**CAAP Quarterly Report**

**12/25/2023**

*Project Name: "Bio-Inspired Rational Design of Bio-Based Inhibitors for Mitigating Internal Corrosion in Metal Pipelines"*

*Contract Number: 693JK32350003CAAP*

*Prime University: University of Miami*

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*Reporting Period: 09/30/2023-12/30/2023*

**Project Activities for Reporting Period:**

[Include the major activities that were completed during this activity. Please describe the relevant tasks in the proposal that have been completed or status of their process]

Project Kickoff Meeting: The project kickoff meeting was held on 11/16/2023 via the Zoom platform. The attendees included Zaid Obeidi (Technical Task Initiator (TTI), Zhou Zhongquan (Subject Matter Expert), Nusnin Akter (CAAP Program Manager), and Ali Ghahremaninezhad (Project Investigator). Each attendee gave a brief description of their role in this project. The PI gave a project overview and the plans to accomplish project tasks/activities. PHMSA CAAP oversight members offered valuable suggestions regarding industrial partnerships.

The PI has initiated efforts to establish industrial partnerships with CORTEC Corporation and Pipeline Research Council International (PRCI).

Student recruitment: One Ph.D. student named Sevil Ozsut has been recruited, who will be involved in various tasks/activities including literature review, experiment design and implementation, and data analysis.

Purchase of chemical/materials and supplies needed to conduct the experiments to study the effect of bio-based polymers on corrosion inhibition of metals has been completed. The experimental setups have been finalized.

A brief summary of literature review

There are several methods to mitigate or prevent corrosion processes occurring on the metal surface, specifically pipeline systems for the oil and gas industry. Corrosion inhibition, anodic protection, cathodic protection, coating, alloying etc are the available methods to mitigate the corrosion process 1. Among all the methods, corrosion inhibitors, which is the method based on the addition of chemicals, are widely used due to their effectiveness and cost efficiency. In recent decades, the pursuit of environmentally friendly corrosion inhibitors has gained significant attention 2,3. The research in the field of corrosion inhibitors has been to replace environmentally harmful substances with affordable, efficient molecules that have little to no environmental impact 4. These inhibitors can be classified into two categories, which are namely organic and inorganic eco-friendly inhibitors. The types of organic inhibitors are easy to degrade, low toxic, accessible and sustainable and they are, generally, derived from various sources, including natural plants, animals, and microorganisms 3.

The working principle for the organic inhibitors is to create a protective layer on the metal surface. The heteroatoms localized on functional groups or aromatic rings in the molecular structure of the organic inhibitors, basically biopolymers can interact chemically or electrostatically with a metal surface. That interaction of the biopolymer and the metal surface leads to the formation of an adsorbed molecular layer which prevents or slows down the reaction between metal and the surrounding environment, thereby reducing the rate of corrosion 4,5. Many research groups have reported the successful use of biopolymers as corrosion inhibitors for metals in various corrosive media. In recent years, large numbers of novel materials have been developed which are bioinspired materials from lotus leaves, shrimp waste protein, chitosan-based protein, rose petals and nepenthes pitcher plants 6 Researchers have used bioinspired substances as corrosion inhibitors to test their efficiency on metallic materials in an acidic medium. They have performed several test methods to observe both electrochemical and surface analyses to investigate the effect of corrosion inhibitors for mitigating the corrosion process. Some of these test methods can be listed as weight measurement, electrochemical impedance spectroscopy, potentiodynamic polarization scanning electron microscopy analyses etc.

A study performed by Farag et al. 7 shows the use of recovery shrimp waste protein to characterize its inhibition effects as a corrosion inhibitor for carbon steel. They found that the corrosion rate decreases with increasing inhibitor concentration. In this study, the inhibition action of the used inhibitor depends on the adsorption on the steel surface by applying Langmuir adsorption isotherm. The obtained free energy of adsorption showed the inhibition process was spontaneous and chemically adsorbed onto the steel surface. In addition, some researchers have focused on the ability of natural proteins to inhibit the corrosion of metals in acidic media. In this regard, a casein which is a milk protein was used to inhibit the corrosion of mild steel in an acidic electrolyte 8. Authors have pointed out that an increase in the concentration of casein resulted in an 88 % decrease in the corrosion rate of mild steel. They have also stated that temperature increase had adverse effects on the surface coverage and the corrosion inhibition efficiency of casein. They have also analyzed the surface improvements of the sample by atomic force microscopy, and they stated the surface of the mild steel has become smoother with the addition of casein as an inhibitor. Liao et al. 3 reported that the Fructus cannabis protein extract powder as a green and effective corrosion inhibitor shows very high corrosion inhibition efficiency with 98 % on carbon steel in an acidic medium. Moreover, the tested carbon steel shows higher hydrophobicity of the surface, making it less prone to interact with water, and greater adhesion force obtained by adsorption of the Fructus cannabis protein. The study also points out that high temperatures affect the bond between the inhibitor and the steel surface weakens or breaks due to increased thermal energy.

