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CHEMICAL PROCESSING

Off-Shore Oil Major Extends Service Life of Seawater Intake Piping with Antimicrobial Corrosion-Resistant Rotational Lining

MIC-GUARD, a customized antimicrobial agent developed and manufactured by BTG Products, Canyon, TX, was incorporated into intake pipeline sections that were rotationally lined with monolithic HDPE by a leading rotational lining company.

Two types of corrosion cause the majority of problems in offshore or seawater applications; aqueous corrosion and microbiologically influenced corrosion (MIC). Aqueous corrosion stems from the alkalinity of the seawater itself where MIC degradation stems from microorganisms in the seawater that cause corrosion and stress cracking in materials. Rotational lining solutions can apply a thick, fully bonded, vacuum resistant, monolithic liner of high-density polyethylene (HDPE) to the inner diameter of piping systems. This coating system has been proven to provide long-term protection against aqueous corrosion in salt-water applications. To combat MIC, a recently developed combination of antimicrobial powder and high-density polyethylene powder was applied through rotational lining. Experiments were conducted to evaluate the biological and mechanical performance of material coatings. Results from microbiological testing showed that coatings enhanced with the material resisted and deactivated over 99% of bacteria. Additional results from mechanical testing show that the additive has no significant negative impact on the corrosion or abrasion resistance of the HDPE lining or on the adhesion of the lining to the substrate. These results are significant because the additive material eliminates the primary source of MIC while maintaining the mechanical and thermal properties of the existing HDPE coating system.

Challenge

Pipe failure is a main component of the operating and maintenance costs of gas industry pipelines. Oil and gas companies have limited options to prevent internal pipe corrosion.

At a Glance

Client: Oil Major

Industry: Chemical Processing—Oil & Gas

Manufacturing Solution: Rotational lining with custom-compounded antimicrobial polymer matrix

PROJECT GOALS

- Limit biofouling buildup during off-peak
- Decrease production turnaround time
- Maintain or improve component performance/life production
- Find an alternative to super duplex 2507 stainless steel components
- Meet or beat budget cost targets

REQUIREMENTS

- Provide exceptional resistance to seawater corrosion
- Address high mechanical-property demands
- Provide a turnkey solution
- Ensure uniform wall thickness in lining complex shapes
- Custom-compound polymer (HDPE) with antimicrobial additive

HIGHLIGHTS

- **Delivered product in less than 4 months vs. 50 weeks for super duplex stainless steel**
- **Tested and validated all materials to ensure design-life requirements met for maintenance-free performance**
- **Saved Customer $5 million in manufacturing costs**
- **On track for improved service life, reducing future maintenance costs and capital expense**

Fresh water intake pipe joint lined with antimicrobial HDPE.

Many producers employ significant resources on materials that are resistant to microbial corrosion (super duplex 2507 stainless), but even these expensive materials are still susceptible to biofilm development. Therefore, many producers are currently flushing piping with various chemicals and biocides to kill off excessive microorganisms.

Replacing these materials and procedures with antimicrobial HDPE linings decrease operating costs and environmental impact without impacting life expectancy. In order to prevent corrosion, pipes and other structures are commonly lined with high-density polyethylene or HDPE that is resistant to aqueous corrosion in salt water or brine. Coatings and linings with this material have been used for many years with great success. Rotational lining solutions can apply a thick, fully bonded, vacuum resistant, monolithic liner of high-density polyethylene (HDPE) to the inner diameter of piping systems. This liner has proven to last over 20 years in brine water services providing long-term corrosion protection to aqueous corrosion in saltwater applications. Defects and microbial degradation of polymer coatings, however, can provide opportunities for localized biological attacks. Additionally, biofouling can gradually build up on top of the lining system and decrease efficiency and capacity of the fluid delivery system.

Solution

The rotational lining partner company and BTG Products spent over 24 months developing a new product to protect fluid delivery systems from microbial and non microbial corrosion. The product development and fabrication phases consisted of:

- Design and engineering

  Custom material formulation and compounding (high-density polyethylene—HDPE—with added antimicrobial agent)
- Testing and validation ·

  Preparation of the host structure
- Rotational lining with complex geometry
- Finishing, painting and delivery for inspection and acceptance

The rotational lining partner provided in-house services throughout all phases of the project and delivered product in about one-third of the time required for stainless steel components.

Results

All aspects of the project ran smoothly and all project requirements were successfully met.

Project turnaround. MIC-GUARD was sourced from BTG Products and mixed into the HDPE powder without any increase in project lead time.

Product performance. Several parts of the project required rounds of testing and validation to meet the customer's stringent design-life specifications for maintenance-free performance.

· The HDPE lining company used standard and proprietary preparation processes to enhance the receiving surface of the host material and better condition it for a successful coating application.

·The HDPE lining company and the customer collaborated to select high-density polyethylene (HDPE) for the lining material. The customer requested the addition of an antimicrobial element, requiring extensive testing of modified batches of material from BTG Products to achieve the design requirements without affecting established mechanical properties.

Cost reduction. BTG Products and their lining partner satisfied the budget requirements. The rotational lining technology saved the customer $5 million on the caisson portion of the offshore project. Relative to the overall project costs approximating $1 billion, the cost-savings contribution was a modest amount. However, meeting or exceeding all other project requirements while generating significant savings was a winning combination for the customer. As the project moves ahead, the use of corrosion-resistant HDPE will increase operational life, reducing maintenance costs and long-term capital expense for the customer.

Customer satisfaction. The project progressed smoothly due to the ongoing successful collaboration of the customer, BTG Products, and the lining company. The customer engineers were highly satisfied with the value provided to the project by the alternative manufacturing materials and technologies. Going forward, the customer has an additional arsenal of manufacturing options—with demonstrated advantages—that it can consider for future projects.

About BTG Products

BTG Products is a developer and manufacturer of safe, effective antimicrobial solutions to support the oil and gas, aviation, healthcare, and consumer markets. We specialize in producing customized antibacterial and mold inhibiting coatings and additives that decrease capital expenditures, increase lifespan, and reduce maintenance costs. We offer turnkey and customized solutions to help customers in their fight against microbial corrosion, biofouling, and fungal defacement.

