal materials/processes into harbourage points on complex equipment	Concerted research	Applied with cross industry - food equipment and food manufacturers	Electrostatic
6	Freedom Hygiene provide chemical detergents and disinfectants to food and beverage manufacturers in the UK. We commonly come across hygiene issues related to food-borne pathogens such as Listeria monocytogenes. Technical Managers and Hygiene Managers within the industry are often unaware that conventional detergent and disinfectant chemistry may not be capable of removing mature biofilms. And so the source of intermittent, but serious infection remains and people stand back and wonder why. Mainstream detergent manufacturers are often unwilling to recommend enzyme surfactant blends as the answer to effective biofilm removal. Could this be due to ignorance, a financial decision, or both?	Education is the answer. Workshops are urgently needed which are specific for the food and beverage industries. Freedom Hygiene had the opportunity last year to present "The rapid identification and elimination of biofilms in food and beverage manufacturing" to the seminar organised by Campden BRI "Listeria moncytogenes - a force to be reckoned with" It explained why, despite traditional robust hygiene programmes Listeria spikes still occur in production and packaging. The response from a handful of delegates was positive and encouraging and resulted in site visits where further information regarding biofilm identification and elimination was shared. The bottom line is this. Conventional chemical cleaning don't work. A fresh approach is needed."	"The biggest single step to closing the gap between current ignorance and knowledge of biofilm identification and elimination is for the mainstream detergent manufacturers to speed up the education process. Everyday food manufacturers place their trust in these long-standing often global detergent suppliers to offer hygiene solutions. They are failing in this regard: Not explaining to clients that conventional chemistry don't work at removing/preventing biofilms and a fresh approach such as enzyme surfactant technology is required to augment traditional hygiene programmes which have been in place for decades without little or no change. Open-mindedness to phage control of L.M and other approaches such as UVC devices should be cultivated as a matter of urgency."	Simple - Regional workshops across the UK. If you like Biofilm Roadshows. Target audience: Food & Beverage Manufacturers. The message: The Rapid Identification and Elimination of Biofilms in Food & Beverage Manufacturing. To be taken seriously these events would need an authoritative source such as Campden BRI and/or NBIC. Freedom Hygiene would be prepared to take the lead in the organisation and delivery.

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7	There is a need for better wound dressings that address biofilms in infected wounds. Current approached mostly involve silver-based wound dressings - most of these only make bacterial barrier claims and have been developed using tests vs. bacteria in the planktonic state. Effectiveness against biofilms is often unknown. Where tested, some silver dressings have been shown to be less effective or even ineffective vs. biofilm. Other antimicrobial agents, such as iodine, are available and there is evidence it is more effective against biofilms than silver. However, alternative antimicrobials are not always available in a format preferred by the users. The presence of biofilms in a wound is not always obvious so better tests/diagnostics that tell the clinician that they need to use an antimicrobial dressing would be useful. The link between biofilms and non-healing wounds is not well understood.	We need to develop better antimicrobial wound dressings that have been demonstrated to be effective against biofilms - not just a bacterial barrier. We probably have agents that are effective against biofilms already but we need to develop better ways of delivering these. Development and validation of good in-vitro and/or in-vivo models would facilitate product development. Development of simple and cost effective diagnostic tests to indicate presence of biofilm. More clinical studies to understand the role of biofilms in chronic wounds are possibly needed."	We need links between industry and academia to get the technologies through to new products and ultimately the patient. Industry is good at developing products but smaller companies may need financial support such as grants. For a dressing to make claims about biofilm clinical data is needed to support regulatory submission. Clinical trials are expensive so financial support, especially for smaller companies, would be helpful. (Woundcare is not a particularly attractive area to investors so can be hard to raise private funding for small companies in this area). May need public funding for more basic research on fundamental science including clinical research on wound healing.	Io-Cyte Ltd is developing a novel wound dressing that combines the benefits of iodine with an absorbent polysaccharide dressing and has been shown to be highly effective against biofilms in a simple in- vitro model. The company is keen to engage with groups who can help in the further development and testing of this product.
8	Regulatory consensus on what constitutes an anti-biofilm product. There are several in vitro models used in the medical device industry. Need a standardised assay/protocol."	Need for better definition of standards and policy development. There is a lack of clinical data to support or validate the in vitro data. Need for a more robust standardised clinically relevant model to assess efficacy.	Improved capabilities to diagnose biofilms within the clinical environment to improve the understanding of the use of medical device products.	N/A

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9	As a researcher I think the problems in managing biofilms are related to several unknown factors in regard to the bacterial interaction and the dependency of co-culture in those. Furthermore, the application of new treatment technologies like cold plasma or ultrasound for the deactivation or killing of bacteria in a biofilm structure.	I study the biofilm formation of foodborne pathogens on the surface of semi solid food models with different fat concentrations and the bacterial behaviour in single and co-culture. By understanding this behaviour the management of biofilms on a food surface would become more approachable and ensure better food safety. It would also bring helpful information for further treatment of foods, packaging material or surfaces.	More research and collaboration with relevant food industries. Which is generally, a problem in academia that research is less applicable for industry and industry is too less involved in research.	If industrial collaborations are possible and of interest, it would be great to get this opportunity as a PhD student to work with expert and exchange knowledge and interests.
10	Our company is offering potential solutions rather than experiencing problems... but we understand that low-temperature, automated prevention/management of biofilms over wide areas/in hard-to-reach areas would be valuable across multiple sectors (healthcare, agri-food, heavy industry). Conventional high-temperature and/or manual decontamination processes can be expensive, infeasible and/or ineffective in certain circumstances.	We are offering anti-biofilm gases produced in-situ from air and electricity (e.g. Nitric Oxide, Nitrogen Dioxide, Ozone, using plasma technology). Our technology is understood and readily available for R&D purposes (it has been used successfully by academics one two NBIC PoC projects - one in wound healing and one in food processing). We are looking for prospective B2B customers, academic partners and funding to help fit our platform technology to specific applications, with a view to us ultimately selling products to B2B customers wanting to incorporate these capabilities into their products or processes.	We need buy-in from prospective B2B customers for solution co-development (funding, market, technical and regulatory expertise and access to representative use environments for design and testing). We also need academics to use our technology for independent optimisation, validation and advocacy. Funding for our/academic's activities would come from the customer and/or grants. For applications with relatively low regulatory barriers to entry (e.g. industrial cleaning, surface treatment), we anticipate a several-£100k partially grant-funded project would be sufficient for demonstrating the technology in a relevant environment for the customer. This would pay for our technology and time (2 FTEs for design and prototyping), time and equipment for academic optimisation and validation (1 FTE) and the customer's time (<0.5 FTE). After successful demonstration and with further funding (mostly coming from the customer) we would work with the customer to develop, supply and maintain a bespoke commercial solution.	We are actively trying to promote NOxLab, our first product for evaluation of Nitric Oxide gas for commercial applications. NOxLab automatically generates limitless, highly controlled and tunable NO outputs from ambient air and electricity and is designed for ease-of-translation from the laboratory to the real world. We think biofilm applications represent a significant chunk of the potential market for NO and we are keen to work with NBIC to maximise the reach and impact of the technology. https://www.fourthstatemedicine.co.uk/no xlab Our modular technology can also be optimised for production of other gases, which may have utility in biofilm prevention/management (Nitrogen Dioxide and Ozone).

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11	Short of supplying biocides to the market, I am unsure of the current approaches available. Biocides come with a huge amount of costly regulation and registration across Europe and other markets. I am still unclear as to whether biodispersants fall under the BPR or not. Also, I have heard that a simple surfactant mixture is useful for removal..? We also are unsure where to go to test our formulations in relation to microbial contamination.	I would like a clear summary of the approaches available, both for preservation before a biofilm is established and treating and removing an existing biofilm. A clear position the biocidal effect of surfactants and biodispersants that affect the biofilm, but don't kill microorganisms specifically, would be helpful. Visibility of testing houses and methodologies (see 3)	Certainly technical expertise to describe the approaches available and their effectiveness. And then a regulatory expertise regarding BPR considerations. Capabilities of testing houses to determine the likelihood of a biofilm forming based on customer formulation. The odd development project working in similar lines.	Fernox is a water treatment company supplying corrosion inhibitors and cleaners for central heating systems across the world. We also sell biocides for low temperature systems but would like to be advised of the latest approaches to biofilms and what we could commercialise/ partner with academia to develop.
12	I think that the definition of biofilm is currently quite broad. As a result, the description of efficacy of disinfectants and development of methodologies that can be consistent across laboratories is limited.	As a research community there needs to be more definition of the term biofilm to assist in the development of suitable standard disinfection technologies.	Basic research with a cross industry focus. As researchers we should be telling companies what types of biofilm exist in which environments, so that money is not being wasted in the development of new antibiofilm products that do not meet the challenge posed.	
13	I'm an academic. There is a lack of standardised testing methods relevant to different types of biofilms eg static, under flow, different substrates and nutrient availability.	Collaboration with companies addressing biofilms and regulatory bodies to have a list of scenarios in which models would be useful eg water pipes, wound environments, relevant sterility testing models to the food and medical industry.	This would be applied research, it would need funding but it wouldn't be prohibitively expensive to do the work. It would need collaborations between companies in the four areas (management, prevention, detection, engineering) and academics to develop suitable models.	

