

**ENVIRONMENTAL BENIGN MITIGATION OF MICROBIOLOGICALLY  
INFLUENCED CORROSION (MIC)**

FIRST QUARTERLY REPORT  
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## ABSTRACT

**Title:** Environmental Benign Mitigation of Microbiologically Influenced Corrosion (MIC)

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**Contract No:** DE-FC26-01NT41158

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**Report Period:** September 2001 through December 2001

**Objective:** The overall program objective is to develop and evaluate environmental benign agents or products that are effective in the prevention, inhibition, and mitigation of microbially influenced corrosion (MIC) in the internal surfaces of metallic natural gas pipelines. The goal is one or more environmental benign, a.k.a. “green” products that can be applied to maintain the structure and dependability of the natural gas infrastructure.

**Approach:** The technical approach for this quarter has been to evaluate a number of real world pipeline sources for microbial communities or consortia that form biofilms under laboratory simulations of pipelines. The microorganisms will be identified using classical and molecular microbiological tools and their activities under pipeline simulating conditions will be studied. The quarter saw the collection of the first samples from the industry for isolation of the microorganisms, as well as the design and construction of the laboratory-scale pipeline simulators.

**Results:** Methods development for MIC and biofilm microbial isolations and identification, and laboratory design and construction of pipeline simulators were the only activities. At this stage of the study (first quarter), only preliminary results are available.

## TABLE OF CONTENTS

<b>ABSTRACT .....</b>	<b>3</b>
<b>TABLE OF CONTENTS .....</b>	<b>4</b>
<b>LIST OF GRAPHIC MATERIALS .....</b>	<b>5</b>
<b>EXPERIMENTAL .....</b>	<b>8</b>
OBJECTIVE 1 – ISOLATE AND CULTIVATE MIC-CAUSING MICROORGANISMS / BIOFILM8	
OBJECTIVE 2 – DESIGN, CONSTRUCT, AND TEST A LABORATORY-SCALE PIPELINE	
SIMULATION SYSTEM .....	9
<b>RESULTS AND DISCUSSION.....</b>	<b>10</b>
<b>CITATIONS.....</b>	<b>12</b>

## **LIST OF GRAPHIC MATERIALS**

Environmental Systems for Pipeline Simulation.....	9
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## INTRODUCTION

The overall objective of this project is to develop, test, and apply environmentally benign agent(s) to control corrosion associated with internal surfaces of metal (iron or steel) pipes used in natural gas transmission. The overall hypothesis is that agents exist in nature that inhibit some or all of the steps executed by microorganisms in the formation of biofilm. As biofilm formation is an absolute prerequisite for the initiation and production of microbially influenced corrosion (MIC), blocking biofilm formation or propagation will block or mitigate MIC.

The general approach is to evaluate natural products isolated from plants, and possibly animals or microorganisms for their abilities to block the attachment, physiology, or reproduction of microbial agents that are responsible for microbiologically influenced corrosion. The first natural product to be tested is the oil that can be extracted from the seeds and pods of pepper plants. These plants are members of the Genus *Capsicum* and the first species evaluated was *Capsicum annuum*. The effective components or constituents (isolation and identification of these constituents in a previous and ongoing project funded by Gas Technology Institute) of this product will then be tested for its environmental impact and effects, effective concentrations, modes of application, and stability against isolated MIC microorganisms under simulated field conditions. A commercially viable agent that aids in MIC control and is environmentally friendly is the ultimate target with preliminary data to determine commercialization potential and cost-benefit analysis.

## EXECUTIVE SUMMARY

The results presented within are a summary of research activities from September/October 2001 through December for the project entitled "Development of an Environmental Benign Microbial Inhibitor to Control Internal Pipeline Corrosion". Corrosion, including microbially influenced corrosion (MIC) negatively impacts the integrity and reliability of the natural gas transmission pipeline operations in the United States and the world. Gas Technology Institute (GTI) proposed using natural chemical compounds isolated from plants for preventing, mitigate and/or eradicating corrosion due to microbial activity inside of metal (iron and stainless steel) natural gas pipelines. The overall hypothesis is that agents exist in nature that inhibit some or all of the steps executed by microorganisms in the formation of biofilm. As biofilm formation is an absolute prerequisite for the initiation and production of microbially influenced corrosion, blocking biofilm formation or propagation will block or mitigate MIC formation inside of natural gas transmission pipelines. The technical approach was to evaluate natural products for their abilities to block the attachment, physiology, or reproduction of microbial agents using modern methods of microbiology, molecular biology, and corrosion engineering. The first natural product to be tested is the oil that can be extracted from the seeds and pods of pepper plants (Genus *Capsicum*). This oil has been fractionated and key classes of organic compounds have been identified for testing for biofilm and MIC inhibition or prevention. The first quarter of work initiated the work on the first two objectives, i.e. Isolate and Cultivate MIC-causing Microorganisms / Biofilm, and Design, Construct, and Test a Laboratory-Scale Pipeline Simulation Systems. A number of samples are being processed and cultivated for their potential for biofilm development and MIC activities. A chemostat system with a direct link to a pipeline test loop and/or Robbins device has been identified and is under construction. At least two units are to be constructed and operated with one used to maintain the biofilm-forming and MIC causing activities, and one loop to test treatments, biocides, monitoring tools, etc. In addition, a Ph.D. chemist with experience in organic and natural product chemistry was added to our research team. She will have the responsibility of the fractionation and identification of the major constituents in the peppers and pepper extracts, as well as any other natural sources of biocides that are identified.