To learn more about how our innovative solutions help you add product features while lowering costs, visit our websites at btgproducts.com and rmbproducts.com.

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Product Validation

MIC-GUARD Concentration Effectiveness

Project Details

Test Facility:	West Texas A&M University Microbiological Laboratory 2401 Russell Long Blvd. Canyon, TX 79015 (806) 651-0000
Testing Performed By:	C. Bouma
Study Complete:	May 21st, 2018
Test Method:	ASTM F895 Standard Test Method for Agar Diffusion Cell Culture Screening for Cytotoxicity

General Information:

This test method is useful for assessing the cytotoxic potential of new materials and formulations and as part of a quality control program for established medical devices and components. WTAMU's Biology Department utilized this testing method to give qualitative results of the potency of antimicrobial powders. Antimicrobial and control powders are poured into several wells that have been punched into the inoculated agar. The testing wells can be compared to one another based on the zone of inhibition of cell or spore growth each has created.

Background:

Escherichia coli: *Facultative anaerobic proteobacteria* found in the environment, foods, and intestines of people and animals. These organisms are a large and diverse group of bacteria and the most prevalent infecting organism in the family of gram-negative bacteria known as enterobacteriaceae.

Sample Procedure:

- MG and a blend of proprietary ingredients were mixed together at varying percentages to compare the efficacy 12 MG blends were created

MIC-GUARD Blends

1: 11% MG	**5:** 33% MG	**9:** 66% MG
2: 17% MG	**6:** 35% MG	**10:** 77% MG
3: 22% MG	**7:** 44% MG	**11:** 88% MG
4: 29% MG	**8:** 55% MG	**12:** 100% MG

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Product Validation

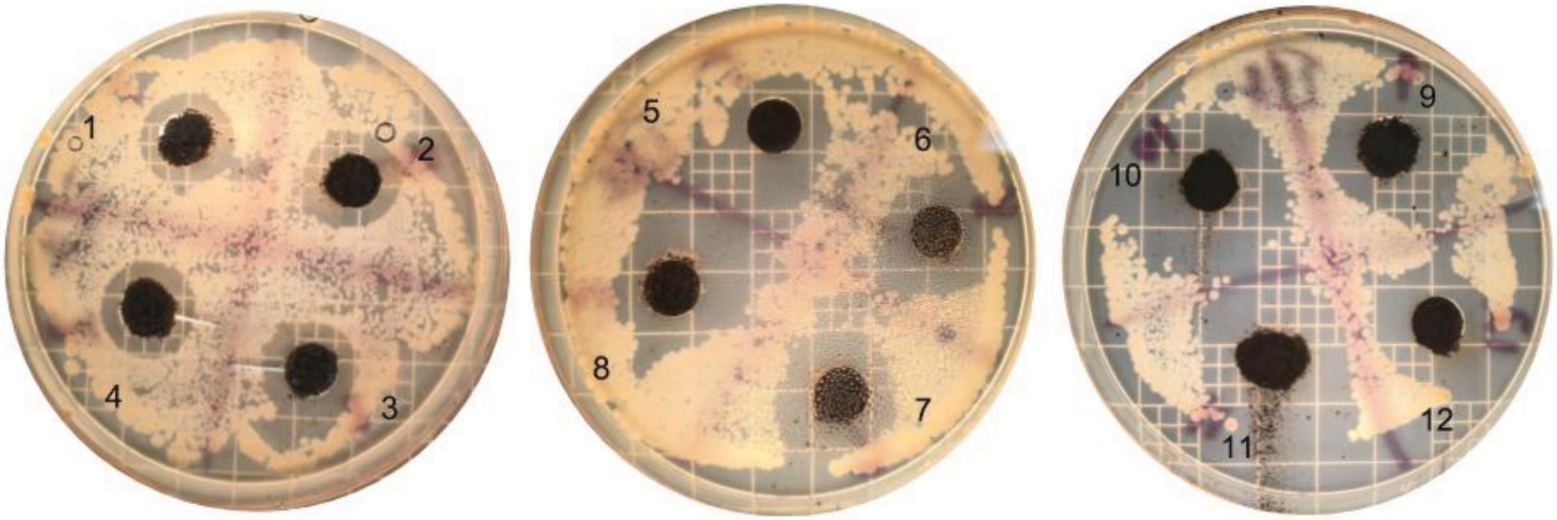
MIC-GUARD Concentration Effectiveness

Microbiological Procedure:

- *E. Coli* cells were spread evenly about the entire surface of the agar
- Wells were created in the agar using the base of a sterile pipet tip
- Each well was punched from the surface of the agar to the bottom of the petri dish
- Each MG Blend was poured into its own well. The wells were filled when the powder became even with the surface of the agar.
- The petri dishes were place in an incubator at 78 degrees Fahrenheit for three days
- The zones of inhibition each well had around itself were then compared.

Results:

As the concentration of MIC-Guard increased the zones of inhibition were improved. Higher percentages of MIC-GUARD should be used in harsh environments with copious levels of bacteria. With lower percentages of MIC-Guard there are still zones of no growth making these ones suitable for more realistic bacteria environments.



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Product Validation

Resistance of MIC-GUARD Against *Staph. aureus*

Project Details

Test Facility:	West Texas A&M University Microbiological Laboratory 2401 Russell Long Blvd. Canyon, TX 79015 (806) 651-0000
Testing Performed By:	B. Scheve
Study Complete:	Sept 13th, 2016
Test Method:	ASTM E2149 Standard Test Method for Determining the Antimicrobial Activity of Antimicrobial Agents Under Dynamic Contact Conditions

General Information:

This test method is designed to evaluate the antimicrobial activity of antimicrobial-treated specimens under dynamic contact conditions with a fluid. This dynamic shake flask test was developed for routine quality control and screening tests in order to overcome difficulties in using classical antimicrobial test methods to evaluate substrate-bound antimicrobials. These difficulties include ensuring contact of inoculum to treated surface (as in AATCC 100), flexibility of retrieval at different contact times, use of inappropriately applied static conditions (as in AATCC 147), sensitivity, and reproducibility.