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14	Trying to maintain good hand hygiene in difficult environments eg slums is a real challenge. Washing hands thoroughly may only occur once in a day and recontamination rates will be high. Running water is probably not available which makes soap use difficult. Alternative solutions are needed which are affordable, simple to use and give protection against recontamination. Developing and proving such solutions requires a better understanding of the nature and dynamics of surface, transient bacteria in such settings, and better methods to evaluate effectiveness in the lab and the field. At the moment effectiveness testing is limited to either suspension tests, which don't take the skin surface into account, or some kind of hand test, which is expensive and can only handle a few samples.	It would be helpful - eg to screen novel actives and formulations - to have some kind of high throughput lab test in which the behaviour of bacteria on the skin, and their interaction with it, are factored in. This would sit between suspension and in vivo tests in terms of hierarchy. I'd like to see some research in the field to develop a proper baseline and methodologies for testing interventions, both in terms of bacterial removal and recontamination rates. Research into the nature of transient bacterial interaction with the skin surface and composition/structure of the biofilms they form would be helpful.	On methodology it requires a collaboration between groups with skin and microbiology expertise. I think this could be done with a graduate research student in the right lab over a year. The field work requires a bigger effort involving experienced field workers, microbiologists and measurement scientists.	

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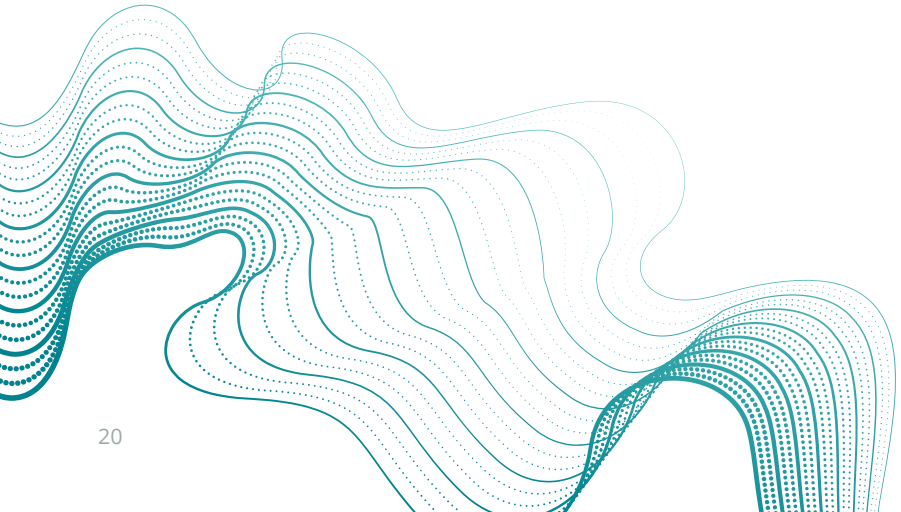
15	Our company is a technology provider with a potential clean solution to biofilm control and management. In short, disinfection with no added chemicals; just water. Our view is that, wherever there are aqueous storage and transfer systems in place, there is the potential for microbial biofilm establishment. From a quality and health perspective, we see the food industry and others as benefitting from moving away from bulk chemical cleaning (especially with chlorine-based solutions), to low embedded carbon, sustainable alternatives.	A firm move away from chlorine-based solutions. Technologies with little or no environmental impact, and a low carbon footprint. The latter are in line with a major current focus in industry and supply chains. Powerful in situ oxidation technology, with little manual input and autonomous control, could be the way forward.	Development funding of course, but more than anything, an openness of mind and willingness to participate (in evaluation and trials) within industry sectors where biofilm control and management have remained relatively unchanged for many years.	Oxi-Tech Solutions already have a POC project with approved funding with the University of Southampton Biofilms group, to evaluate in situ oxidation (electrolytic oxidation) as a means to avoid, control and manage biofilms. We also have pilot plant equipment mobilised in the dairy industry evaluating the same technology in CIP (Clean In Place). Results are extremely encouraging, and we see the next steps as engineering standard units for this and other applications where there is a strong need to improve current practices. As an example, mastitis control in UK dairy herds is causing havoc and markedly reducing productivity, and is high on the hit list for improvement in the UK dairy sector; our technology has shown that by replacing traditional CIP chemicals, we are able to significantly reduce mastitis occurrence in dairy herds by reducing cow to cow cross- infection in milking parlours. There must be many similar applications which could benefit from similar innovation.



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16	One issue is the transition from bench to bed/chairside. Compound libraries and basic high throughput screens have allowed for the identification of numerous candidate antimicrobial/fungal molecules. However, the pathways involved in translation to a therapeutic product are complex and expensive. In addition, a target compound can be taken through animal models and on to first in man trials and fail at this stage despite heavy investment. How can we limit the risks? how can we be more selective in terms of prescreening approaches to focus on compounds with a greater chance of success? For me in comes down to limitations in vitro models. Better models will allow for earlier identification of compounds which will more likely be successful.	A unified approach to model development. Standardization of models across the sector. Consideration of use of simple in vivo models as a tool such as Galleria infection models as a pre-screen before monies invested in expensive mouse models. Development and agreement on a rational pipeline for getting a compound from bench to bed/ chairside. Focus on repurposing compounds?	Basic research but with industrial input. Collaboration between institutions to standardize models and making the models developed accessible to all.	
17	When developing antimicrobials to treat biofilm infections, the best biofilm models currently used have some elements from the host environment and may even include several microbial species usually encountered in these infections but are still far from the real world. This is one of the main causes of treatment failure, partly due to the fact that there are still many unknowns about the host environment, how it responds to polymicrobial infections, how polymicrobial biofilms respond to the host and many of the factors behind antimicrobial failure in these environments.	We need to understand better the key contributors to antimicrobial failure. This is includes not only biofilm factors but also those from the host side.	You would need to bring together experts in omics (transcriptomics, proteomics etc), immunologists, molecular microbiologists, medicinal chemists, physicists, modellers, engineers to address this issue. As a first step it would be important identify key factors that differ in an infection responsive to treatment from one that doesn't, especially when the bacterial isolates from the non-responding infections are sensitive to treatment. This would have to be done taking samples from patients. For this first step you are likely to require more than 40 FTE, around £30M and a minimum of 7-8 years. This would be basic research but it could involve industrial collaborators.	It would be important to lobby to funding bodies about this unmet need eg. MRC, Wellcome T, NIHR. As a first step a data-mining exercise on what is know to date in this area would be useful.

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18	Difficult for active molecules to penetrate into biofilms and have any effect.	Understand the barriers and design strategies to overcome them that are novel.	Money to fund researchers in fundamental and applied research using state of the art technologies. The technological platforms available currently need to be developed to increase their sensitivity and resolution to work on the required scale. Cross industry collaboration key to finding enough resource.	
19	• Poor diagnostics for biofilms - difficulty in distinguishing microbial basis between planktonic and biofilms cells • Lack of clarity between biofilms and microbiomes - there seems to be some interchangeability of these terms, but we need to be clear the difference between communities and biofilm phenotype. Related problems are the drive to undertake microbiome studies without understanding the functionality of the communities - "stamp collecting". There is a need for more informatics to improve capacity to analyse these data and metagenomic/transcriptomic data-sets. • Too much focus on treating biofilms rather than prevention	• Diagnostics (at least health related) needs dialogue with health professionals to determine whether these resources would be used and implemented into care pathways • More training and funding for bioinformatics and software development in the field • More education and unified statements from NBIC related to 'tolerance' rather than 'resistance' in the field. • Direct more effort to prevention studies rather than treatment - coatings, physical interventions, etc.	• Focus groups within health sector to understand their needs rather than what we think they need • Centre for biofilm bioinformatics - BBSRC support? • Needs more engineers and physicists, rather then biologists.	
20	Preventation of creation of biofilms during production in areas of high organic material and water, and also areas where water is minimised. Destruction of biofilms within tight timescales.	Surfaces which are able to prevent biofilm formation or at least allow rapid destruction during hygiene windows but still food contact friendly.	Think it is all three of the above, basic and applied research and cross industry action. There is a need for expertise to be able to utilise learnings from other industries but also understand the restrictions within the food industry	

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21	In my case for the removal of clinically relevant biofilms from medical devices, approaches with deeper penetration of RONS is probably the most urgent need. Current approaches seem to be unable to remove total biofilm mass/cells from endoscopes and other medical devices.	Refinement of devices that generates RONS aiming the production of these under conditions that leads to decreased surface damage.	Cross industry action. Atmospheric plasma are promising alternatives for biofilm removal from medical devices. More studies on how improving RONS production for total bacterial inactivation and how these interact with biofilm cells should bring advances in this field of study, resulting in the application of this methodology in the market. Partnerships between research facilities and companies involved in the manufacturing of medical devices would help to close gaps in the management of clinically relevant biofilms.	
22	Biofilm-centred medical device infections are an enormous cause of mortality and morbidity in healthcare settings and require innovative solutions. These should avoid the incorporation and use of antibiotics given the antibiotic tolerance of biofilms, the rise of multi-antibiotic resistant pathogens.	One approach is the discovery and development of novel bio-instructive polymers for coating or fabricating medical devices that prevent biofilm formation and promote an appropriate host immune response	Significant funding and additional basic and translational research	At UoN, we have broad expertise and high through-put screens for the discovery of biofilm resistant polymers that have applications well beyond healthcare. We are happy to discuss potential projects across multiple applications including beyond the biomedical.
23	Medical implant contamination. Antibiotic resistance. Ineffective sterilisation	Development of new drugs/ surface treatments for microbial death/biofilm destruction.	Applied research into new drugs with a biofilm/surface focus and pathways into clinical testing. This would need industrial partnerships and investment.	

