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A new direction in fighting infection.

## **MBEC™ Assay**

**For High-Throughput Antimicrobial  
Susceptibility Testing of Biofilms**

### **PROCEDURAL MANUAL**

#### **Version 1.1**

**For use with the following product codes:**

MBEC™ Biofilm Inoculator with 96-well base  
**19111** – 25/case, **19112** – 100/case

MBEC™ Biofilm Inoculator with trough base  
**19121** – 25/case, **19122** – 100/case

MBEC™ Biofilm Inoculator with 96-well base & hydroxyapatite coated pegs  
**19131** – 25/case, **19132** – 100/case

MBEC™ Biofilm Inoculator with trough base & hydroxyapatite coated pegs  
**19141** – 25/case, **19142** – 100/case

**Table of Contents**

PRODUCT DESCRIPTION.....	3
PRODUCT USES .....	4
INTRODUCTION TO BIOFILMS.....	5
PRECAUTIONS .....	7
MATERIALS AND EQUIPMENT .....	7
MEDIA AND SOLUTIONS .....	8
PROCEDURES .....	9
MICROSCOPY .....	18
SURFACE COATING THE MBEC™ ASSAY .....	20
COMPANY INFORMATION .....	21
WARRANTY .....	21
CONTACT INFORMATION.....	21

## **PRODUCT DESCRIPTION**

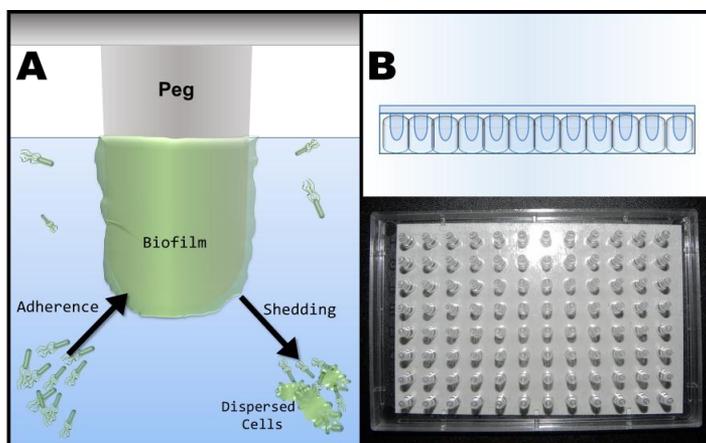
The MBEC™ (Minimum Biofilm Eradication Concentration) Assay is a high throughput screening assay used to determine the efficacy of antimicrobials against biofilms of a variety of microorganisms. The MBEC™ Biofilm Inoculators consist of a plastic lid with 96 pegs and a corresponding base. There are two types of bases that may be used with the MBEC™ lid. One base contains 96 individual wells (Figure 1). The individual wells allow for the growth of a variety of species of microorganisms in one device. The other base is a corrugated trough base that can contain only one species of microorganism (Figure 2). Biofilms are established on the pegs (Figure 3) under batch conditions (no flow of nutrients into or out of an individual well/plate) with gentle mixing. The established biofilms are transferred to a new 96-well plate for antimicrobial efficacy testing. The assay design allows for the simultaneous testing of multiple biocides at multiple concentrations with replicate samples, making it an efficient screening tool.



**Figure 1.** A 96-well base. Found in products 19111, 19112, 19131, and 19132.



**Figure 2.** A trough base. Found in products 19121, 19122, 19141, and 19142.



**Figure 3.** The MBEC™ Assay. A) Biofilms form on the pegs of the MBEC™ Biofilm Inoculator when planktonic bacteria adhere to the surface. In the presence of shear, these bacteria become attached and form mature biofilms. Biofilms are encased in ‘slime’, which is sometimes visible to the naked eye. Dispersed cells are also shed from the surface of biofilms, which serve as an inoculum for MIC determinations. B) The peg lid has 96 identical pegs. The average surface area of each peg on the MBEC™ device is 108.9 mm<sup>2</sup>. This lid fits into a standard 96-well microtiter or trough plate with channels that are set up to contain an inoculated growth medium. The entire device is placed on a gyrorotary shaker or a rocking platform in an incubator, which provides the shearing force for facilitating the formation of 96 biofilms on the peg lid.

## **PRODUCT USES**

- Antibiotic, biocide, disinfectant, and heavy metal susceptibility testing of biofilms to determine a minimum inhibitory concentration (MIC), a minimum biocidal concentration (MBC), and a minimum biofilm eradication concentration (MBEC).
- Basic research in the physiology and genetics of biofilms (such as screening to identify mutants impaired in their ability to form biofilms).
- Comparative biofilm growth assays of different isolates under identical culture conditions.
- Comparative studies of gene expression in multiple isolates or mutants.
- Selection criteria applied against biofilm microorganisms.
- Checkerboard assays to identify synergistic interactions between antimicrobials used to treat biofilms.