Background:

Staphylococcus aureus: Gram-positive facultative aerobic spherical bacteria that produces a very heat stable toxin. Colonies of *S. aureus* appear in pairs, chains, or clusters. The organisms is prevalent in many regions of the world and is a universal health concern, specifically in the food handling and healthcare industries. The organism is responsible for a large number of nosocomial infections each year. *S. aureus* is also a well recognized for its ability to develop biofilm, a multilayered structure comprising of bacterial communities embedded within the extracellular hydrated polymeric matrix.

Substrate Procedure:

- MIC-GUARD was blended with dry HDPE powder at 0.2, 1, and 3 % weight
- Three MG-HDPE plaques and one control HDPE plaque were rotationally lined using standard processing
- A 2x2 in. square was removed from the middle of each plaque and labeled for testing

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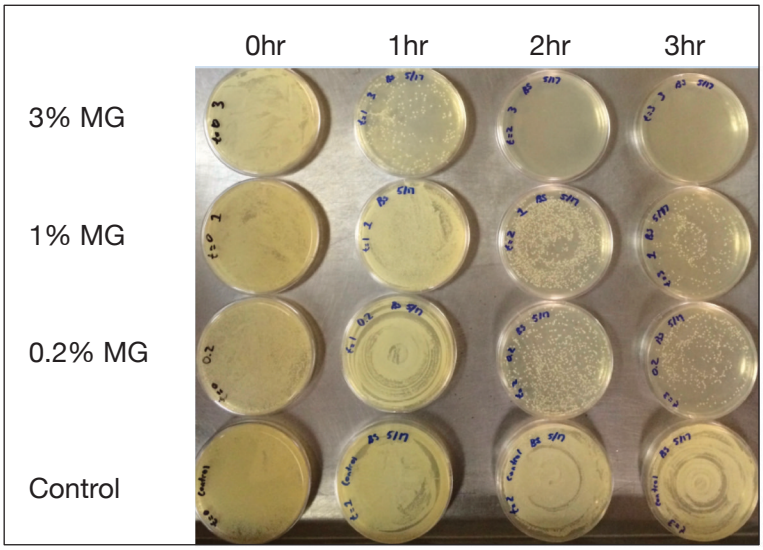
Product Validation

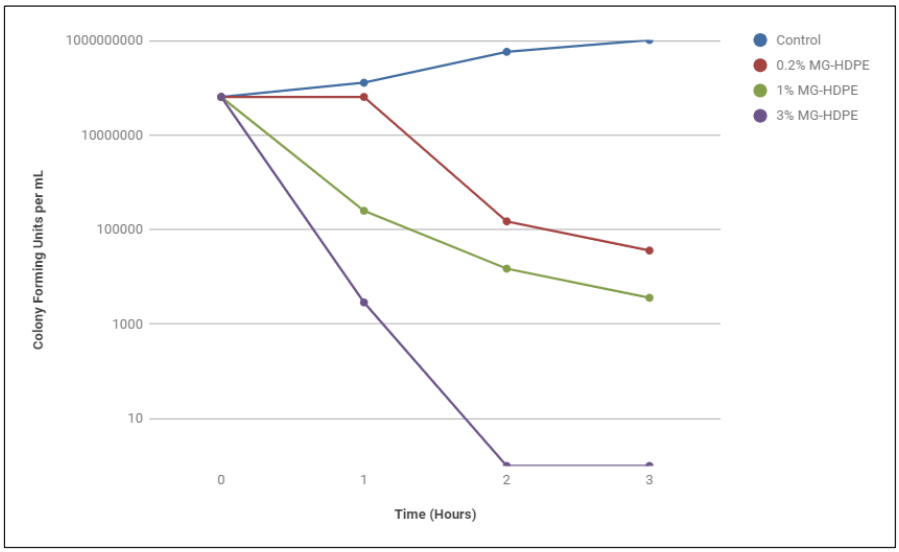
Resistance of MIC-GUARD Against *Staph. aureus*

Microbiological Procedure:

- 500 mL flasks were sterilized with 100 mL dH2O. Next, 1 mL *S. aureus* (1000 VC/mL in 20% glycerol) was added to each flask
- Samples (3 x 0.1 mL) were taken immediately from each flask and spread on TSA plates
- The flasks were incubated in a 37°C shaking incubator at 200rpm. Samples (3 x 0.1mL) were removed and plated at 1-hr intervals.
- Plates were left for growth at 25°C for 60 hr. Colonies were counted and the average VC/mL was calculated

Results:





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Antifouling Efficacy

Marine Testing of HDPE Enhanced with MIC-GUARD

Project Details

Test Facility:	Sacred Heart Marine Research Centre - Poseidon Beach Road, Tuticorin Bay, India 628001 Tel: 91 944 332 3491
Testing Performed By:	Sr. Avelin Mary, Ph.D, Director SHMRC - Poseidon
Samples Immersed:	Dec 04, 2018
Test Method:	Static Immersion in Shallow Seawater Conditions with High Microbiological Activity

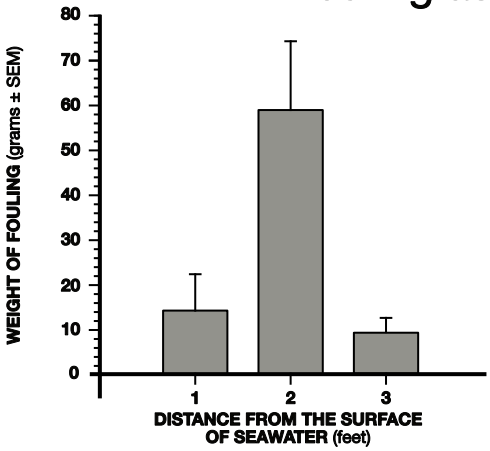
General Information:

This test method is designed to evaluate ability of coatings and materials to resist biological fouling in static, immersed seawater conditions. The testing is performed in a stable tropical environment with continuous barnacle fouling conditions. The seawater temperature remains above 20°C all year and reach as high as 35°C. The samples are held in continuous immersion at a depth below 2 feet. The water salinity remains oceanic, except during short monsoon season, when it drops precipitously. However, barnacle fouling remains unaffected by the brief decline in salinity. As described by researchers at SHMRC, fouling in these conditions is very aggressive. An unprotected surface becomes covered by juvenile barnacles within 2 weeks. A low copper coating, will foul within a month and show massive fouling from barnacles, algae and sponges as the immersion continues.