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24	As a brassware manufacturer, we are the first person to get accused of mis-management of biofilms in plumbing systems opposed to the system as a whole. Current approaches don't seem to work that well, or rely on very onerous procedures to keep Biofilm formation at bay.	Ideally a new form of system (full building) treatment for all water systems would be developed. This could be in the form of; • Either a non-toxic [to humans at the absolute least] which can pass approvals of consumption, drainage, etc • A hardy surface coating which can be applied to all internal surfaces to stop biofilm adhesion and limit breeding. • System filtration acute enough to filter bacteria and viruses (probably for new build or virgin systems)	The easiest route could be for NBIC to circulate a case study email to understand what research is currently being undertaken in this precise field. The upcoming NBIC event in Nottingham will be an ideal networking event for technology. Other metrics of cost and research actions is not quite our field and so we are unable to comment on this until we have some leads unfortunately!	We do have a potential solution for both Point-Of-Use and whole system bacteria elimination in a chemical form, but we have yet to trial fully via University links and we need to understand legislation regarding biocidal use and drainage implications.
25	The cosmetics industry has lost many preservatives due to legislation and clean beauty trends. This has a led to a smaller choice for formulators increasing skin sensitivity amongst users and the possibility for biofilms to become resistant to them. The industry is looking for safe, natural alternatives that offer broad spectrum activity. Many organisations/companies consider the microbiological attach of cosmetic products to be in the form of a biofilms so greater understanding of biofilms is paramount. Of particular challenge to the industry in the yeasts and molds.	Research into natural mechanisms of controlling/killing biofilms, especially on the yeast/mold side.	Time, money, ability to screen many compounds, research into natural biological mechanisms to fight biofilms, learnings from other industries, it is a big challenge so needs most aspects from the above list.	
26	Removal or degradation if biofilm material without use of traditional biocides	Focus on physical or biological methods	Cross-industry collaboration together with applied research	

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27	The answer to this depends on the environment in question. For clinical biofilms there are still few if any options other than long-term suppression or clinical revision for implant infections (for example). Likewise, there are few approaches for preventing or combating biofilms in other environments where physical removal, high temperatures, or harsh chemicals are not appropriate.	There are few short-term solutions. Concerted research effort is required and in this respect it is great to see what NBIC are facilitating.	All of the above. Apologies for the somewhat blunt answer but the challenge of biofilm recalcitrance/tolerance could be likened to that of cancer (and there are some similarities in the biology too). Yes, progress has been made but we are some way of a widely applicable solution.	Some, but not that would be easy to share in short-form.
28	1. in vivo imaging 2. rapid identification /treatment of biofilm infections	Development of new methodologies for imaging novel methodologies for treatment	Mixture of basic science plus applied research	Potential ideas/ proposal to tackle in-vivo identification / treatment
29	Evidenced based approaches to preventing biofilm formation in existing assets. Quantitative evaluation of species present and risk of MIC	Continued collaboration between industry and academia. Using real world biofilms for academic projects.	Applied research but also basic research to understand synergistic effects of metallurgy and biology.	
30	More investment in industrially faced research . One health approaches linked to Antibiotic Resistance research funding where there is major funding and investment from UKRI at present.	Make the argument from industry and academia of the value of significant investment via say Innovateuk	All of the above more understanding by the public - true of most of microbiology!	Most industry have technical issues around biofilms that often for business reasons they don't want to share but finding a suitable UK forum to allow them to do this and a mechanism where Universities can help would be ideal.

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31	Better understanding of the role of biofilms in delaying chronic non healing wounds – the interplay between the microbiology and the clinical biology at a fundamental science level is required. Elucidating the mechanism of action where biofilms delay chronic wound healing is needed. We know there are biofilms in wounds that do not go onto heal but the mere presence of a biofilm does not mean wounds fail to heal. A robust and agreed understanding here would be useful. Despite the lack of this fundamental knowledge, commercial products that target chronic wound biofilms are littering the market! These approaches cannot be compared due to the heterogeneity of in vitro test models. In addition, no robust pre clinical data exist using animal models due to complexity of developing chronic wound systems while clinical evidence remains elusive. Techniques and Technologies (diagnostics) that allow us to study how these 'biofilm management products' impact chronic wound biofilms is greatly needed.	Basic research at academic + clinical science level to unravel the interplay between the microbiology and the clinical biology. Developing standardised terminology that is used by the chronic wound community would be advantageous e.g. biofilm infections in chronic wounds, bacteria in biofilm mode etc. A recognised and agreed understanding of the role of biofilms in delaying chronic wound healing. Accepted/Standardised models which can be used to compare efficacy of 'biofilm management products' that target chronic wounds across industry, academia and regulatory bodies. Clinical research to prove outcome of therapies. Diagnostics that help detect chronic wound biofilms in the clinic.	Basic research (Post doc level) – 150 K/year per post doc over the next 3 years (longer) with several key research centres employing multiple post docs. (Industry funding will be hard to achieve (e.g. due to IP issues, short–term company objectives, competitive edge) and thus Government funding would unlock some of the fundamental questions that can be adopted by industry). Applied research - Independent model development that fits the bill across Industry + Academia + Reg Agencies (Global acceptance?). Driven independently by a neutral body (NBIC)."	NBIC's role in engaging with industry, identifying partners, POC funding, News Bulletins and Workshops are all outstanding. This has allowed greater visibility of NBIC across the UK. However, what is lacking is the visibility of the key academic lab research activity. It would be helpful if the academic researchers at NBIC communicates activity through NBIC Science Forums/Conferences where basic science can be discussed in terms of where it is at and where it is heading! NBIC Research Publications with collaborative efforts appear somewhat lacking."

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32	Our work is largely in the field of dentistry. Management is not typical in that many/most biofilm management issues are related to preventing them forming or eliminating them once formed. We concentrate often on shifts in the balance of the ecology to keep on the side of health. We need to move away from Triclosan and there are emerging problems with agents such as chlorhexidine in terms increasing resistance and cross-resistance to antibiotics. Agents that we know are effective in terms of protection against caries and gingivitis would not get through screens looking for anti-biofilm agents.	Hard to say! We need some agreement on models – we are all using subtly different multi-species biofilm models and there is no consensus about how complex a model community needs to be to provide meaningful results. We also need to explore standards for agents that modulate rather than eliminate biofilm communities – I don't know how achievable this is. I think mathematical modelling would help but few of understand it well enough and I think it is seen as rather niche – not the case in other areas of biofilm/microbial community research.	It is basic and applied research and requires action bringing together researchers and relevant industry.	
33	Prevention - of growth in medical devices (eg indwelling catheters), more industrially (inside pipes, ships hulls) Medically - treatment is a current problem. Resistance to antibiotics, inaccessible sites etc. Early detection of biofilm formation (a different 'arm' of NBIC I know!)	New antimicrobial resistant materials, new high throughput models to test novel antimicrobials, Creative thinking!	Time, experienced workers. Cross disciplinary work between materials scientists/microbiologists/ chemists/engineers/industry...	We recently developed 3D printed antimicrobial parts that need applications! We have some ideas but would like to speak with interested collaborators in industry to see if we can meet any needs. We have 3D models of biofilm infection on human tissue - skin, oral mucosa, cornea, 'teeth' and 'bone' (more basic models) that can be used to test developments on. Skin, oral mucosa, cornea not terribly high throughput though, but we can do multispecies biofilms.