- Time course studies of biofilm formation or treatment in a single assay, since the pegs are designed to be easily removed from the peg lid.
- Scanning electron microscopy (SEM) and confocal laser scanning microscopy (CLSM) to examine biofilm structure.
- Many conventional assays for attachment, growth, survival, or metabolic activity to measure the parameters of interest to the researcher. These can be done while the biofilm is intact on the peg or following sonication to again produce a planktonic population.

## **INTRODUCTION TO BIOFILMS**

The expertise of Innovotech Inc. is microbial biofilms. Biofilms are a cohesive matrix of microorganisms, mucopolysaccharides (slime), and other extracellular constituents. Biofilms exist in virtually every natural environment. Biofilms form in response to the presence of a solid surface, as well as other factors such as shear force (flow), as a mechanism to avert being removed from their surroundings. Biofilm formation is a developmental process that has been likened to differentiation in multicellular organisms, with intercellular signals that regulate growth. A typical biofilm forms when bacteria adsorb to a surface and become attached, triggering a change in physiology. The bacteria then grow and divide to form layers, clumps, or stalk-and-mushroom shaped microcolonies, all under the control of specific biofilm-expressing genes. The production of an extracellular polymeric matrix on the surface further protects the biofilm.

Once formed, biofilms are difficult to remove, as they show an increased tolerance to biocides and antibiotics when compared to planktonic (free-floating) microorganisms. Studies have shown that biofilms may have greater than a one hundred-fold increase in tolerance to antibiotics when compared to the same bacteria in a planktonic state [1, 2, 3]. This is thought to be due to the physiological alteration of the microorganism upon attachment to the surface, as well as to cell specialization that may occur within biofilms.

Microbial biofilms naturally exist on inanimate and living surfaces. Biofilms may be found just about anywhere, from hard surfaces in food processing facilities to the water lines of dental equipment. The organisms present on these surfaces frequently include a number of normally benign bacteria and fungi. However, these biofilms may also serve as a haven for serious human and animal pathogens. Further, the Center for Disease Control and Prevention estimates that 60% of clinical infections in the Western world are caused by biofilms. This includes heart, wound, and middle ear infections;

illnesses associated with implanted medical devices such as artificial joints and catheters; and tooth decay and gum diseases (which arise from dental plaque – an oral biofilm). Information on biofilm control properties of existing products and protocols is not available to most industries as there has been minimal biocide testing for microorganisms in the biofilm state.

The MBEC™ assay allows microorganisms to grow on 96 identical pegs protruding down from a plastic lid. By placing the biofilm-coated pegs into the wells of a microtiter plate, an array of antimicrobial compounds with varying concentrations can easily be assessed. This allows for rapid testing of compounds including antibiotics, disinfectants, biocides, and metals for anti-biofilm activity [2, 4-6]. Many different bacterial and yeast species have been grown using this assay, including *Escherichia coli* [2], *Pseudomonas aeruginosa* [2], *Staphylococcus* spp. [2, 7], *Mycobacterium* spp. [8], *Candida* spp. [9], *Burkholderia* spp. [10, 11], and many more. To date, the MBEC™ assay has been featured in more than 100 peer-reviewed publications.

## References

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- [10] Tomlin, K.L., Malott, R.J., Ramage, G., Storey, D.G., Sokol, P.A., and Ceri, H. (2005) Quorum-sensing mutations affect attachment and stability of *Burkholderia cenocepacia* biofilms. Applied and Environmental Microbiology 71, 5208-5218.
- [11] Tomlin, K.L., Coll, O.P., and Ceri, H. (2001) Interspecies biofilms of *Pseudomonas aeruginosa* and *Burkholderia cepacia*. Canadian Journal of Microbiology 47, 949-954.

## **PRECAUTIONS**

- Single use only.
- Aseptic techniques and standard laboratory practices should be observed throughout all procedures, with special awareness that the plates and inoculation lid, once inoculated, could contain potentially pathogenic organisms.
- All biohazardous waste should be decontaminated by autoclave, incineration, or chemical means prior to disposal in compliance with facility/institutional guidelines.

## **MATERIALS AND EQUIPMENT**

- MBEC™ Biofilm Inoculator (peg lid with 96-well microtiter plate base or corrugated trough base)
- Sterile 96-well microtiter plates (Recommended manufacturer: Nunc™ Nunclon™ 96-well tissue culture microtiter plates. Sterile and individually packaged.)
- Sterile cotton swabs
- Sterile 16 × 100 mm glass culture tubes (Recommended manufacturer: FisherBrand, borosilicate glass disposable culture tubes)
- Sterile physiological saline solution (ex. phosphate buffered saline, or 0.9% NaCl)
- 0.5 McFarland Barium Sulfate Turbidity Standard or alternative
- Sterile micropipette tips (2-200 µL), in racks of 96
- Sterile 1 mL and 25 mL pipettes
- Sterile 50 mL culture tubes
- Sterile reagent reservoirs
- Agar and broth growth media specific for the microorganism to be cultured
- Platform shaker (to be set at 110 and 150 revolutions per minute (rpm) for use with 19111, 19112, 19131, and 19132) (Recommended manufacturer: New Brunswick Scientific – Excella Platform Shaker)