Background:

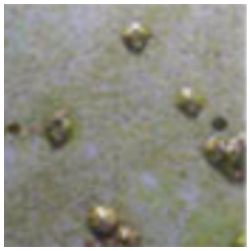
The primary fouling organism at this location is the barnacle *Balanus amphitrite*. This is also the most common fouling organism found in most parts around the world and likely distributed worldwide by seagoing vessels for many centuries. Additional biofoulers at the location include bryozoans (such as *Bugula neritina*), hydroids (such as *Hydroides elegans*), sea anemones, corals, and sponges. Seasonal changes at the location create variation in the amount of the various foulers that accumulate of the course of the year. Maximum composite fouling by weight occurs December through March. The samples were immersed at a depth of 2 feet to capture maximum fouling potential as shown below (credit: Poseidon).

Fouling as a Function of Depth at SHMRC



IMMERSION AT 3 FT

IMMERSION AT 2 FT



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Antifouling Efficacy

Marine Testing of HDPE Enhanced with MIC-GUARD

Sample Procedure:

The testing sample contain BTG Products antimicrobial agent (MIC-GUARD) bound within a rotationally molded HDPE substrate. All samples contain 900 grams of black HDPE dry powder rotationally molded within a 14x7x1.5 inch aluminum mold. The various blends of MIC-GUARD were added to each mold in addition to the 900 grams of HDPE. The mold was placed on a rotational molding system and then in an oven at 350 degrees Fahrenheit for 8 hours. The samples were removed and allowed to cool for one hour.

The samples were removed and prepped per Poseidon's instructions. Each molded rectangular prism sample was cut to 12 inches in length, 6 inches in width, and approximately 0.25 inches thick. Holes were drilled in top corners. Each sample was labeled in the bottom right corner with the labeled side being side A (this is the outside of the molded part. The backside of each sample, which has no labeling, is side B.

The samples contain the following:
Control: 100% HDPE; A1: 90% HDPE + 10% MIC-GUARD (MGA blend); A2: 88% HDPE + 12% MIC-GUARD (MGB blend); A3: 99.8% HDPE + 0.2% MIC-GUARD (MGC blend); A4: 90% HDPE + 12% MIC-GUARD (MGD blend); A6: 90% HDPE + 10% Commercial Antimicrobial

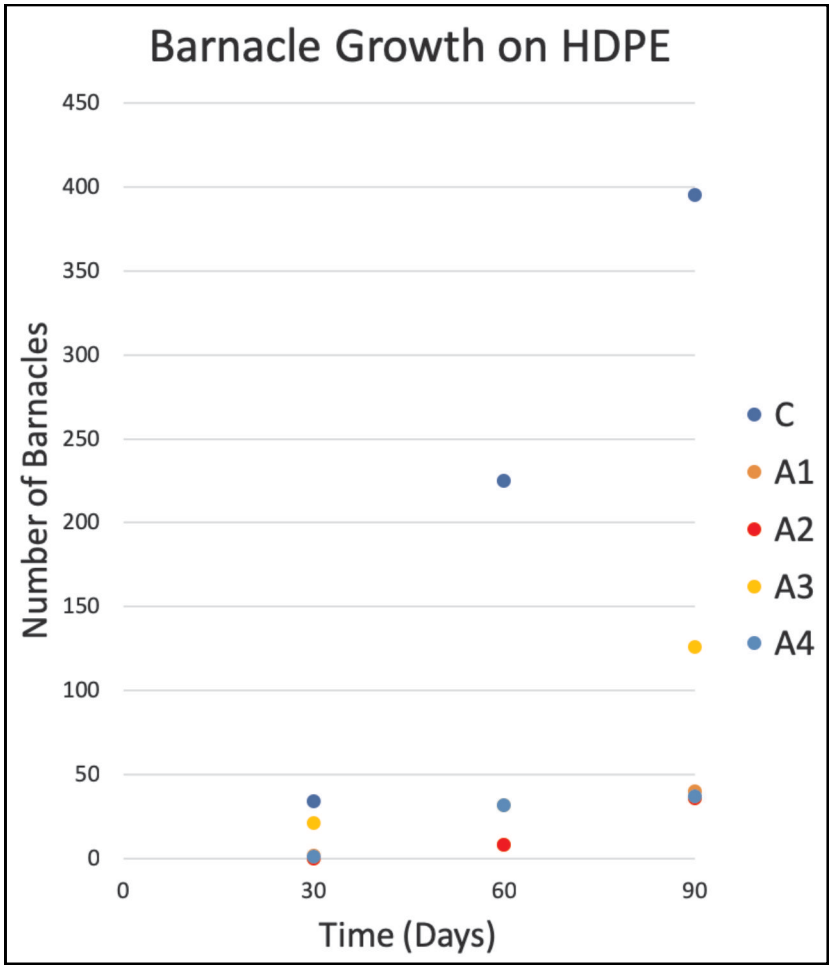
Quantitative Results:

Number of Barnacles

Panel ID	30 Days	60 Days	90 Days
C	34	225	395
A1	2	8	40
A2	0	8	36
A3	21	32	126
A4	1	32	37