## EXPERIMENTAL

### Objective 1 – Isolate and Cultivate MIC-causing Microorganisms / Biofilm

A number of industry partners have been contacted and pipeline contents samples have been collected and transferred to GTI for the isolation of potential MIC-causing microorganisms. These contacts include:

- Mr. Greg Murphy, Panhandle Eastern Gas, Waverly, IL.
- Mr. Mike Jones and Mr. Robert Dillard, corrosion scientists, Trunkline Gas Co., Houma, LA
- Ms. Jennifer Walker, corrosion scientist, SoCal Gas, Los Angeles, CA.

Materials collected to date for this study include the following:

- Production water from gas pipelines and wells; and
- Condensation water from drip traps of gas pipelines

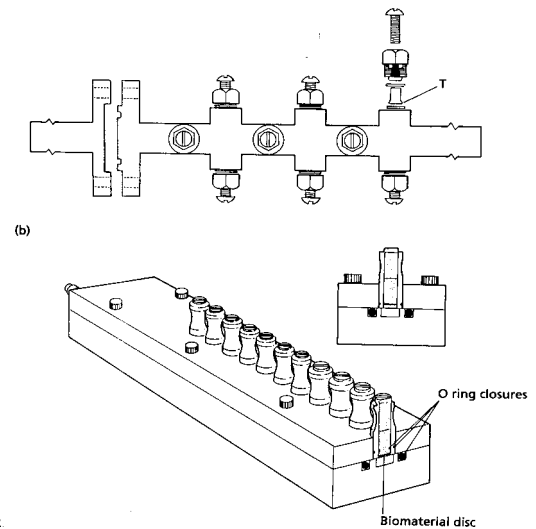
These samples have used to isolate both non-MIC and MIC-generating microorganisms, consortia (mixtures of two or more microbial species), and biofilms for future testing. Anaerobic techniques, many of which have been developed and refined at GTI and by the PI for this project, were used to isolate, culture, and characterize the microbial communities present in each of the samples. Because of their significance in the MIC process, special attention will be paid to the isolation and characterization of any sulfidogenic, methanogenic, and/or acidogenic anaerobic bacteria, including members of the genera *Desulfovibrio* and *Desulfolobus*. Metal-respiring bacteria, such as *Geobacter* sp. will also be sought in the samples. All microbial groups reported in the literature to be directly and indirectly involved in MIC will be tested for using classical microbial methods, as well as methods developed by molecular biology. Samples, especially metal coupons or samples exhibiting corrosion, will be studied with advanced methods such as environmental scanning electron microscopy (ESEM) and epi-fluorescence microscopy. In all cases, microbial cultures or consortia, once isolated, will be re-inoculated onto clean metal slides or coupons to prove that their MIC capacity is present and maintained.

## Objective 2 – Design, Construct, and Test a Laboratory-Scale Pipeline Simulation System

Chemostats already in use at GTI are being modified to create two natural gas pipeline test cells that will be loaded with pipeline alloy metal coupons. One system will be operated to maintain a stable microbial community or consortium that forms biofilms on the coupons and may cause MIC. The second systems will allow testing of biocidal and anti-biofilm constituents under near-field conditions. Both systems will be operated in a manner that simulates the conditions found in the natural gas transport system pipelines, as close as possible in the laboratory. Operators have sufficient control over temperature, moisture or relative humidity, microbial load, and composition and flow rate of the gaseous atmosphere that all of these parameters can be adjusted to mimic conditions deemed appropriate to simulate the field conditions that support maximal MIC activities. Environmental conditions will be ascertained from industrial reports/feedback. Figure below indicates a commercial representation of the design system.



Chemostat



Test loop or Robbins Device

### Environmental Systems for Pipeline Simulation

## **RESULTS AND DISCUSSION**

The samples obtained from the various pipeline sources are being cultivated using classical microbiological techniques, especially anaerobic methods (Aranki and Freter, 1972; Balch and Wolfe, 1976; Hungate, 1969; Macy *et al.*, 1972; and Miller and Wolin, 1974). The preliminary design on the laboratory pipeline simulator, i.e. test loops have been completed and material for construction are being obtained.

conclusion

The project has been successfully initiated and the first objective is underway and on schedule.

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