- Rocking table (for use with 19121, 19122, 19141, and 19142. Set at 3-5 rocks per minute and 9-16° of inclination) (Recommended manufacturer: Bellco Glass Inc. – Rocker with Tray Platform)
- Single and/or multichannel micropipettes to measure volumes of 10 µL, 20 µL, 100 µL, 150 µL, 180 µL, and 200 µL.  
**NOTE:** *This procedure may be performed using only single channel micropipettes (recommended sizes: 2-20 µL and 20-200 µL); however, 12-channel micropipettes are suggested (recommended sizes: 5-50 µL and 30-300 µL).*
- Ultrasonic cleaner (water bath sonicator) with stainless steel insert tray (Recommended manufacturer: VWR Scientific, Aquasonic Model 250)
- Inoculation loop
- Incubator for biofilm growth with temperature settings specific to test microorganisms
- Bunsen burner
- Needle nose pliers
- Pipette bulb or aid
- Recommended – Biological safety cabinet (laminar flow hood)

## **MEDIA AND SOLUTIONS**

### **Stock antimicrobial solutions:**

Antibiotic and other antimicrobial stock solutions should be prepared in advance at the highest concentration to be used in the challenge plate. Clinical Laboratory Standards Institute (CLSI) document M100-S22 may be consulted for details of which solvents and diluents to use. Stock solutions of most antibiotics are stable for a minimum of 6 months at -70°C.

### **Neutralizing and biofilm recovery agents:**

For research applications, it is appropriate to employ a neutralizing agent for determination of minimum bactericidal and fungicidal concentrations. These agents reduce toxicity from the carry-over of biologically active compounds from challenge to recovery media. For example, it is possible to use β-lactamase to neutralize penicillin, or L-cysteine to neutralize Hg<sup>+2</sup> and some other heavy metal cations. Innovotech Inc. often uses a universal neutralizer in biocide susceptibility assays that are required for regulatory aspects of product development. This neutralizer also contains a surfactant that aids in recovering any remaining biofilm from the device following the challenge. Examples of universal neutralizers are presented below:

### Universal Neutralizer (for biocide testing)

#### Ingredients:

- 1.0 g L-histidine
- 1.0 g L-cysteine
- 2.0 g reduced glutathione

#### Procedure:

1. To make the universal neutralizer, make up to 20 mL in double distilled water. Pass through a syringe with a 0.20 µm filter to sterilize. This solution may be stored at -20°C.
2. To make surfactant supplemented growth medium, make up 1 liter of the appropriate growth medium (for example, cation adjusted MHB). Supplement this medium with 20.0 g per liter of saponin and 10.0 g per liter of Tween-80. Adjust with dilute NaOH to pH 7.0 ± 0.2 at 20°C.
3. Add 500 µL of the universal neutralizer to each 20 mL of the surfactant supplemented growth medium used for recovery plates (Step 6b below).

**D/E Neutralizing Broth** – prepare as per manufacturer’s instructions.

**NOTE:** *There are no standard neutralizer recipes that can effectively work with all antimicrobial treatments. Neutralizer recipes can be adjusted and modified to achieve the optimum recovery results with different antimicrobial agent(s).*

### **Organism specific media (OSM):**

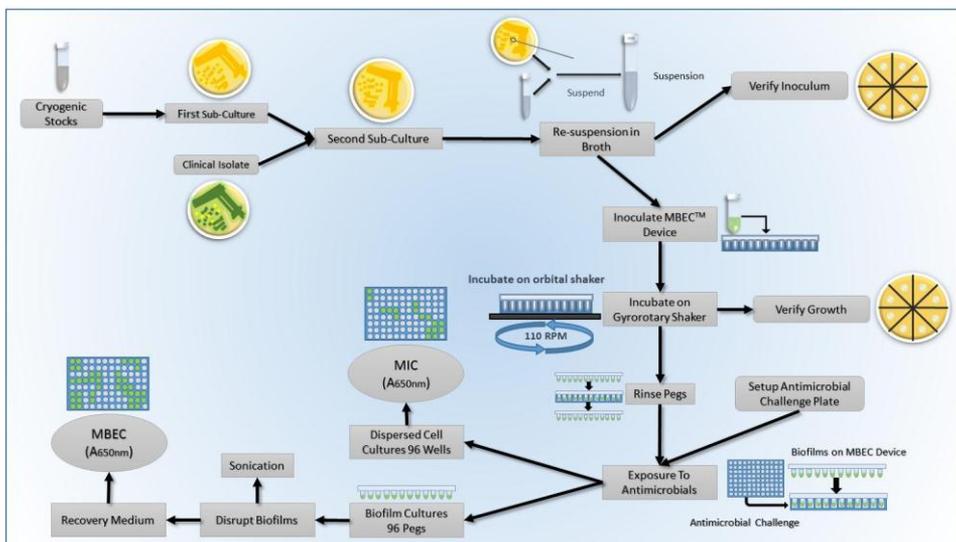
Prepare agar and broth growth media specific for the microorganism to be cultured as per manufacturer’s instructions (common examples are Tryptic Soy Broth/Agar, and Sabouraud Dextrose Broth/Agar).