Appendix 2: Syndicate outputs

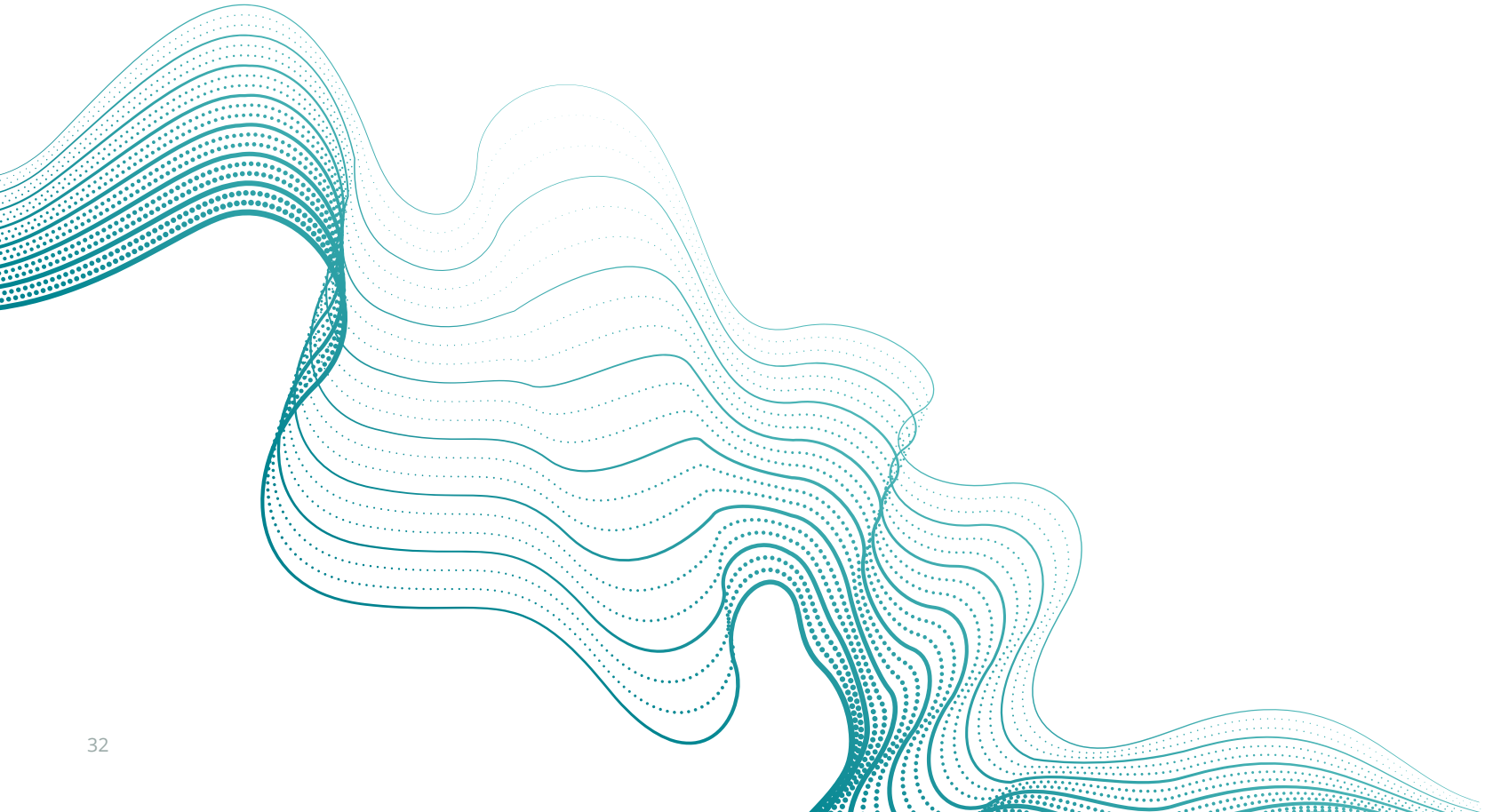
Group	What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms?	What needs to be done to address these problems? :	What would it take to move this forward (type of activity , skills,time and cost (£)?:
AM group 1	Models: • Industry access to academic expertise. • Relevant models e.g. water pipes. End user/ clinician/ customer engagement: • Focus research on real problems. • Terminology, language: do they know what a biofilm is? • Integration is challenging. Bioinformatics • 'Brain drain' to industry.	Bioinformatics: • Competitive salaries • Long-term research • Industry buy in	Models: • 1 FTE x 12 months. £30-50k End user/ clinician/ customer engagement: • NBIC workshops ~£5k • Partner search Bioinformatics: • DTP ~£8-10m 50%
AM group 2	• Infective chemical - Regulatory restrictions/ slow pathway • Need to boost/ repurposing current chemical/ physical/ biologically active ingredients. • Combination therapies. • Real physical models (don't have them). • Need cross validation of technologies/ methods. Addressing the problem/ need. • Understanding whether/ who? an agent penetrates a biofilm. • 'Real' world models including environmental context. • Standardisation of methods/ platforms. • Bring together the 'right' people considering the supply chain. • Data/ statistical modelling.	• Regulatory body 'education'. • KTP/ placements, (real world) PhDs • Cross-disciplinary teams: focussed workshops, co-developed grants. • Collating current data: information on real world models including interaction with active 'agents'. [A1] - in silico models.	

Group	What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms?	What needs to be done to address these problems? :	What would it take to move this forward (type of activity , skills,time and cost (£)?:
AM group 3	• Unrepresentative models: different strains, non standardised. • Easy measurement for biofilms: HTP, LIPs etc, growth, viability, vitality. • Ease of classification and validation. • Notified bodies: not enough, long waiting list, ill informed. • Funding for independent testing of management products. • Access to NHS and other healthcare professionals: once proved, still difficult to sell.	• Funding for developing models. • Access to facilities.	• Potential NBIC facilities map/ hub. • Foster/ more reactive follow on funding.
AM group 4	• Biofilm definition - identification - detection: Better models for factory setting - where is the biofilm, education around biofilms. • Regulatory pathways for solutions and the associated costs. • Early investigative (testing) costs: i.e. does in work? At the moment to get to this stage it's very expensive. • Linking academia with industry so both have sight of what the other is working on. • Lack of mechanistic understanding of how biofilms form. • More discussion needed between industries i.e. medical, marine, food - bringing understanding together - interdisciplinary.	• Academic access to industry. • Forums for more interdisciplinary discussions bringing the knowledge of industries and academics together. • Joint industry projects: Reduces financial risk, increases the chances of successful solution, reduce project lead times. • Forums where the members can offer testing facility/ capabilities i.e. early stage validation testing. • NBIC regulatory influence."	• Increased education around biofilm and its effect on each sector. • Larger scale initiatives to potentially bring industries together and discuss what they are doing to address biofilm and see if there is synergy. • Understanding biofilm management in food industry."

Group	What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms?	What needs to be done to address these problems? :	What would it take to move this forward (type of activity , skills,time and cost (£)?:
AM group 5	• In food industry staff are ignorant of biofilms: methods of removal, not open to new tech. • No BSEN standard for biofilm testing. • Lack of solid understanding/ definition of biofilm in each field. (Characterise the problem) (what to test against). • Lack of consumer friendly presentation for cosmetics and medical devices. • Bad press not changing. • Biofilm management less integrated. Detect are more focused 'industry specific'. • Basic research: Applied research in a functional manner."	• Food and beverage hygiene education: presentations, credibility/workshops to NBIC/CBRI for focus groups. • Conventional chemistry doesn't work: • Price sensitivity of mainstream disinfectants. • Transfer knowledge to customers/NHS: that tests that biofilm related. • Better integration between industry and academia: Academia lead but industry relevant, not niche. e.g. silicon vs polymethane multidisciplinary. How nature deals with biofilms - transfer to more and trial products."	

Group	What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms?	What needs to be done to address these problems? :	What would it take to move this forward (type of activity , skills,time and cost (£)?:
PM group 5	1) Robust and representative biofilm models needed: • Different for e.g. oral, wound, catheters. • Accepted definitions. • Accepted by regulators. 2) 2) New strategies needed for management: • e.g. surface modification - no actives. • Better delivery/ use of existing actives. • Biofilm breakdown. 3) Oral biofilms - need better understanding of healthy microbiome and link to general health. 4) Health economics - evidence needed for e.g. catheters and would treatment (vs cost of disposables). 5) Challenge of making claims which will be accepted by regulators - no standard tests. 6) Opportunity to measure EPS as evidence of biofilm. 7) Bringing academics up to speed on regulatory essentials at start of project would be cost effective. Healthcare and wounds: • 'Biofilm' meaning in regards to wounds? • No ISO on biofilm testing for implants. • Regulatory guidance such as for biofilm disruptors on hard surfaces in the USA. NOTE ADDED: Clinical impact and clinical outcomes. Water treatment: • Only tests for selected organisms. • How do treatments (chemical/physical) alter biofilms? • A lot of unknowns. Oil & Gas: • Microbial influenced corrosion (MIC). • Do biocides work? Treatments are routine, are they effective? • Why does corrosion occur asymmetrically within a system? NOTE ADDED: I like the sub-categories in this area. Makes sense to divide and conquer! Sense check they are the right ones.	1) Joint activities (academics, regulators and industry): Collaboration to agree on best standards for models. 2) Prove causation link especially biofilms - wound healing, clinical trials. NBIC to speak to clinical community."	

Group	What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms?	What needs to be done to address these problems? :	What would it take to move this forward (type of activity , skills,time and cost (£)?:
PM group 1	• Unified models/ purposes/ application. • Translation and access to models. • Understanding the regulatory side for each field of research; medicine, oil industry, oral? • Lack of integration between industry and academia.	• Hub/ database for guidelines on regulatory criteria on biofilm management technologies. • Signposting: grants/ partners. • Public awareness of importance of biofilms. • Industry awareness of biofilm problems.	• Road map/ white paper: 0.5 FTE for 12 months. • Awareness events/ learning: Industry/ academia and visa versa.



Group	What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms?	What needs to be done to address these problems? :	What would it take to move this forward (type of activity , skills,time and cost (£)?:
PM group 3	• Sludge i.e. iron oxide, lime scale, microbes (MIC). (lime scale and microbes in water heating systems). • Low temperature systems: e.g. food. Decreased efficiency or full blockages. • Not really sure what is there. • Product type 11: EU regulations different to UK: Regulations are problematic and costs prohibitive for rolling out to other markets. • Large range of materials used in these systems. • Access to funding in showing translation of research to 'real world'. • Catch 22 as short term pressure can't be done. • Ethics approval for some testing is a long process and time consuming. • Animal methods and what is available. • TRL translation via grant can stall due to grant time scales. • Assistance is needed in grant writing/ applications. Food surfaces • Harsh cleaning agents damage surfaces. • Biofilms associated with hard surfaces. • Hard to get some food industry to understand enzyme: Lots of misperceptions about enzymes. • Some issues with cleaning enzymes for fabric. • Food industry is reluctant to change. • Detection of biofilm formation: Italian company ALVIN. • Enzyme for surface cleaning have been produced with commercial protocol. • Education for uses is needed. • Monopoly of few controlling companies. • Regulatory alignment/ priority. • Some standards are not suitable for testing with new products/ methods of management.	Needs • Standards lag behind development: Things need to be faster. • Regulations for chemicals is slow (European Chemical Agency): Why? • The supply chains of some sectors can be problematic e.g. NHS. • Standardisation models/ testing. • Unified standards. • Communication - academia and industry. • Speed of development. • Larger scale models - real world (super). • Understand biofilms - talk to end user. To be done • Models: Communication, collaboration, central repository. • Communication - 'end user' and researcher. • Large collaborative 'NBIC' projects. • Consortium projects.	How • Models: Systematic review - 3 people, 2 years, £500K. • Communication: Workshop - £13K. • Large consortia projects - 7 years, 40 FTE, £30 million.

