Authors See Bright Future for Refinery Corrosion Prevention

Kerry Cole

High pressure and high temperatures mean a high risk of corrosion in refineries worldwide, but two research scientists in Saudi Arabia say the future of refinery corrosion prevention looks leaner and greener thanks to technologies such as superhydrophobic coatings and nanomaterials.

Aisha H. Al-Moubaraki and Ime Bassey Obot set out to study corrosion in the refinery industry. They discovered that information on the topic was plentiful but widespread and therefore difficult to find. The two Saudi Arabia-based research scientists then made it their mission to write a definitive paper on refinery corrosion, its effect on the environment, and its future.

"Corrosion in the refinery is a serious problem in Saudi Arabia and globally, costing the industry millions of dollars in maintenance and replacement cost," says Al-Moubaraki, associate professor of physical chemistry at the University of Jeddah. "Our research interest is mainly focused on corrosion control using sustainable corrosion inhibitors."

She and Obot authored "Corrosion Challenges in Petroleum Refinery Operations: Sources, Mechanisms, Mitigation, and Future Outlook," in which they explain that refineries are important, not only for the energy sector, but for household and business needs. Refined oil products and byproducts produce plastics, industrial fabrics, paints, dyes, medications, fertilizers, and other consumer goods.

The refining industry is regarded as high-risk because refineries are large and complex sites that carry out numerous operations while operating at high levels of pressure and temperature. This combination of factors makes refineries vulnerable to a variety of corrosion.

Refinery corrosion not only can bring about costly repairs and plant downtime but can result in serious accidents, impacting workers, the environment, and the economy. While corrosion occurs throughout the petroleum industry, corrosion in refineries draws the most public attention because of their size and the potential severity of corrosion-based incidents.

They cite corrosion-caused damage that led to catastrophic failures in oil refineries, such as those that occurred in the Silver Eagle Refinery in Utah in 2009 and the Chevron Richmond Refinery in California in 2012 (Figure 1).

"The review concludes that corrosion in the refinery has not received wide attention in the literature like other corrosion issues in the petroleum industry," says Obot, associate professor of physical chemistry at King Fahd University of Petroleum and Minerals in Dhahran. "The advancement of research in the area of real-time and accurate prediction models, collection of sufficient data regarding ammonium bisulfide (NH_4HS) corrosion

Figure 1 Examples of refinery accidents caused by corrosion failure: (a) Silver Eagle Refinery, (b) Richmond Refinery, (c) and (d) Chevron Refinery.

Figure 2 Some failure parts caused by ammonium bisulfide (NH_4HS).

(Figure 2) in the refinery plant, development of novel smart nanomaterials coating, and environmentally friendly high-temperature corrosion inhibitors are needed for effective mitigation of refinery corrosion."

The United States, they report, has the world's largest refining capacity, producing more than 18 million barrels of refined petroleum products per day. Worldwide, refineries typically process 100,000 to 2 million barrels of crude oil per day into petroleum products.

Al-Moubaraki and Obot expect corrosion problems in refineries to become an even greater challenge as the demand for crude oil rises.

Figure 3 Some failure parts caused by naphthenic acid corrosion.

Sources of Corrosion

Corrosion in refineries can be found in storage tanks, desalting units, crude oil distillation units, hydrotreating units, and fluid catalytic cracking units, the authors write.

Selecting the appropriate material is essential when designing a plant to handle the aggressive substances used in refineries. Researchers across the world are pushing to develop green corrosion inhibitors that are effective at high temperatures and are environmentally friendly, non-toxic, and biodegradable.

"Our research discovered that there is a need to continue to develop innovative sustainable solutions to corrosion mitigations such as improved coatings based on nanomaterials, predictive models, and high-temperature corrosion inhibitors," says Al-Moubaraki, who earned a Ph.D. in physical chemistry from King Abdulaziz University.

Basics of Corrosion at Refinery Units

Corrosion of metallic equipment and structures in refineries occurs at low temperatures and high temperatures.