### **PROCEDURES**

The example procedure provided in these instructions describes an assay for testing single or multiple organisms grown as biofilms against a single antimicrobial agent. This protocol may need to be optimized to best suit your needs. Although the majority of microorganisms form biofilms as part of their lifecycle, not all are amenable to growth in the MBEC™ assay. Please contact Innovotech for help in developing a methodological design specific to your requirements.

The number of days required to complete this protocol is dependent on the growth rate and biofilm formation time of the microorganism being examined.

This protocol has been developed for use with Nunc™ Brand, flat bottom, 96-well microtiter plates. Figure 4 shows a schematic of the steps to be followed.



**Figure 4.** A flow diagram representing the steps in the experimental process for antimicrobial susceptibility testing using the MBEC™ assay with a 96-well base.

## 1. GROWING SUBCULTURES:

- If using a cryogenic stock (at -70°C), streak out a first sub-culture of the desired bacterial or fungal strain on an appropriate agar plate. Incubate at the optimum growth temperature of the microorganism for an appropriate period of time. For most bacterial strains, the first sub-culture may be wrapped with Parafilm™ and stored at 4±2°C for up to 14 days after incubation is complete.
- Check the first sub-culture for purity (i.e. only a single colony morphology should be present on the plate).
- From the first sub-culture or from a clinical isolate, streak out a second sub-culture on an appropriate agar plate. Incubate at the optimum growth temperature of the microorganism for an appropriate period of time. The second sub-culture should be used within 24 hours starting from the time it was first removed from incubation.
- Verify the purity of the second sub-culture (see 1b).

**NOTE:** *It is not recommended to grow subcultures on media containing selective agents. Antibiotics and other antimicrobials may trigger an adaptive stress response in bacteria and/or may increase the accumulation of mutants in the population. This may result in an aberrant susceptibility determination.*

## 2. INOCULUM PREPARATION:

- a. Choose approximately 4-5 large, or 5-10 small, well isolated colonies from an 18-24 hour culture (second sub-culture).
- b. Inoculate a flask containing 100-200 mL of organism specific broth and incubate on a shaker at 150 rpm at the appropriate growth conditions. Viable cell density should be between  $10^7$ - $10^9$  CFU/mL (cell density is dependent on the microorganism) and may be checked by serial dilution and spot plating.
  - i. Place 180  $\mu$ L of sterile saline or buffered water into each well of rows B-H of a fresh 96-well plate. Place 100  $\mu$ L of inoculated broth into row A.
  - ii. Prepare a serial dilution ( $10^0$ - $10^7$ ) by transferring 20  $\mu$ L from each well in row A to each well in row B and so on down each of the 8 rows, mixing well and discarding tips between each transfer.
  - iii. Remove 20  $\mu$ L from each well and spot plate on Organism Specific Agar (OSA) plates.  
**NOTE:** *For some types of OSA, 20  $\mu$ L spots may run together, in which case 10  $\mu$ L spots may be appropriate.*
- c. Dilute the flask culture 10x-1000x in a tube of sterile OSM to adjust the inoculum to an approximate cell density of  $10^5$  CFU/mL. Vortex the diluted sample for approximately 10 seconds to achieve a homogenous distribution of cells.
- d. As an alternate to Steps 2b-c, emulsify the colonies from the second sub-culture in sterile distilled or deionized water in a glass test tube and mix well. If required, adjust the cell concentration to achieve a turbidity equivalent to a 0.5 McFarland standardized suspension. Alternatively, measure the absorbance in a spectrophotometer at a wavelength of 625 nm, with water as a blank. Adjust the suspension to achieve an absorbance between 0.08-0.13. Dilute the standardized suspension in OSM to achieve an approximate cell density of  $10^5$  CFU/mL

- e. Perform an inoculum check by serially diluting and spot plating the diluted culture to confirm the cell density and purity (Steps 2bi-iii). If a mixed culture is present on the agar plate after incubation, re-isolate the test colonies and retest the inoculum (Steps 1 and 2).

### 3. **INOCULATION AND BIOFILM FORMATION:**

It is recommended that the following steps be carried out in a biological safety cabinet (if available). However, it is possible to perform these steps using aseptic technique on a bench top for microorganisms that do not require handling in a BSC.

#### 3.1. MBEC™ Biofilm Inoculator with **96-Well Base:**

- a. Open a sterile MBEC™ Biofilm Inoculator with a 96-well base (Product codes: 19111 and 19112). Pour the inoculum into a reagent reservoir. Using a multichannel pipette, add 150 µL of the inoculum to each well of the 96-well base that is packaged with the MBEC™ Biofilm Inoculator. Place the peg lid onto the microtitre base. Ensure that the orientation of the plate matches the orientation of the lid (i.e. peg A1 must be inserted into well A1 of the microtiter plate, otherwise the device will not fit together correctly).

