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Preface on corrosion inhibition: A green and sustainable approach

Corrosion is a major challenge across various industries, leading to structural damage, financial losses, and safety hazards. Traditional corrosion prevention methods often involve synthetic inhibitors, many of which are toxic and pose environmental hazards. However, growing environmental concerns and stringent regulations have driven the search for sustainable, eco-friendly alternatives—giving rise to green corrosion protection. Sustainability in corrosion prevention is not merely a trend but a necessity for long-term environmental protection and resource conservation. The call of this Special issue, “Corrosion Inhibition: A Green and Sustainable Approach” was set to cover the most current developments and explorations of green technologies in corrosion inhibition. Some of these studies, which include both experimental and modeling work, are presented in the eight articles that are part of this Special Issue.

Yadav et al. [1] provide a review of the application of green nanoparticles in sustainable corrosion prevention. They demonstrate that green nanoparticles have the potential to revolutionize material protection, but further research and development are necessary to harness their benefits fully. The study highlights both the opportunities and challenges of using green nanoparticles for corrosion prevention. Two studies on the use of natural extracts as corrosion inhibitors have been included in this special issue. The first one [2] investigates the effectiveness of *Tithonia diversifolia* leaf extract (TDLE) as an eco-friendly corrosion inhibitor for 304 stainless steel in acidic and high-temperature environments using experimental electrochemical techniques and theoretical studies. They reported that TDLE reached an inhibition efficiency of 98.5% at studied conditions and methyl 3,5-dicaffeoyl quinate in TDLE is identified as a compound with the highest potential to be adsorbed on the metal surface to form a protective layer. The second study focuses on the efficiency of *Tinospora cordifolia* extract based on the concentration of methanol as a solvent on the corrosion of carbon steel in artificial marine media [3]. There is an increasing need for environmentally benign corrosion inhibitors for the marine environment due to heightened worries about the usage of dangerous inhibitors and rigorous regulatory requirements. The study showed that *Tinospora cordifolia* extract reached an inhibition efficiency of 86% due to the presence of many chemicals containing N and OH bonds in the *T. cordifolia* extract verified by FT-IR analysis. Another study in the marine environment on synthesis and the inhibition potential of Ce-based metal-organic framework (Ce-MOF) on copper in a chloride-rich environment has been successfully demonstrated by Anadebe et al. [4] using different experimental approaches to molecular level prediction. The importance of using metal-organic frameworks (MOFs) in the field of corrosion control has gained attention due to their unique structural and chemical properties. Through cathodic inhibition,

the Ce-MOF inhibitor, a covalent metal-organic framework, can reverse the corrosion attack in a chloride environment, protecting Cu. Computational studies validate strong Ce-MOF interaction with copper, enhancing its protective properties. Within the context of the marine environment, Chen et al. [5] reported their recent work on the effect of Cl^- concentration on the corrosion response of a selective-laser-melted (SLM) Al-Mg-Sc-Zr alloy in marine atmospheric conditions. The study concludes that Cl^- ions significantly affect the corrosion resistance of SLM Al-Mg-Sc-Zr alloys, with higher concentrations accelerating pitting and oxide layer degradation. This research provides valuable insights for designing corrosion-resistant aluminum alloys for marine environments.

The positive effect that Li salts play in protecting Al and Al alloys from corrosion has long been recognized but there was no in-depth analysis of the impact of the Li-salts' anionic component in the literature. Trinh et al. [6] investigate the influence of the anion in lithium salts on the corrosion inhibition of AA2024 aluminium alloy using different lithium salts (lithium nitrate, lithium oxalate, and lithium carbonate). The study confirms that lithium salts can serve as effective corrosion inhibitors for aluminium alloys. However, lithium oxalate and carbonate demonstrate self-healing capabilities making them potential alternatives for inhibitive species in organic coatings.

Udunwa et al. [7] theoretically and experimentally explore the corrosion protection potential of a novel imidazole-based ionic liquid, 1-butyl-3-methylimidazolium tetrachloroindate ($[\text{C}_4\text{MIM}][\text{InCl}_4]$) for aluminum alloy in potassium hydroxide solution. They demonstrate that ionic liquid significantly reduces corrosion, with inhibition efficiencies reaching 88.5% at 0.8 g/L concentration. Computational simulations validate the experimental findings, supporting the ionic liquid's strong adsorption onto the metal surface.

In the work of Serrano et al [8], quantitative-structure activity relationship (QSAR) modeling was used to predict inhibition efficiency of commercial drugs on steel surfaces based on computed descriptors such as ionization energy and molecular orbital energies. Different modeling approaches were compared, including nonlinear autoregressive moving average with exogenous inputs (NARMAX) with forward regression with orthogonal least squares (FROLS), ordinary least squares (OLS), and IBM Watson's extra trees regressor. Evaluation with mean absolute percentage error (MAPE), mean-squared error (MSE), and root-mean-squared error (RMSE) showed that models with fewer variables and up to second-order terms performed best.

For estimating corrosion inhibition across a wide range of chemicals, QSAR models offer a practical and affordable alternative because they can estimate inhibition efficiency with an error of about 6%.

In conclusion, this special issue provides insights into recent research, challenges, and prospects in the future exploration of green

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technologies in corrosion inhibition. We are thankful to coordinating editor Andrei Rotaru, editor-in-chief Guido Grundmeier and associate editor Filippo Parisi for the opportunity.

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Ivana Martinović^{a,*}, Zora Pilić^a, Željka Petrović^b

^a Department of Chemistry, Faculty of Science and Education, University of Mostar, 88 000 Mostar, Bosnia and Herzegovina

^b Ruđer Bošković Institute, Division of Materials Chemistry, 10 000 Zagreb, Croatia

* Corresponding author.

E-mail address: ivana.martinovic@fpmoz.sum.ba (I. Martinović).