Maximum Diameter of Barnacles

Panel ID	30 Days	60 Days	90 Days
C	8	10	12
A1	4	7	8
A2	0	2	6
A3	5	11	11
A4	4	6	6



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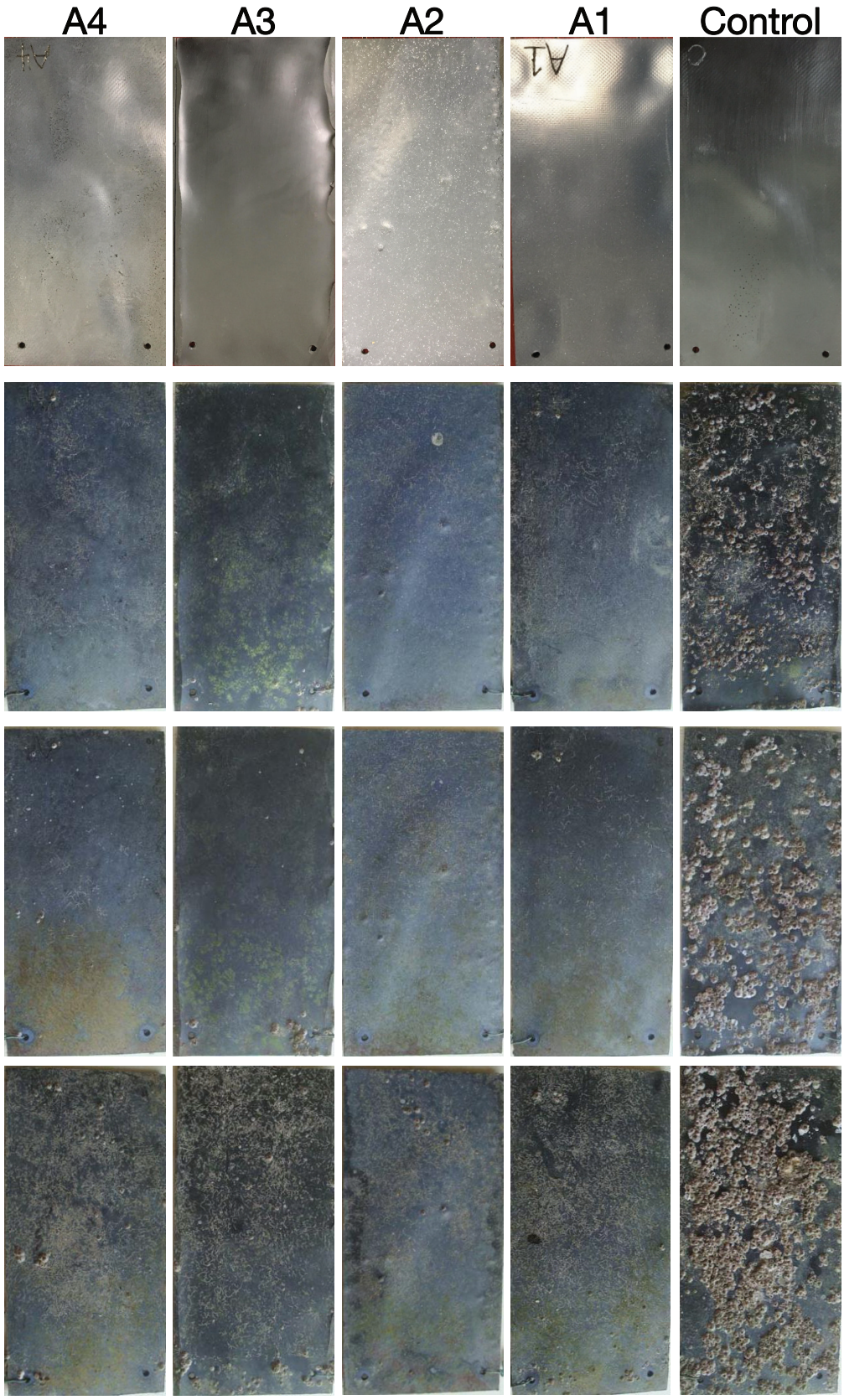
Antifouling Efficacy

Marine Testing of HDPE Enhanced with MIC-GUARD

Qualitative Results:



Antifouling Efficacy

Marine Testing of HDPE Enhanced with MIC-GUARD

Qualitative Results Continued:

90 Days

Control

A2

A4

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Antimicrobial Efficacy

Molded Fiberglass Enhanced with MIC-GUARD

Project Details

Test Facility:	West Texas A&M University Microbiological Laboratory 2401 Russell Long Blvd. Canyon, TX 79015 (806) 651-0000
Testing Performed By:	C. Bouma
Study Complete:	Jan 11, 2019
Test Method:	ASTM E2149 Standard Test Method for Determining the Antimicrobial Activity of Antimicrobial Agents Under Dynamic Contact Conditions

General Information:

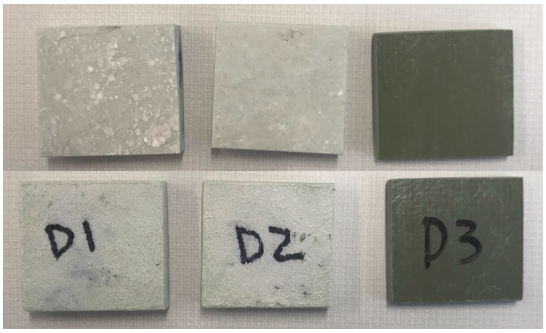
This test method is designed to evaluate the antimicrobial activity of antimicrobial-treated specimens under dynamic contact conditions with a fluid. This dynamic shake flask test was developed for routine quality control and screening tests in order to overcome difficulties in using classical antimicrobial test methods to evaluate substrate-bound antimicrobials. These difficulties include ensuring contact of inoculum to treated surface (as in AATCC 100), flexibility of retrieval at different contact times, use of inappropriately applied static conditions (as in AATCC 147), sensitivity, and reproducibility.

Background:

Escherichia coli: *Facultative anaerobic proteobacteria* found in the environment, foods, and intestines of people and animals. These organisms are a large and diverse group of bacteria and the most prevalent infecting organism in the family of gram-negative bacteria known as enterobacteriaceae.

Sample Procedure:

The testing sample contain BTG Products antimicrobial agent (MIC-GUARD) bound within a moulded fiberglass reinforced vinyl ester substrate (AIMS Composites, Houston, TX, USA). The test samples were prepared by mixing MIC-GUARD into the liquid resin before pouring over the fiberglass mat. The additive was blended at 10% wt with the resin then the mixture was poured into the mold. The control fiberglass plate was purchased from McMaster-Carr, USA. All substrates were manufactured with 0.25 in thickness. All samples were cut into 1.25 x 1.25 x 0.25 inch pieces and labeled according to composition. D1 and D2 are fiberglass molded substrates that contain MIC-GUARD and D3 is molded fiberglass not containing any MIC-GUARD