**NOTE:** *The volume of inoculum used in this step has been calibrated such that the biofilm covers a surface area that is immersed entirely by the volume of antimicrobials used in the challenge plate set up in Step 4 (below). Using a larger volume of inoculum may lead to biofilm formation higher up on the peg that physically escapes exposure in this challenge step.*

- b. Place the device on a platform shaker set at 110 rpm in a humidified incubator at the appropriate temperature.
- c. Incubate for the appropriate time required to achieve an inoculum density of approximately  $10^4$ - $10^6$  CFU/mL (determined as per Step 5 below). Biofilm growth time will vary between strains, however 16±2 hours is sufficient for many bacterial organisms.

#### 3.2. MBEC™ Biofilm Inoculator with **Trough Base:**

- a. Open a sterile MBEC™ Biofilm Inoculator with a trough base (Product codes: 19121 and 19122). Pour the inoculum into a reagent reservoir. Using a sterile pipette, add 22 mL of the inoculum to the trough base. Place the peg lid onto the base.

**NOTE:** The volume of inoculum used in this step has been calibrated such that the biofilm covers a surface area that is immersed entirely by the volume of antimicrobials used in the challenge plate set up in Step 4 (below). Using a larger volume of inoculum may lead to biofilm formation higher up on the peg that physically escapes exposure in this challenge step.

- b. Place the device on a rocking table set to between 3 and 5 rocks per minute in a humidified incubator at the appropriate temperature.

**NOTE:** It is critical that the angle of the rocking table is set to between 9° and 16° of inclination. This motion must be symmetrical.

- c. Incubate for the appropriate time required to achieve an inoculum density of approximately  $10^4$ - $10^6$  (determined as per Step 5 below). Biofilm growth time will vary between strains, however  $16 \pm 2$  hours is sufficient for many bacterial organisms.

#### 4. PREPARATION OF THE ANTIMICROBIAL CHALLENGE PLATE:

Using a sterile 96-well microtiter plate, the following steps describe how to aseptically prepare the challenge plate. Figure 5 provides a sample plate layout and the steps below describe how to set up a challenge plate with this layout. The steps must be modified appropriately if a different layout is used.

	1	2	3	4	5	6	7	8	9	10	11	12
A	100	100	100	100	100	100	100	100	100	100		
B	50	50	50	50	50	50	50	50	50	50		
C	25	25	25	25	25	25	25	25	25	25	SC	SC
D	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	SC	SC
E	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	SC	SC
F	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	GC	BGC
G	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	GC	BGC
H	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	GC	BGC

**Figure 5.** The above challenge plate layout represents a serial two-fold dilution gradient of a single antimicrobial ( $n=10$ ). This is only one example - the antimicrobial challenge plate may be set up in any manner desired with any combination of antimicrobials at any desired concentration(s). It is important that the final volume in each well of the challenge plate is 200 $\mu$ L. This is to ensure complete submersion of the biofilm in the antimicrobial. SC = Sterility Control, GC = Growth Control, BGC = Biofilm Growth Check.

- a. Prepare sufficient biocide stock solution of disinfectant for the experiment.
- b. Add 200  $\mu\text{L}$  of sterile OSM to the GC, BGC, and three of the SC marked wells in columns 11 and 12 of the challenge plate (see Figure 5). Add 200  $\mu\text{L}$  of the biocide working solution (the highest concentration of the biocide required for testing) to the remaining three SC wells. These wells will serve as the sterility controls, growth controls, and biofilm growth checks.
- c. Add 100  $\mu\text{L}$  of the appropriate diluent for the biocide to each well in columns 1-10 of rows B-H.
- d. Add 200  $\mu\text{L}$  of the biocide working solution (the highest concentration of biocide required for testing) to each well in columns 1 to 10 of row A of the microtitre plate.
- e. Add 100  $\mu\text{L}$  of the biocide working solution to each well in column 1-10 of rows B and C.
- f. Using a multichannel micropipette, mix the contents of columns 1 to 10 of row C by pipetting up and down. After mixing, transfer 100  $\mu\text{L}$  from the wells in row C to the corresponding wells in row D. Discard pipette tips after each transfer.
- g. Mix the contents of columns 1-10 of row D and transfer 100  $\mu\text{L}$  from each well to the corresponding wells in row E. Repeat this mix-and-transfer process down the length of the microtitre plate until reaching row H.  
**NOTE:** *Perform this for challenge columns (e.g. columns 1 to 10 in Figure 5) only.*
- h. Using a multichannel pipette, remove 100  $\mu\text{L}$  from each well in columns 1-10 of row H and discard the liquid appropriately.
- i. Add 100  $\mu\text{L}$  of diluent to each well in columns 1-10 of rows C-H so that each well of the challenge plate contains 200  $\mu\text{L}$ .
- j. Aseptically cover the freshly prepared challenge plate and let it stand at room temperature for 30 minutes to equilibrate prior to use.  
**NOTE:** *The challenge plate should be prepared fresh on the day of the challenge.*

## 5. **BIOFILM GROWTH CHECK**

- a. Prepare one rinse plate by filling each well of a new sterile 96-well plate with 200  $\mu\text{L}$  of sterile saline.
- b. After removing the MBEC™ Biofilm Inoculator from the incubator following biofilm formation, rinse dispersed cells from the biofilms

that have formed on the pegs of the MBEC™ device by placing the lid into the rinse plate for approximately 10 seconds.