Group	What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms?	What needs to be done to address these problems? :	What would it take to move this forward (type of activity , skills,time and cost (£)?:
PM group 4	• Banning of preservatives with no new ones in the pipeline. • Even if the UK regulations are increased what about EU, USA etc. • No easy way to access NHS.	• Central Hub for testing any new model. Could be based at a university. Needs to be accessible, affordable and agile. NOTE ADDED: Include development of new models and then validation. NOTE ADDED: For industry speed is everything. If proof of concept is positive need to move quickly to prototype etc. • NBIC list of new preservatives/ antimicrobials - specific to yeast, moulds etc. • Exploit commonality in sectors - surfaces etc. • Develop an early detection model for efficacy.	
AM Group 6	• Detection of biofilms: Wounds and food. • Fundamental research into mechanisms of development and collapse. • Link between biofilm and would healing. • Questioning development of general approaches targeting specific microorganisms. • Lack of public understanding. • Lack of professional/ academic understanding: Need more multidisciplinary approach. Global challenge. • Need for better models: in vitro, in vivo, computational (visualisation). • Lack of regulatory standards.	• Funding. • Health economic studies: cost of biofilms to the NHS. Cost and benefits of research spread over the supply chain. • Collaboration academia/ industry and cross industry. • Underlying fundamental research. • Promote research.	• Collaboration: Multidisciplinary, national consortium, agree common themes/ goals (for modelling, tools and standards). • Source of trusted information. • More funding into research. • Make data available.

Group	What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms?	What needs to be done to address these problems? :	What would it take to move this forward (type of activity , skills,time and cost (£)?:
PM Group 6	1) Communication between industry and academia - Relevant, translational research. 2) Relevant models for each industry. Standardisation and testing. Regulatory concerns re standard biofilm testing. Being a part of the conversation. 3) Contamination in sampling in the water industry (extent of biofilm formation). Flushing regime ancient, does it help or hinder? Risk of sediment/ benefit unstable biofilm. 4) Wound healing models - antibiofilm claims but models don't compare clinical studies. What is the role of a biofilm in wounds? Growth of biofilm on nylon sheet: move past limitations - species? sheet? waste water?	• Visibility of needs. • Dragon's Den. • Understand industry problems. • Meetings. • Newsletters. • Influencing regulations - investment from NBIC. Regulatory conversation - NBIC partners to advise - ISO standards? • Basic biofilms research in nature. Industry to understand risk and causing issue by flushing it?	<u>Models:</u> • Multifactorial. • European steering group (e.g. NBIC steering group) governed by 'a bible' of ISO standard meetings (as in the water industry which is regulated by the government. All chip in - time within the industry). • Validation and other protocols. Different levels of complexity. (these are similar but not the same). • All industries to pull together with one aim. No one prepared to do that yet more competitive (e.g. medical device and wound care industries). 'We' need to set criteria, viability, composition, matrix in tick (academics to validate). To be run by an independent body not a company. NBIC to say that this is a credible test - publication/ requested standard. • Enforce complexity, rigour in academic engagement and not faster/ cheaper. Set regime e.g. 'use NBIC SOP' comparable to... <u>What would it take</u> • 1 year to resolve problem for water industry. • Clinical models link to biofilm research in wound healing. • Industry and clinic and academia. • Back to basic research - which species... • Symptoms of clinical infection related to biofilm research. • Universally relevant research for anti-microbials. CBC bioreactor validated for pseudomonas. What is anti-biofilm?

Group	What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms?	What needs to be done to address these problems? :	What would it take to move this forward (type of activity , skills,time and cost (£)?:
AM Group 7		• International standard models developed and endorsed by an independent body (NBIC). • Models would be somewhat generic; oil & gas/ water treatment - piped model for example. • Models should be based on industrial needs."	
AM Group 8	1) Regulatory pathway: Can be hard to navigate. 2) Formulation and design: in vitro - in vivo. 3) Robust models: HTP Assays, visualisation. 4) Diagnostics for wound biofilm. Interplay between clinical/ lab research in wound healing. Regulation - what claims? Models that are redundant. 5) Models/ regulation and development of STDC.	• Communication and development of standards STDC. • Models for the fields and updates of these. • Identify what key data is needed (minimum viable data). • Overview of models used by NBIC: Large organisation needs to be involved. • Do we need an NGO for biofilms?	• Regulatory workshop. • Guided strategy for SMEs to get into the markets. • Control release of compounds. How do we do this? (government engaged?). Formulation design in some sectors is difficult. • Business development in regards to technology and translation - value chains - SMEs need help with this. • What are the threats in biofilms? Clothing hygiene? • Technology translation funding body. • Biofilm catalyst: prototype hub. NBIC translation/ prototype fund for POCs?
PM Group 8	• Basic fundamental research about biofilms (NBIC publications). • Standardisation models/ generate a catalogue of models with variables. • Limited diagnostics/ models with variables. • Standardise biofilm measurements. • Lack of regulatory frameworks.	• Interdisciplinary expertise required. • Coordination between experts."	

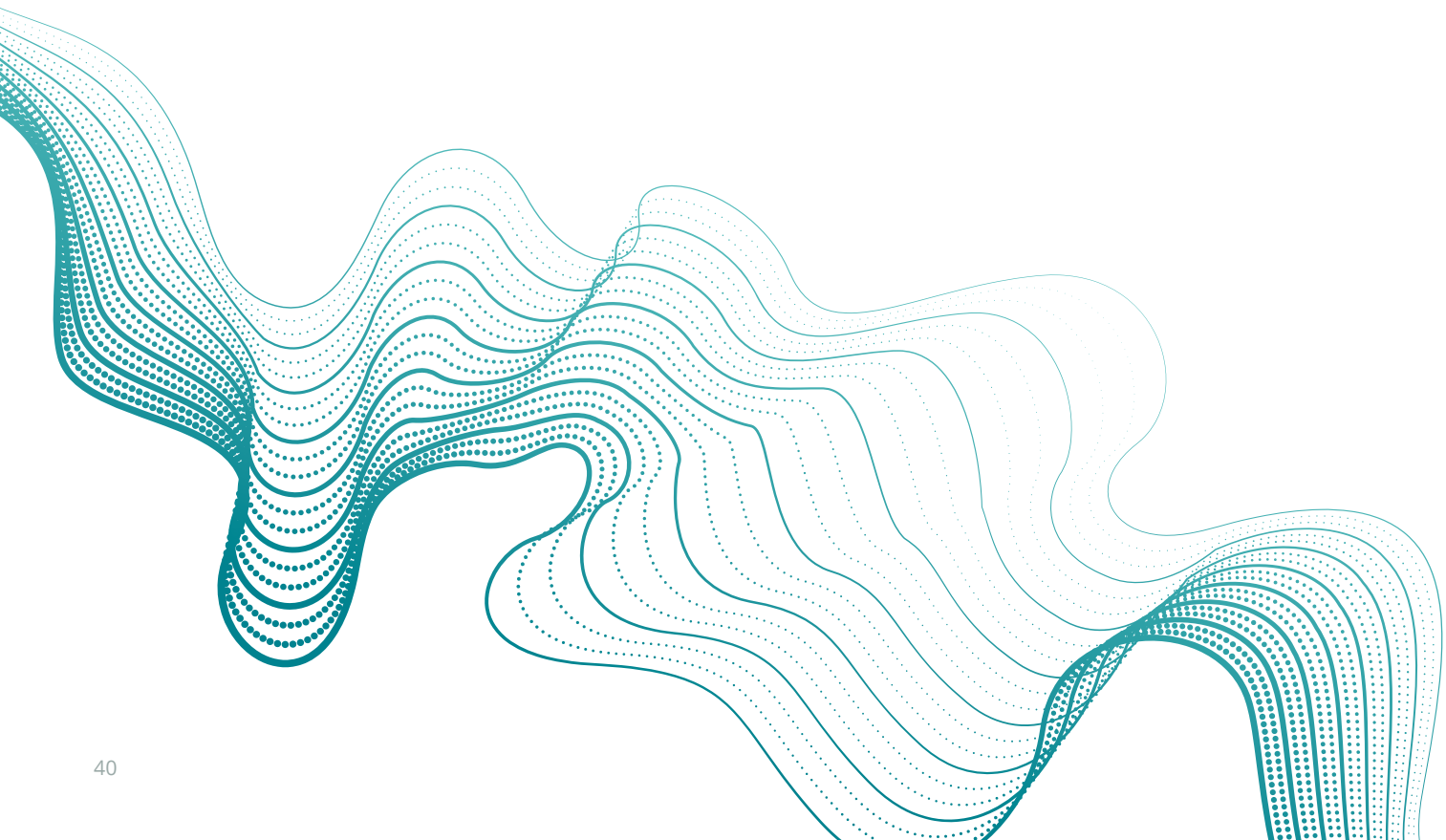
Group	What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms?	What needs to be done to address these problems? :	What would it take to move this forward (type of activity , skills,time and cost (£)?:
AM Group 9	<u>Heating systems</u> • BPR for new biocides (costs). • Low temperature systems driving need for better control (e.g. heat pumps). • Further vs health agendas. • Companies set up to make the application to BPR - slow process. Test methods • Need for some kind of intermediate tests between lab and regulatory - approved tests. • Models could be designed/ modified from existing systems and relevant surfaces. • Needs to be high throughput. Physical methods • Accessibility of systems to interventions (e.g. UV in pipes) may be difficult. <u>Probiotics</u> • Could be one approach for heating systems e.g. bacillus. <u>Antifouling/fabric molecules/wounds</u> • Trying to avoid killing/ persuade bacteria not to colonise. • Need controlled release systems to sustain effort. • Need expertise in growing biofilms - third parties. • Interested in dynamics (Nottingham Uni). • Interested in probiotics: Tackle via skin or fabrics? • Question mark over whether probiotics is the right approach for these applications - what happens if it goes wrong? • Imaging of biofilms is powerful in communications.		