Fiberglass molded samples D1, D2, and D3

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Antimicrobial Efficacy

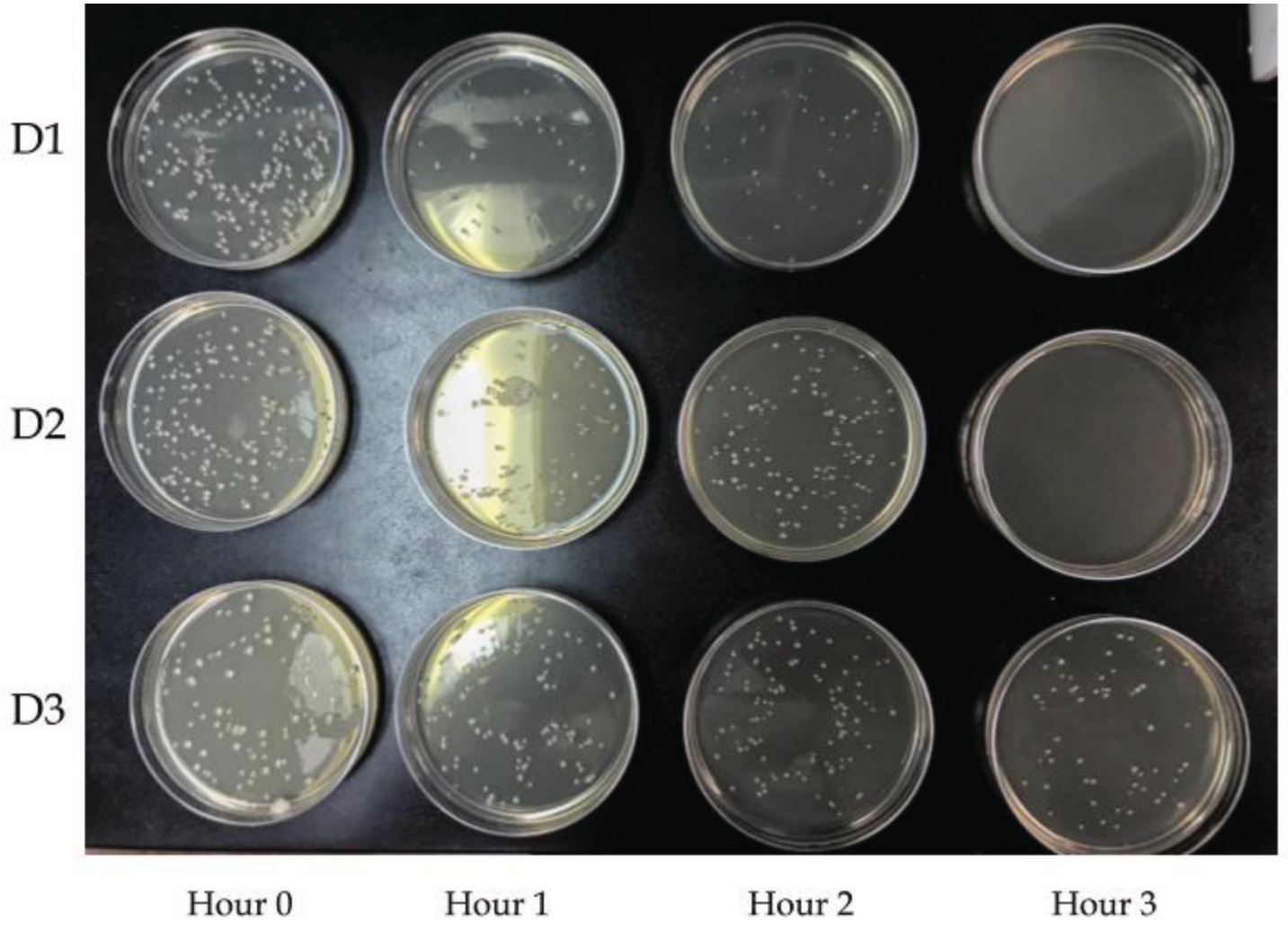
Molded Fiberglass Enhanced with MIC-GUARD

Microbiological Procedure:

- *100 ml sterile dH2O was inoculated with E. coli to approximately 1 x 10^6 cells/mL.*
- *Aliquots were removed (0.25 mL), diluted in a 10-fold series in 20% glycerol (101 to 103), and plated w/EddyJet 2 (0.1 mL linear) on TSA.*
- *Plates were incubated overnight at 37°C and colonies were counted with Sphere Flash.*

Results:

Plated samples of the aliquots revealed a statistically significant trend of decreased viable colonies as treated time progressed in comparison to the control.