- c. Following the rinse step and prior to the antimicrobial challenge, break off the biofilm growth check (BGC) pegs (F12, G12, and H12 in Figure 5) with sterilized (flamed) pliers.
- d. Place each peg into 200  $\mu\text{L}$  of neutralizer recovery media in row A of a new sterile 96-well microtiter plate.
- e. Transfer the plate to the sonicator and sonicate on high for 30 minutes to dislodge the biofilm.

**NOTE:** *Place the plate in a dry stainless steel insert tray which sits on the water in the sonicator. The vibrations created in the water by the sonicator transfer through the insert tray to actively sonicate the contents of the 96-well recovery plate.*

- f. Following sonication, place 180  $\mu\text{L}$  of sterile saline or buffered water into each well of rows B-H, directly below the BGC pegs in row A of the recovery plate.
- g. Prepare a serial dilution and spot plate per Step 2bi-iii.
- h. Incubate the plates for the appropriate time and temperature, and count colonies to determine the biofilm density on the pegs (Biofilm Growth Check).

## 6. ANTIMICROBIAL CHALLENGE AND RECOVERY OF THE BIOFILM

- a. Following the rinse step and after breaking off the BGC pegs (Steps 5a-5f), transfer the MBEC™ lid with biofilm growth to the challenge plate prepared in Step 4 and incubate at the appropriate temperature for the desired contact time.
- b. Prepare the neutralizer/recovery plate by placing 200  $\mu\text{L}$  of the appropriate neutralizer recovery solution in each well (including GC and SC wells) of a new, sterile 96-well microtiter plate.
- c. After the challenge, transfer the MBEC™ lid to the neutralizer/recovery plate and let stand for 30 minutes to equilibrate prior to the next step. Retain the challenge plate as it will be used in Step 7.
- d. After the equilibration time, transfer the neutralizer/recovery plate to the sonicator and sonicate on high for 30 minutes to dislodge the biofilm. The plate is placed in a dry stainless steel insert tray which sits in the water of the sonicator.

## 7. DETERMINATION OF MINIMUM BIOCIDAL CONCENTRATION (MBC)

- a. Fill every well of a fresh, sterile 96-well microtiter plate with 180  $\mu\text{L}$  of organism specific broth (OSB).
- b. After the MBEC™ peg lid has been removed from the challenge plate (Step 6c), remove 20  $\mu\text{L}$  from each well of the challenge plate and add it to the corresponding wells of the plate prepared in Step 7a.
- c. Cover the plate with a sterile non-pegged lid and incubate it under appropriate growth conditions. Retain the challenge plate as it will be used in Step 8.
- d. Following sufficient growth time (growth control wells should have visible growth), determine the MBC (Minimum Biocidal Concentration) for the antimicrobial for the organism(s) tested. Sterility wells should be clear - if SC wells contain growth, results are inconclusive and testing should be repeated, ensuring aseptic technique is carefully followed.
- e. To determine the MBC values, visually check for turbidity in the wells of the MBC plate. Alternatively, use an automated plate reader to obtain optical density measurements at 650 nm ( $\text{OD}_{650}$ ). The MBC value represents the lowest concentration of antimicrobial which kills 99.9% of the population of the dispersed cells that have been shed from the biofilm. Clear wells are evidence of effective biocidal concentration following the chosen contact time.

## 8. DETERMINATION OF MINIMUM INHIBITORY CONCENTRATION (MIC)

- a. Following Step 6c, place a fresh sterile non-pegged 96-well microtiter plate lid or a plate sticker on the challenge plate and incubate it under appropriate growth conditions.
- b. Following sufficient growth time (growth control wells should have visible growth) determine the MIC (Minimum Inhibitory Concentration) values for the antimicrobial for the organism(s) tested. Sterility wells should be clear - if SC wells contain growth, results are inconclusive and testing should be repeated, ensuring aseptic technique is carefully followed.

**NOTE:** *Due to the optical density/opacity potential of some antimicrobial agents, determination of MIC may not be possible.*

- c. To determine the MIC values, visually check for turbidity in the wells of the challenge plate. Alternatively, use an automated plate reader to obtain optical density measurements at 650 nm ( $\text{OD}_{650}$ ). The MIC is defined as the minimum concentration of antimicrobial that inhibits

growth of the dispersed cells from the biofilm. Clear wells are evidence of inhibition following the chosen contact time.