References

(1) Goni, L. K. M. O.; Jafar Mazumder, M. A.; Quraishi, M. A.; Mizanur Rahman, M. Bioinspired Heterocyclic Compounds as Corrosion Inhibitors: A Comprehensive Review. *Chemistry - An Asian Journal*. John Wiley and Sons Ltd June 1, 2021, pp 1324–1364. https://doi.org/10.1002/asia.202100201.

(2) Salleh, S. Z.; Yusoff, A. H.; Zakaria, S. K.; Taib, M. A. A.; Abu Seman, A.; Masri, M. N.; Mohamad, M.; Mamat, S.; Ahmad Sobri, S.; Ali, A.; Teo, P. Ter. Plant Extracts as Green Corrosion Inhibitor for Ferrous Metal Alloys: A Review. *Journal of Cleaner Production*. Elsevier Ltd July 1, 2021. https://doi.org/10.1016/j.jclepro.2021.127030.

(3) Liao, B.; Ma, S.; Zhang, S.; Li, X.; Quan, R.; Wan, S.; Guo, X. Fructus Cannabis Protein Extract Powder as a Green and High Effective Corrosion Inhibitor for Q235 Carbon Steel in 1 M HCl Solution. *Int J Biol Macromol* **2023**, *239*. https://doi.org/10.1016/j.ijbiomac.2023.124358.

(4) El Ibrahimi, B.; Jmiai, A.; Bazzi, L.; El Issami, S. Amino Acids and Their Derivatives as Corrosion Inhibitors for Metals and Alloys. *Arabian Journal of Chemistry*. Elsevier B.V. January 1, 2020, pp 740–771. https://doi.org/10.1016/j.arabjc.2017.07.013.

(5) Al-Taie, I.; Center, R.; Aramco, S.; Saudi, D.; Gray, A. J. M.; Knauf, G.; Lu, M.; Murray, A.; Santos, B.; Zhou, J. *Oil and Gas Pipelines*; New Jersey, 2015. www.wiley.com.

(6) Xiang, T.; Zheng, S.; Zhang, M.; Sadig, H. R.; Li, C. Bioinspired Slippery Zinc Phosphate Coating for Sustainable Corrosion Protection. *ACS Sustain Chem Eng* **2018**, *6* (8), 10960–10968. https://doi.org/10.1021/acssuschemeng.8b02345.

(7) Farag, A. A.; Ismail, A. S.; Migahed, M. A. Environmental-Friendly Shrimp Waste Protein Corrosion Inhibitor for Carbon Steel in 1 M HCl Solution. *Egyptian Journal of Petroleum* **2018**, *27* (4), 1187–1194. https://doi.org/10.1016/j.ejpe.2018.05.001.

(8) Rabizadeh, T.; Asl, S. K. Casein as a Natural Protein to Inhibit the Corrosion of Mild Steel in HCl Solution. *J Mol Liq* **2019**, *276*, 694–704. https://doi.org/10.1016/j.molliq.2018.11.162.

**Project Financial Activities Incurred during the Reporting Period:**

[Include a cost breakdown list to indicate the expenses during the reporting period in each of the categories according to the budget proposal.

|  |  |
| --- | --- |
| Category | Amount |
| Materials and Supplies | $1,500 |
| Ph.D. student Stipend | Will start January 2024- Student is recruited to start in Spring 2024. The student recruitment started as soon as we received the notice of award which was early October 2023. |
| Tuition | Will start January 2024 |
| PI salary | Will occur in Summer 2024 |

**Project Activities with Cost Share Partners:**

[Include the major activities that were conducted during this reporting period with cost share partners]

N/A

**Project Activities with External Partners:**

[Include the major activities that were conducted during this reporting period with any external partners or sub-universities]

N/A

**Potential Project Risks:**

[Include potential projects risks that have been noticed, and those that may arise in the next reporting period. This section could also include risks.]

N/A

**Future Project Work:**

[Include significant work that will be completed in the next 30, 60, and 90 days]

Corrosion experiments with several different bio-based polymers will be conducted. The electrochemical characteristics along with physical changes will be documented. A decision will be made as to which bio-based polymers will be studied further using advanced microscopic analysis.

**Potential Impacts to Pipeline Safety:**

[Include in this section the projects potential impact to pipeline safety at the current phase of the project]

The findings from this project will have the potential to introduce a new paradigm in the development of green inhibitors and processes that address internal corrosion in pipeline systems.