Al-Moubaraki and Obot divide the causes of corrosion into three groups: corrosion from crude oil components, corrosion from chemicals used in refining processes, and environmental corrosion. Although crude oil is not corrosive in and of itself, impurities and components containing nitrogen, sulfur, and oxygen can be found in crude

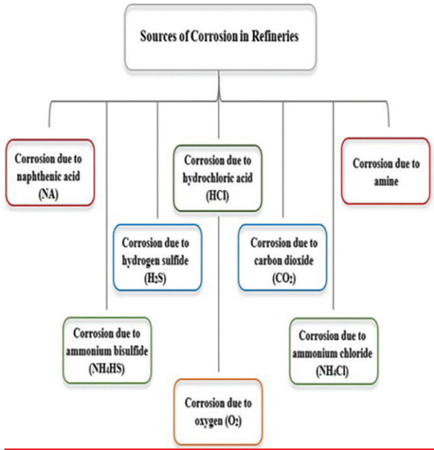

Figure 4 Sources of corrosion in refineries.

Figure 5 Examples of corrosion caused by hydrogen sulfide.

oil and can be corrosive.

They cite naphthenic acid as the most corrosive agent typically found in crude oil (Figure 3). Hydrogen sulfide (H_2S), carbon dioxide (CO_2) or sweet corrosion, ammonium bisulfide (NH_4SH), and ammonium chloride (NH_4Cl) are among other culprits (Figures 4 and 5).

Mitigation

In an aggressive environment, it is critical to protect metallic equipment from corrosion by using mitigation methods such as the application of a coating or the injection of corrosion inhibitors.

Nanomaterial-containing coatings offer much better material and processing properties than conventional coatings, the researchers found. Nanomaterials are characterized by their tiny size, measured in nanometers, according to the National Institute of Environmental Health Sciences. A nanometer is one millionth of a millimeter, which is approximately 100,000 times smaller than the diameter of a human hair.

These nanomaterials in refineries can cause increased indentation resistance, high elasticity, fast drying, no expansion after contact with water, and high water-vapor permeability, Al-Moubaraki and Obot report. Graphene in particular has exceptional thermal, mechanical, and electrical properties that are advantageous for coating applications.

"Nanotechnology can help in the

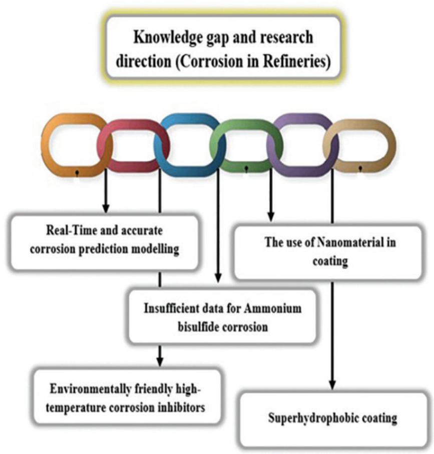

Figure 6 Knowledge gap and future research direction.

development of self-healing coatings which can ensure long lasting protection of refinery assets," says Obot, who earned a Ph.D. in physical chemistry from the University of Ibadan, Nigeria, and has extensive experience in teaching and research in both university and industrial settings. "Nanomaterials offer much better material and processing properties than conventional coatings."

Corrosion resistance also has improved because of the use of superhydrophobic coatings, the authors say, revealing that the concept can be found in nature in the form of some plants, which have water-repellent leaves. Water droplets can easily roll off their leaves due to these repelling qualities, keeping the surface clean.

Superhydrophobic coatings, the researchers say, can be viewed as a low-cost solution to corrosion in pipelines and equipment. Silver nanoparticles used to create superhydrophobic surfaces are reported to be highly resistant to microorganisms.

"Superhydrophobic coating can help ensure that the coating system lasts in harsh environments like high temperatures and aggressive environments," Al-Moubaraki says. "Superhydrophobic coatings include properties such as self-cleaning, anti-icing, oil-water separation, and viscous drag reduction, making them a good and low-cost solution to corrosion and fouling in pipelines and equipment in refineries."

The authors are optimistic about the future of corrosion prevention in refineries and improved means of protecting the environment (Figure 6).

"Refinery operators need to understand the need to replace toxic chemicals with sustainable technologies in their corrosion control operations," Obot says. *MP*