## 9. DETERMINATION OF LOG<sub>10</sub> REDUCTION

- a. Following sonication of the neutralizer/recovery plate (Step 6d), place 100 µL from each well of row A into the 12 empty wells of row A of a fresh 96-well microtiter plate. Place 100 µL from each well of row B (of the challenge plate) into the 12 empty wells of row A of a second fresh 96-well microtiter plate. Continue doing this until the samples in all 8 rows of the challenge plate are transferred into row A of eight fresh 96-well microtiter plates. Place 180 µL of sterile saline or buffered water in the remaining rows (B-H) for all eight 96-well serial dilution plates.
- b. Prepare a serial dilution and spot plate all eight plates per Step 2bi-iii.
- c. Incubate the plates for an appropriate time and temperature and count colonies to determine the quantity of viable microorganisms remaining on the pegs following the challenge.
  - i. Count the appropriate number of colonies on the spot plates according to the plating method used. Count colonies from a spot where the individual colonies are visibly distinct from each other within the plated spot, and preferably more than one colony is present. The section in which this spot is located gives the order of magnitude for the cell enumeration, i.e. which dilution from 10<sup>0</sup>-10<sup>7</sup>.
- d. Calculate the log density for one peg as follows:

$$\text{Log}_{10} \left( \frac{\text{CFU}}{\text{peg}} \right) = \text{Log}_{10} \left[ \left( \frac{X}{B} \right) (D)+1 \right]$$

Where:

X = CFU counted on spot plate

B = volume plated (Ex. 0.02 mL)

D = Dilution (Ex. 10<sup>4</sup>)

- e. The log density per mm<sup>2</sup> may also be calculated as follows:

$$\text{Log}_{10} \left( \frac{\text{CFU}}{\text{mm}^2} \right) = \text{Log}_{10} \left[ \left( \frac{X}{B} \right) \left( \frac{V}{A} \right) (D)+1 \right]$$

Where:

X = CFU counted on spot plate

B = volume plated (Ex. 0.02 mL)

V = well volume (0.20 mL)

A = peg surface area (46.63 mm<sup>2</sup>)

D = Dilution (Ex. 10<sup>4</sup>)

- f. Calculate the overall biofilm accumulation by calculating the mean of the log densities for the chosen number of replicates.
- g. Calculate the Log<sub>10</sub> Reduction for each dilution as follows:

$$\text{Log}_{10}\text{Reduction} = \frac{\text{Mean Log}_{10} \text{ Untreated Control Pegs}}{\text{Mean Log}_{10} \text{ Treated Pegs}}$$

## **10. DETERMINATION OF MINIMUM BIOFILM ERADICATION CONCENTRATION (MBEC)**

- a. Discard the MBEC™ lid appropriately.  
**NOTE:** *The lid should be treated as a biohazard at this point.*
- b. Add 100 µL of sterile OSB into each well of the neutralizer/recovery plate (to replace the volume removed for spot plating in Step 9a). Cover the plate with a fresh non-pegged lid or a sterile plate sticker. Incubate the refilled plate at the appropriate conditions.
- c. Following sufficient growth time (growth control wells should have visible growth) determine the MBEC (Minimum Biofilm Eradication Concentration) values for the antimicrobial for the organism(s) tested.
- d. To determine the MBEC values, visually check for turbidity in the wells of the neutralizer/recovery plate. Alternatively, use an automated plate reader to obtain optical density measurements at 650 nm (OD<sub>650</sub>). The MBEC is defined as the minimum concentration of antimicrobial that eradicates the biofilm. Clear wells are evidence of eradication following the chosen contact time.

### **MICROSCOPY**

The following protocols may be used to prepare biofilms for scanning electron microscopy (SEM) and confocal laser scanning microscopy (CLSM). You may include pegs for microscopy into your MBEC™ assay according to your desired plate layout. If using a challenge plate with the same or a similar layout to that in Figure 5, pegs in columns 12 of rows A and B may be used for microscopy.

**NOTE:** *It is easiest to remove pegs for microscopy from the outer pegs on the lid; i.e. rows A or H and columns 1 or 12.*

The following procedures may be performed immediately following biofilm formation and rinsing (prior to Step 5c above) or may be performed following the antimicrobial challenge, but prior to recovery (i.e. prior to neutralization and sonication - immediately following Step 6b above).

## **1. SCANNING ELECTRON MICROSCOPY (SEM)**

- a. Break the appropriate pegs from the MBEC™ Biofilm Inoculator lid with sterilized (flamed) needle nose pliers.

**NOTE:** *With the pliers, grasp the base of the peg to prevent disruption of the biofilm.*

- b. Place each peg into an empty receiver vial. In a fume hood, add primary fixative (5% glutaraldehyde in 0.1M Na cacodylate buffer, pH=7.5) to each vial to completely cover the peg. Cap the vials and incubate at 4±2°C for 16-24 hours.
- c. Decant the fixative with a disposable pipette and discard all liquid waste in an appropriate organic waste container.
- d. Loosely cap the samples and place them in a fume hood to air dry for 72-96 hours.
- e. Mount the samples on aluminum stubs by applying epoxy resin to the flat, upper surface of each stub. Using forceps, carefully affix the pegs to the stubs, ensuring that they are appropriately labelled.
- f. Follow an appropriate procedure for use of the SEM.