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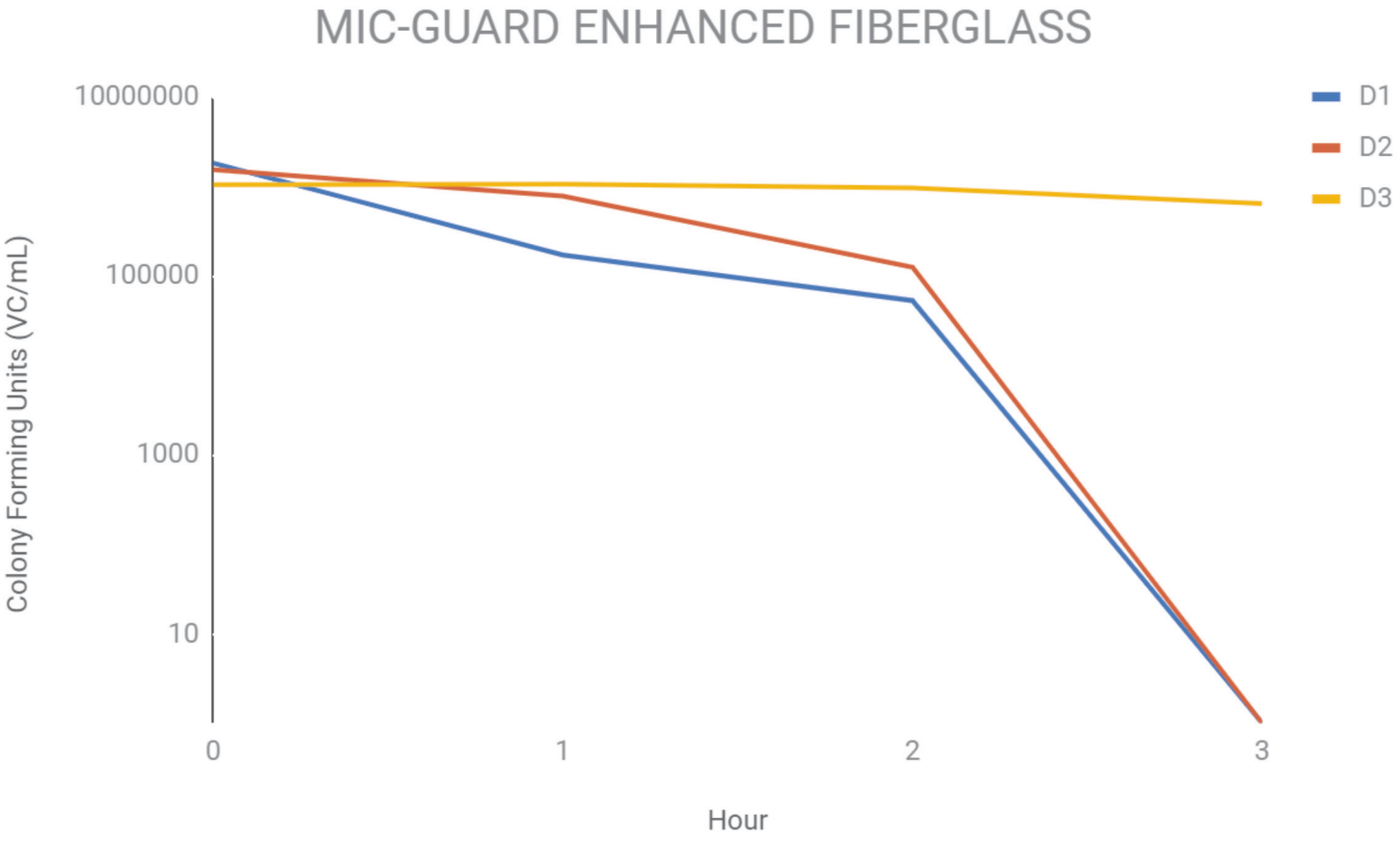
Antimicrobial Efficacy

Molded Fiberglass Enhanced with MIC-GUARD



Discussion:
The testing of MIC-GUARD bound in the fiberglass substrate was successful over all the testing intervals. The plate counts of viable cells demonstrated all three samples beginning with the same colony count of approximately 1 x 10^6 VC/mL of E.Coli. Samples D1 and D2 behaved very similarly, creating decreased viable cell counts throughout the timeframe of the test; achieving complete mitigation of viable E. Coli cells by the third hour. From these results it is evident that MIC-GUARD enhanced fiberglass resists the growth of bacteria in dynamic fluid conditions.

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Antifouling Efficacy

Marine Testing of Fiberglass Enhanced with MIC-GUARD

Project Details

Test Facility: Sacred Heart Marine Research Centre - Poseidon
Beach Road, Tuticorin Bay, India 628001
Tel: 91 944 332 3491

Testing Performed By: Sr. Avelin Mary, Ph.D, Director SHMRC - Poseidon

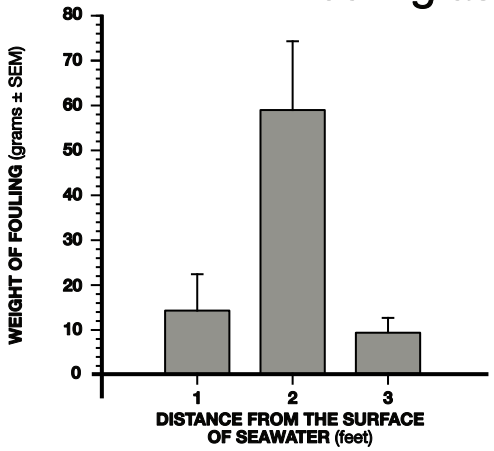
Samples Immersed: Feb 11, 2019

Test Method: Static Immersion in Shallow Seawater Conditions with High Microbiological Activity

General Information:
This test method is designed to evaluate ability of coatings and materials to resist biological fouling in static, immersed seawater conditions. The testing is performed in a stable tropical environment with continuous barnacle fouling conditions. The seawater temperature remains above 20°C all year and reach as high as 35°C. The samples are held in continuous immersion at a depth below 2 feet. The water salinity remains oceanic, except during short monsoon season, when it drops precipitously. However, barnacle fouling remains unaffected by the brief decline in salinity. As described by researchers at SHMRC, fouling in these conditions is very aggressive. An unprotected surface becomes covered by juvenile barnacles within 2 weeks. A low copper coating, will foul within a month and show massive fouling from barnacles, algae and sponges as the immersion continues.

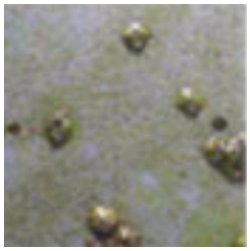
Background:
The primary fouling organism at this location is the barnacle *Balanus amphitrite*. This is also the most common fouling organism found in most parts around the world and likely distributed worldwide by seagoing vessels for many centuries. Additional biofoulers at the location include bryozoans (such as *Bugula neritina*), hydroids (such as *Hydroides elegans*), sea anemones, corals, and sponges. Seasonal changes at the location create variation in the amount of the various foulers that accumulate of the course of the year. Maximum composite fouling by weight occurs December through March. The samples were immersed at a depth of 2 feet to capture maximum fouling potential as shown below (credit: Poseidon).

Fouling as a Function of Depth at SHMRC




IMMERSION AT 3 FT


IMMERSION AT 2 FT


IMMERSION AT 1 FT

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Antifouling Efficacy

Marine Testing of Fiberglass Enhanced with MIC-GUARD

Sample Procedure:

The testing sample contain BTG Products antimicrobial agent (MIC-GUARD) bound within a molded fiberglass reinforced vinyl ester substrate (AIMS Composites, Houston, TX, USA). The test samples were prepared by mixing MIC-GUARD into the liquid resin before pouring over the fiberglass mat. The additive was blended at 10% wt with the resin then the mixture was poured into the mold. The control fiberglass plate was purchased from McMaster-Carr, USA. All substrates were manufactured with 0.25 in thickness and were cut to 12 inches in length, and 6 inches in width per SHMRC specifications.