Group	What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms?	What needs to be done to address these problems? :	What would it take to move this forward (type of activity , skills,time and cost (£)?:
AM Group 10	• Defining the purpose of biofilm models. • Do we want to kill? Modulate? • Change of perspective (skin - oral). Kill - (control/ protect microbiome)? • Harnessing host responses. • Understanding the balance between bacteria/ pathogens. • Is there any point of simple models? • Consensus about the biofilm models criteria for screening. • Where are academia and industry meeting points? Interface. • Duplication of effort/ sharing. • Acceptability of negative results. • Academic understanding of regulatory pathways for a product/ visa versa. • Academic understanding of industry needs. Visa versa.	• Repurposing/ retesting. • Data/ knowledge hub by NBIC. • Bridging gap between academia and industry. • Unified standard/ criteria for models. Minimise risks?	• Development of early partnership between industry/ academia. • Repurposing/ retesting. • Database of compounds/ biofilm also general data (biofilm research/ resources). • Consensus on methods/ criteria in defined areas. • Gathering cross over areas i.e. skin/ oral.

Group	What do you see (from your perspective, company or interests) as the problems or needs in the management of biofilms?	What needs to be done to address these problems? :	What would it take to move this forward (type of activity , skills,time and cost (£)?:
PM Group 10	• No biofilm standard. • Early stage formation of biofilm - very little known. • Lack of real world models (no standard). • Specialists in specifics - fungi, pseudomonas etc looking at individual species (not all joined up). No holistic view. • Global regulation: Standardised approach, systematic analysis. • Combined approach: physical and chemical. • US standards - healthcare. • Focus groups - per industry. • Education. • Surface manipulation. • Realise limitations: better education. • Definition of the problem. • Information technologists: biofilm experts, mathematicians.		

Appendix 3: Collated votes

Theme	Number of votes
Combination approaches and therapies.	9
Cross-disciplinary (industry-academia, with regulators and between sectors of industry) engagement including workshops, partner searches and in the development/execution of project proposals and models	39
Data Centralisation and Management: Including collating of existing data, bioinformatics and data/statistical modelling	11
Education of and access to markets.	8
Models and methods for characterisation, visualisation and detection: Relevant (environmental context e.g. factory), standardised and accessible to industry and academia	91
New strategies needed for biofilm management.	1
PhD (real world) and placements/KTP with realistic timescales.	3
Regulatory pathways for solutions, time frames and associated costs	28
Time and costs associated with early investigating work and product testing.	4
Understanding biofilms: definition, formation (prove causative link), collapse, host response, control vs kill and characterisation including agent penetration	22
Grand Total	**216**



Appendix 4: Companies and organisations registered for the workshop

BBSRC	Symrise
Bear Valley Ventures	The University of Manchester
Chilled Food Association	The University of Sheffield
DNV GL	Unilever
Edinburgh Napier University	University of Bristol
Fernox	University of Edinburgh
Fourth State Medicine Ltd.	University of Glasgow
Freedom Hygiene Limited	University of Huddersfield
iFormulate	University of Hull
Kimal PLC	University of Leeds
MedTrade Products Limited	University of Lincoln
Moy Park	University of Liverpool
National Biofilms Innovation Centre (NBIC)	University of Nottingham
Nottingham Trent University	University of Southampton
Oxi-Tech Solutions	University of Warwick
PZ Cussons	Varicon Aqua
Severn Trent Water	Warwick University
Smith & Nephew	Xiros Ltd

Appendix 5: 3 minute pitches

FOURTH STATE MEDICINE

Dr Tom Wantock and Dr Tom Harle

Nitrogen Oxides (NOx) and Ozone gases chemically attack biofilms at high concentrations, while low doses can be used to subtly "hack" biofilm behaviour by manipulating redox signalling. Benefits of these gases for biofilm management include uniform treatment of large/complex manifolds, multiple modes of action, and stability in air (allowing integration with other room temperature/pressure processes). Fourth State offers precise, on-demand, electronic NOx/Ozone synthesis from nitrogen and oxygen in ambient air, using plasma technology (ionised gas: the fourth state of matter). The company's compact, integrated, programmable modules and bespoke design services help B2B/OEM customers to integrate NOx/Ozone into their products and processes.

NOxLabTM, Fourth State's new Nitric Oxide (NO) development kit, will soon be on sale to companies and academic researchers for R&D purposes, having been initially validated through NBIC PoC projects with University of Surrey (food processing, hard surfaces) and University of Hull (wound healing).

FLUID-DRIVEN ANTI-BACTERIAL TECHNIQUES

Dr Sepideh Khodaparast , School of Mechanical Engineering, University of Leeds

Living organisms in nature have evolved well-engineered sustainable solutions to survive different environmental conditions and threats. Among these, the inspiring self-cleaning and anti-microbial functionalities, established in many plants and animals, lay the foundation of my research on chemical-free self-cleaning approaches. In the context of biofilms, my current research is focused on two lines of development: (1) Bubble-driven cleaning technologies, which rely on interfacial forces applied to bacterial cells and biofilms that are submerged in a liquid medium, as they come in contact with air bubbles. (2) Biomimetic fabrication of bactericidal coatings, particularly those inspired by nanostructured surfaces of insect wings. My research investigates effectiveness of in-expensive large-scale fluid-based techniques for fabrication of nano-structured surfaces in polymer coatings that exhibit bactericidal behaviour. Development of such technologies strongly depends on better understanding of physical properties of bacterial colonies and their interactions with surfaces and complex fluid media, that requires extensive multidisciplinary research in the field.

IO-CYTE LTD

Dr David Farrar

Io-Cyte Ltd exists to support patients with non-healing chronic wounds, and the nurses and doctors who care for them, by developing relevant biomaterial innovation. The company formed in October 2019, as a spin-out from the Leeds-based orthopaedic company Xiros Ltd. Over the years, Xiros has funded a biomaterials research facility with expertise on fibres and this has created a number of non-core technologies. In this case, they have created innovative methods of incorporating drugs into highly absorbent fibres that are used for dressing chronic wounds. As well as being effective in killing bacteria that are found in wounds, the dressing has been shown in simple single-species models to disrupt biofilm. It uses povidone-iodine which has also been shown in research to support and even accelerate wound healing. The company are in the process of driving this technology through to clinical trial and through regulatory approval to market. Io-Cyte is keen to develop collaborations with groups that are able to support the development of its technology. Of particular interest is work to evaluate the effectiveness of the dressing against biofilms using more challenging and clinically relevant models, be they in-vitro or in-vivo.

FREEDOM HYGIENE LTD

Paul Browning

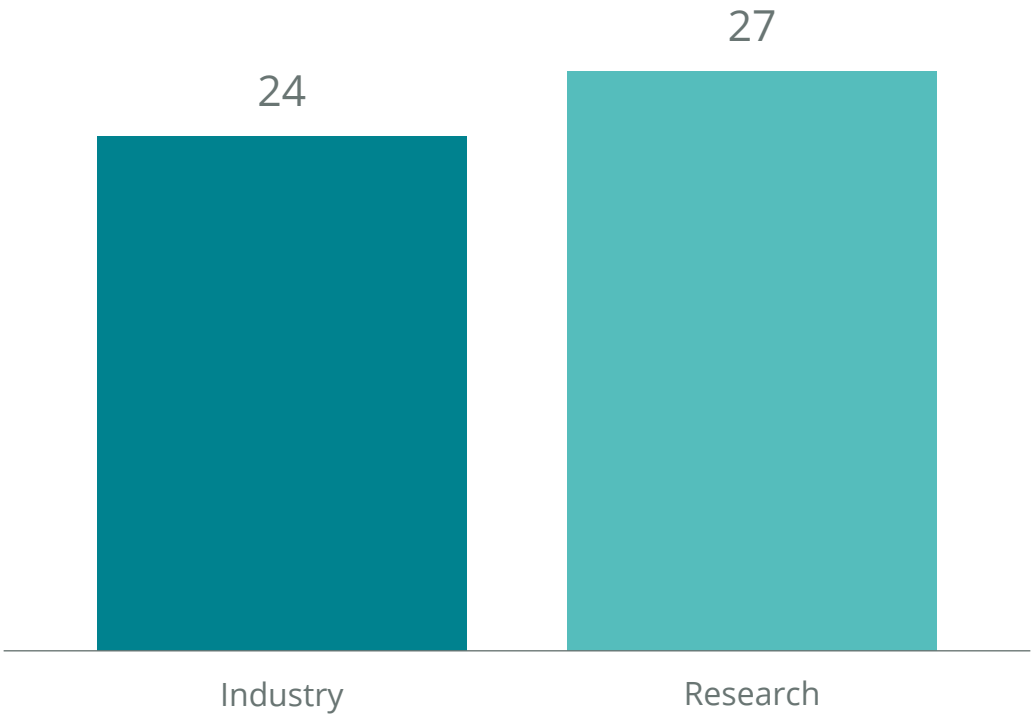
Paul Browning is a microbiologist and the owner of Freedom Hygiene Ltd, a technology driven company whose mission is to seek out new technologies and offer innovative solutions for the detection and removal of biofilms in food and beverage processors. Paul has over 40 years of experience working in the food and beverage industries. He started his long career in hygiene with the Nottingham Public Health Laboratory Service as a junior microbiologist and spent time at the Nottingham City Hospital working in pathology, haematology, biochemistry and cytology departments. He qualified as a microbiologist at Trent Polytechnic Nottingham, now Nottingham Trent University.