**NOTE:** Example SEM images are shown in Figure 6.

## **2. CONFOCAL LASER SCANNING MICROSCOPY (CLSM)**

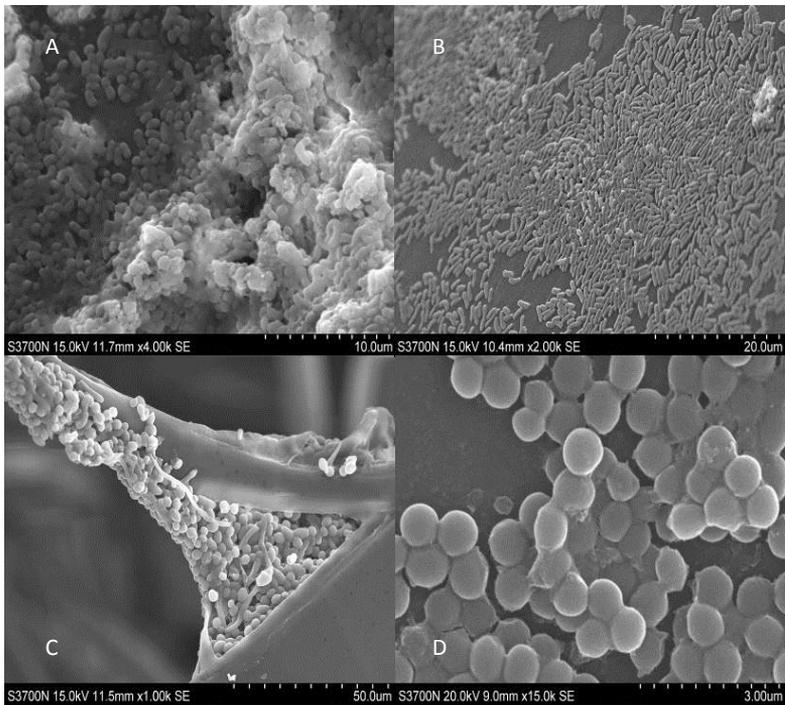
- a. Break the appropriate pegs from the MBEC™ Biofilm Inoculator lid with sterilized (flamed) needle nose pliers.

**NOTE:** *With the pliers, grasp the base of the peg to prevent disruption of the biofilm.*

- b. Place each peg into an empty receiver vial and stain with a LIVE/DEAD Viability Kit containing 3.35 µM SYTO-9 and 20 µM propidium iodide (Recommended kit: Invitrogen, Cat.# L10316).
- c. Follow the staining instructions for the stain of your choice.
- d. Wash the fluorescently stained pegs twice with 0.9% saline.
- e. The viability of biofilm cells should then be examined immediately using a CLSM. To minimize artefacts associated with simultaneous dual wavelength excitation, all samples should be sequentially

scanned, frame-by-frame, first at 488 nm and then at 561 nm. A ×63 oil objective lens is recommended.

- f. If using an inverted CLSM, the pegs may be placed in a glass bottomed petri dish to obtain images (Recommended manufacturer: Mat Tek Corp, 50 mm glass bottom dish, part # P50G-1.5 14F).



**Figure 6.** Bacterial biofilms formed on the pegs of the MBEC™ Biofilm Inoculator. Biofilms were grown in rich medium for 24 to 48h, then fixed and dehydrated. Images were captured by scanning electron microscopy (SEM). Organisms imaged are A) *Aggregatibacter actinomycetemcomitans*, B) *Candida albicans*, C) *Klebsiella pneumoniae*, and D) *Staphylococcus aureus*.

### SURFACE COATING THE MBEC™ ASSAY

The surface of the MBEC™ Biofilm Inoculator lid may be coated with a number of materials to facilitate the growth of fastidious microorganisms. For example, biofilm formation by certain *Candida* spp. is enhanced by coating the pegs with hydroxyapatite. Hydroxyapatite coated plates are available for purchase through

Innovotech (Product code: 19131 for a case of 25 with 96-well bases, 19132 for a case of 100 with 96-well bases, 19141 for a case of 25 with trough bases, and 19142 for a case of 100 with trough bases) and may be used following the same procedures as above. The MBEC™ lid may also be coated with poly-L lysine, cellulose, collagen, etc. For additional protocols, or to purchase specialized plates, please contact Innovotech.

### **COMPANY INFORMATION**

Innovotech Inc. was first formed in 2001 as a research and product development company, and has world recognized expertise in bacterial biofilms. The assay methods and protocols presented in this document are protected by patents. The company also holds patents on the analysis of surface coatings using the Biofilm Eradication Surface Test, or BEST™ Test. This assay has been used extensively in the development of surface coatings for catheters and other implanted devices.

### **WARRANTY**

Products purchased from Innovotech Inc. are warrantied to meet stated product specifications and to conform to label descriptions when used and stored properly. Unless otherwise stated, this warranty is limited to one year from the date of sale for products used, handled, and stored according to Innovotech Inc. instructions. Liability of Innovotech Inc. is limited to replacement of the product or refund of the purchase price. If you are not satisfied with the performance of a product purchased from Innovotech Inc., please contact us.

### **CONTACT INFORMATION**

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