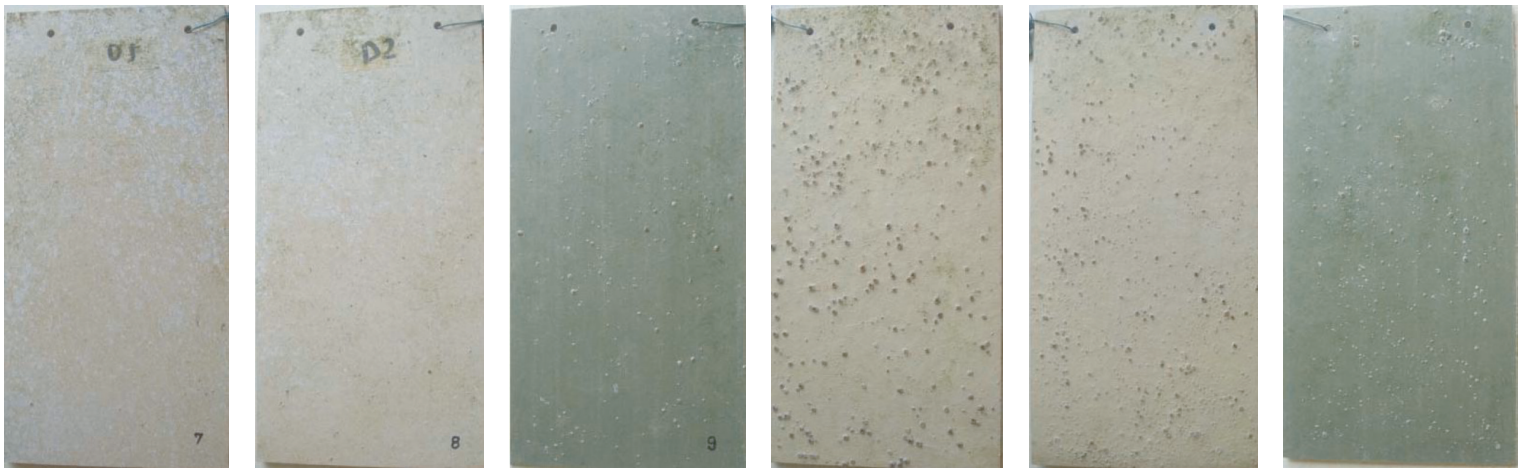
Quantitative Results:

30 Days of Immersion in High Microbiological Activity Shallow Water

Panel ID	Side	No. of barnacles on the surface of the panel	Maximum diameter in mm
D 1	A	0	0
D 2	A	8	2
D 3	A	105	3
D 1	B	265	5
D 2	B	185	4
D 3	B	145	5

Qualitative Results:

D1-A D2-A D3-A D1-B D2-B D3-B



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MIC-GUARD
ENGINEERING DATA SHEET

PRODUCT DESCRIPTION
MIC-GUARD Coating Additive is a powder product that is incorporated into industrial linings, coatings, and molded products to inhibit the growth of mold, mildew, bacteria, and other microorganisms. MIC-GUARD enhanced products create surfaces that neutralize bacteria and inhibit the development of biofilm accumulation. MIC-GUARD utilizes a patented combustion synthesized material to fight microbial growth, even in the most harsh conditions. Mix it into industrial coatings and linings to fight microbiological influenced corrosion, mold and mildew accumulation, and biofouling.

TYPICAL USES
Polyethylene linings, corrosion inhibiting coatings, antifouling applications

ADVANTAGES
- Protects coated surfaces and molded products from microbiological growth
- Compatible with a wide variety of coatings and lining systems
- Combustion synthesis production yields a cermet material capable of neutralizing microorganisms in extreme environments
- Laboratory proven to kill bacteria and other microorganisms
- Rugged, hard particles are capable of increasing abrasion resistance of host coatings
- Adds antimicrobial properties to coatings without negatively impacting original coating properties

SPECIFICATIONS

Boiling Point: Not applicable
Freezing Point: Not applicable
Color/Finish: Light grey speckled
Cure Time: May slightly increase cure time of coating
Recoatability: Does not impact coating
Compatibility: Polyethylene linings, oil based coatings, epoxies and urethanes, water based coatings
Application Temperature: Per coating manufacturer specs

Bulk Loose Density: 500 kg/m³ - 600 kg/m³
Bulk Packed Density: 1012 kg/m³ - 1,100 kg/m³
Color: Light grey
Melting Point: 1975°C
VOC: 0.0 g/liter
Solids by Weight: 100%
Recommended WFT: Per coating manufacturer specs
Shelf Life: Indefinite shelf life

SUBSTRATE PROTECTION CHARACTERISTICS

Fungi

Passes severe ASTM D5590 paint film fungal defacement testing, even when subjected to combined strains of mold and mildew spores.

Aspergillus niger - EFFECTIVE

Penicillium funiculosum - EFFECTIVE

Aureobasidium pullulans - EFFECTIVE

Coating Degrading/Fouling Bacteria

Passes ASTM E2180 standard test for evaluating antimicrobial agents in polymeric materials.

Demonstrated effective against a wide strain of bacteria in laboratory conditions.

Aerobic - EFFECTIVE
Anaerobic - EFFECTIVE
Gram Negative - EFFECTIVE
Gram Positive - EFFECTIVE
Spore Forming - EFFECTIVE
Non-Spore Forming - EFFECTIVE

DIRECTIONS FOR USE

Incorporate MIC-GUARD into coatings, linings, resins, and molded products per project specifications. Ensure that MIC-GUARD is mixed well before blending into host coating or lining. Thoroughly blend product into coating and follow manufacturer guidelines for product application, cleanup, and required personal protective equipment.

SAFETY INFORMATION

Avoid ingestion, contact with skin or eyes. When brushing, rolling or spraying any type of paint or coating, appropriate NIOSH approved respiratory protection is recommended. See Safety Data Sheet for complete safety data before use, available at www.btgproducts.com. It is the applicator's responsibility to understand these safety precautions and the work environment, to protect themselves and/or others.

2200 4th Ave, STE 303 - Canyon, TX 79015 - 806.344.8678 - www.btgproducts.com