He spent time in the food industry before embarking on a 17 years career with the Diversey Corporation in the UK and Europe developing chemical cleaning business in the food and drinks industries. In 1995 he created his own company from scratch, Pentasol FB Ltd, manufacturing and supplying cleaning chemicals and technical support primarily to breweries and soft drinks plants. Pentasol was eventually sold to CCL and became part of the highly successful CCL Pentasol Ltd. For the last 3 years Paul has devoted his time to assisting food and beverage manufacturers across the UK identify the source of microbial infections. His most recent projects include developing a biofilm elimination and preventative programme for a pizza manufacturer, a fish processor, soft drinks company, a vegetable processor, prepared meals factory and several dairies. All of these companies were experiencing chronic Listeria issues.

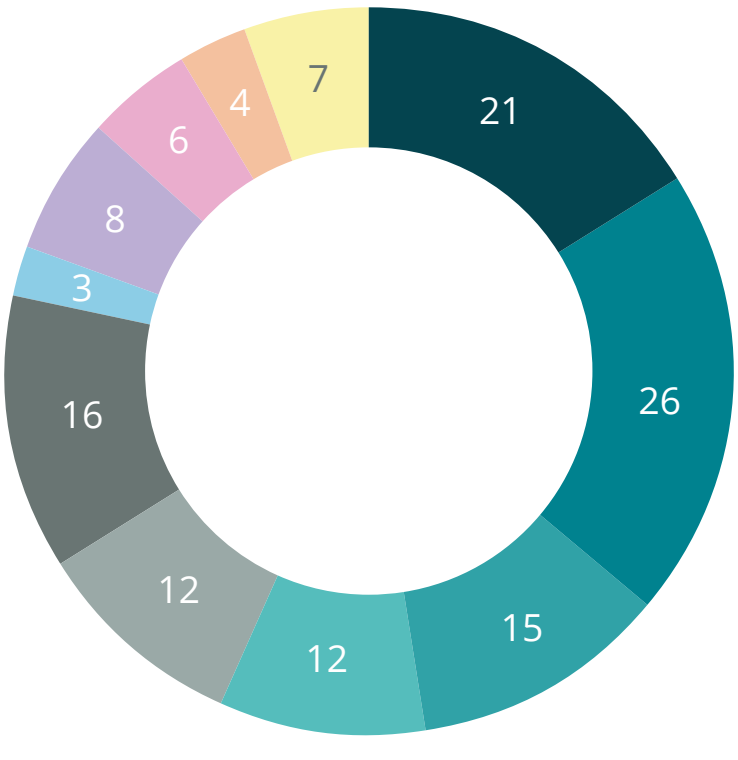
The key to his successful record is the introduction of new technology for the detection of biofilms on both open surfaces and in CIP systems, enclosed tanks and circuits, and then employing enzyme technology for biofilm removal. Following on from this success, Paul is now looking to explore opportunities for projects in other markets where biofilms are an issue; and where enzyme surfactant technology may be applied to eliminate them such as Healthcare and Industrial processes. If you have any concerns over biofilms in your area of expertise and would like to discuss the potential application of enzyme technology call Paul on 07774 898904 or paul@freegiene.com.

Appendix 6: Mentimeter polling during meeting

ARE YOU AN INDUSTRIAL OR ACADEMIC PARTNER?



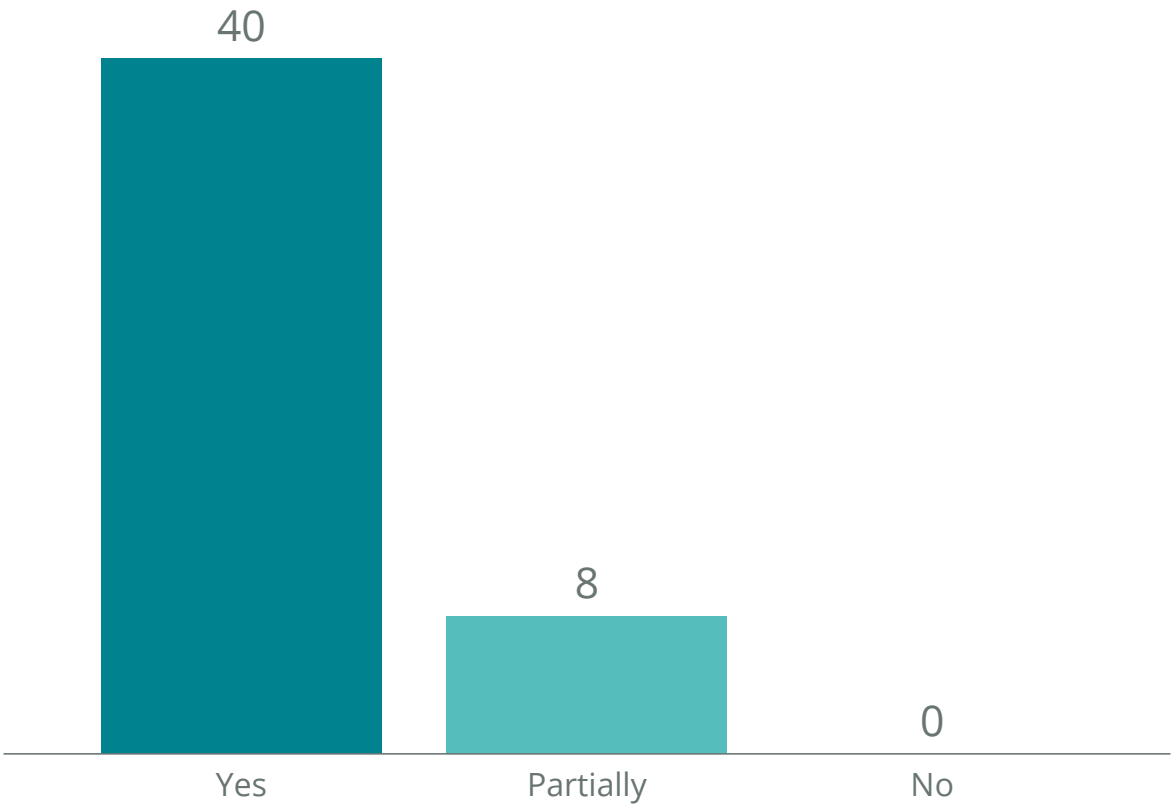
WHICH SECTORS BEST REPRESENT YOUR BUSINESS OR RESEARCH AREA?



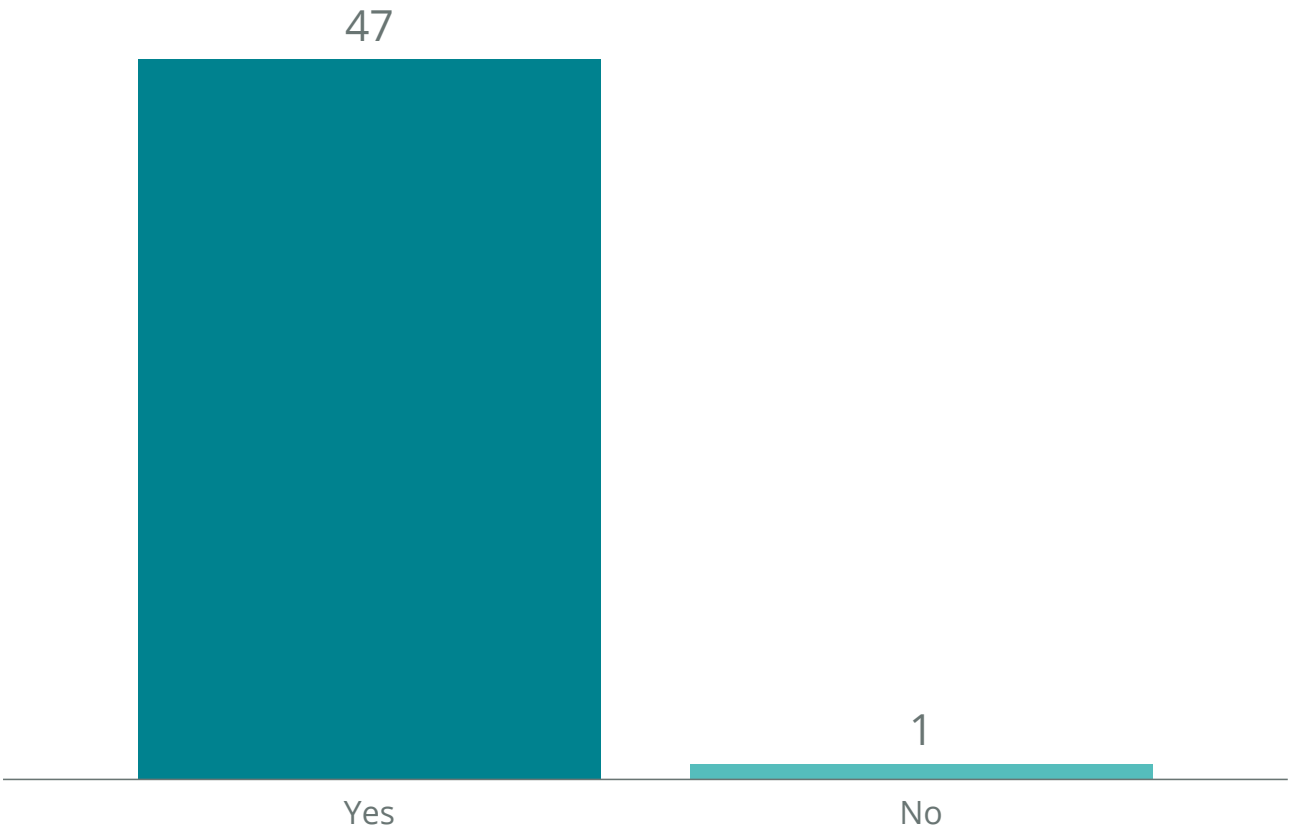
21	Health Pharma
26	Health-Devices
15	Personal Care
12	Water & Wastewater
12	Food & Agriculture
16	Oral
3	Industrial and Institutional (building management and design)
8	Home Care
6	Marine
4	Oil & Gas
7	Energy & Waste

WHAT ISSUES ARE YOU HOPING TO USE BIOFILM MANAGEMENT TO SOLVE?

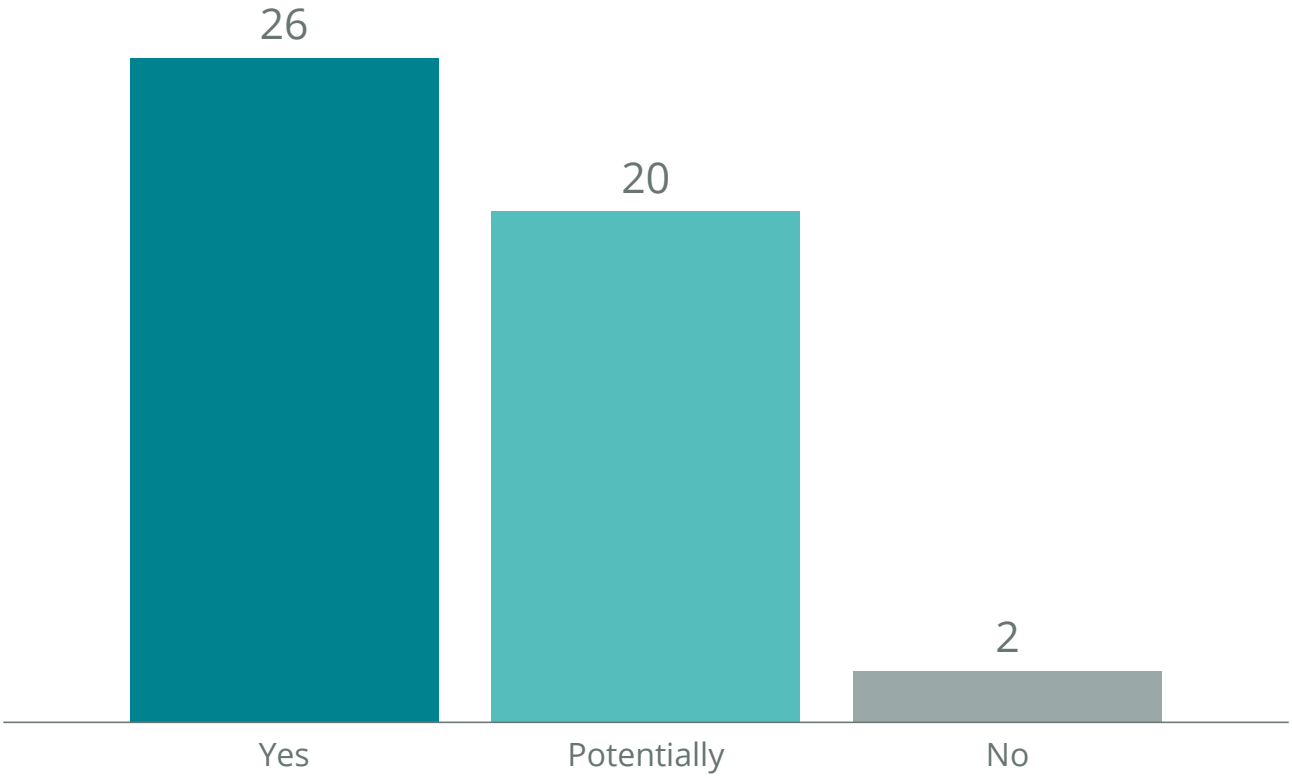
HAS TODAY BEEN HELPFUL IN UNDERSTANDING THE STATE OF BIOFILM MANAGEMENT IN SECTORS OTHER THAN YOUR OWN?



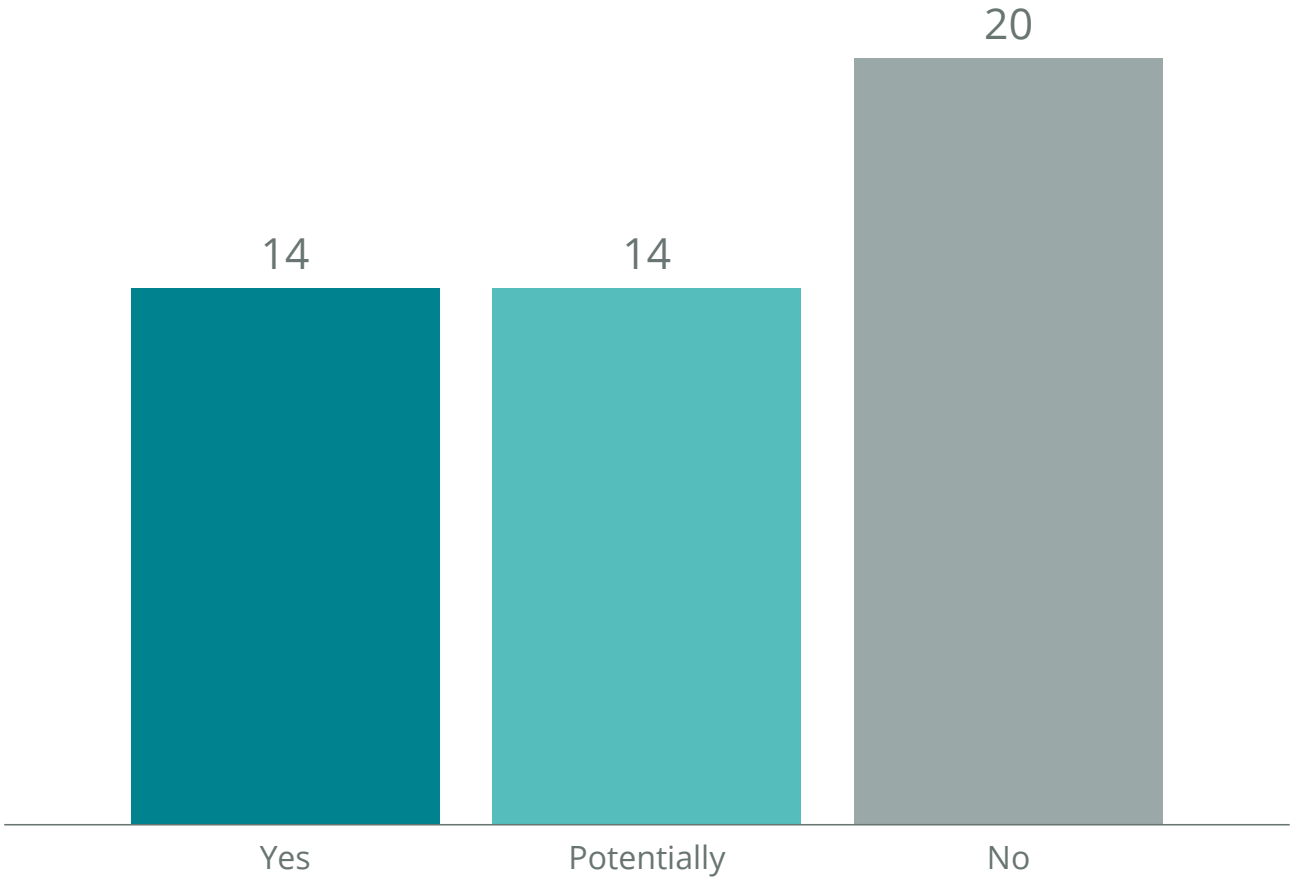
HAS TODAY BEEN HELPFUL IN FORMING NEW RELATIONSHIPS AND CONNECTIONS?



HAS TODAY BEEN HELPFUL IN FORMING NEW RELATIONSHIPS AND CONNECTIONS?



ARE YOU CONSIDERING APPLYING FOR THE UPCOMING POC MANAGE FUNDING CALL?



Thank you

For further information please contact nbic@biofilms.ac.uk