Pinky [Subject: Chemistry] [I.F. 8.921] International Journal of Research in Humanities & Soc. Sciences

Vol. 14, Issue 11, November 2026
ISSN(P) 2347-5404 ISSN(O)2320 771X

Biodegradable Corrosion Inhibitors Derived from Natural Amino Acids: A Review

Pinky

Research Scholar

Department of Chemistry

Sanskaram University, Jhajjar, Haryana- 124108

ORCID ID- https://orcid.org/0009- 0009- 5780- 9664

Abstract : Natural amino acids offer a chemically diverse base for the design of environmentally favorable corrosion inhibitors due to the presence of amino, carboxyl, sulfur-containing and aromatic groups capable of interacting with metal surface and regulating interfacial electrochemical processes. The review evaluates corrosion inhibition efficiency of both unmodified amino acids and their selected derivatives, with the emphasis on corrosion of steel in acidic media and taking into account the potential for wider application. The evidence is analyzed with the view to structure, solution chemistry, experimental methodology and environmental qualification. The data show significant dependencies on concentration, temperature, electrolyte composition and metal type. In one comparative study, the maximum efficiencies of cysteine inhibition were reported to reach 97.3%, 89.7% and 84.4% in hydrochloric, phosphoric and sulfuric acids correspondingly. These numbers are specific for laboratory conditions and cannot provide universal ranking. The key point is the separation of biological origin, corrosion inhibition property and biodegradability. The future development should unite corrosion tests with compound-specific biodegradability, toxicity and industrial suitability assessments.

Keywords : Amino acids; corrosion inhibition; biodegradability; adsorption; mild steel; sustainable materials protection.

Introduction

Corrosion inhibitors protect metals through modification of the reactions occurring at metal–electrolyte interface. Their relevance increases in cases when corrosive solution contacts the steel during cleaning, processing or industrial operation. The choice of an inhibitor takes into account protective efficiency, chemical compatibility, handling requirements and environmental implications of discharge.

Natural amino acids can serve as an attractive base for the design of inhibitors due to the presence of molecular structures with amino, carboxyl, sulfur-containing and aromatic groups allowing the investigation of structure–property relations in a relatively well-defined molecular class.

However, some differences should be noted. Biological amino acid is not necessarily environmentally friendly when used industrially. Compound synthesized from

amino acid is not necessarily environmentally benign compared to its original form. Finally, efficient corrosion protection is not necessarily equal to biodegradability.

This review deals with these distinctions in conjunction with the electrochemical evidence. The key question is the influence of amino-acid structure and conditions on corrosion protection and the additional evidences needed to claim biodegradability and environmental friendliness.

The discussion focuses on selected verified publications and excludes exhaustive systematic review. The numerical data is taken from the available literature; no experimental data or meta-analytical estimates are generated.

Review Methodology

Scope and Source Selection

Targeted narrative review was conducted by means of scholarly databases, publishers' archives, institutional repositories and chemical-testing guidelines. Searches were performed with the use of keywords related to amino acids, cysteine, methionine, tryptophan,

© 2026. This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0).

Vol. 14, Issue 11, November 2026
ISSN(P) 2347-5404 ISSN(O)2320 771X

corrosion inhibition, adsorption, biodegradation and green chemistry.

Publications were selected for relevance to inhibitor–structure relationships, electrochemical interpretation or environmental assessment. The primary literature is the source of compound-specific information, while reviews provide the context and reveal the weaknesses of the existing data.

The review includes the foundational and the more recent publications. No restriction on the age of publication was imposed as old experiments can still be relevant to the mechanism of adsorption and testing practices.

Evidence Extraction and Interpretation

The evaluation took into account inhibitor identity, metal substrate, electrolyte, concentration, temperature, measurement technique and scope of environmental claims.

Results obtained by weight loss, polarization and electrochemical impedance spectroscopy are not treated equally. Maximum reported inhibition efficiencies are presented as experiment-specific values and not averaged into a general mean.

No screening-flow counts, effect sizes or publication-bias estimates are reported. The differences between the experimental systems preclude a defensible meta-analysis without a more detailed, standardized extraction procedure.

Literature Review

Development of Amino-Acid Inhibitors

El Ibrahimi et al. (2020) reviewed amino acids and their derivatives across metals and alloys. The synthesis shows that the corrosion inhibition depends on molecular structure and surrounding chemical environment and presents examples of the cases when amino acid promotes corrosion rather than inhibits it. Thus, the biological origin of the compound does not define its electrochemical behavior a priori. (Arabian Journal of Chemistry)

Ashassi-Sorkhabi, Majidi, and Seyyedi (2004) investigated alanine, glycine and leucine against steel corrosion in hydrochloric acid, reporting the inhibition efficiencies ranging from 28% to 91%. This wide range demonstrates the importance of concentration and acid strength and cannot be interpreted as a unique characteristic efficiency of these compounds. (Sciencedirect)

Morad (2008) studied sulfur-containing amino acids and derivatives in sulfamic acid, using polarization and impedance measurements for identification of the adsorption differences between the compounds. (Springer Nature Link)

Sulfur-Containing and Aromatic Compounds

Mobin, Zehra, and Parveen (2016) studied cysteine in hydrochloric acid and mixtures of this amino acid with various surfactants, showing the importance of the formulation effects and temperature-dependent testing. Rewritten text:

However, the enhanced performance of a mixture cannot be attributed to the cysteine only, and the environmental characteristics of each additive are also important.

Fu et al. (2010) investigated the effect of tryptophan on the corrosion of low-carbon steel in hydrochloric acid using weight-loss measurements, polarization studies and computational methods. Their results support the consideration of the aromatic functionality along with amino and carboxyl groups. The observed behavior under the experimental conditions was more cathodic than anodic, meaning that “mixed-type inhibition” cannot be automatically ascribed to every amino acid.

Elabbasy, Toghan, and Gadow (2024) compared the efficiency of cysteine in three acidic electrolytes. Their results illustrate the dependence of efficiency on electrolyte and, combining the surface analysis with electrochemical and theoretical examinations, make the interpretation go beyond the single efficiency number.

Derivatives and Environmental Qualification

Mazumder (2019) investigated cysteine-containing synthetic polymers as inhibitors of mild-steel corrosion in hydrochloric acid, extending the amino-acid chemistry into macromolecular inhibitors with multiple surface-interaction possibilities. However, the incorporation of cysteine residues into a synthetic polymer does not, by itself, demonstrate the biodegradability of the entire macromolecule.

Marzorati, Verotta, and Trasatti (2019) conducted a review of corrosion inhibitors derived from natural resources and biomass wastes. Their analysis supports

© 2026. This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0).

Vol. 14, Issue 11, November 2026
ISSN(P) 2347-5404 ISSN(O)2320 771X

the transition from screening natural substances to improved chemical characterization, practical relevance and environmental justification. Natural origin should be considered along with processing and formulation performance.

Verma et al. (2024) connect corrosion protection with the principles of green chemistry. Their review provides a more general framework, including synthesis, resource utilization, chemical hazards and applications, and supports the evaluation of the complete inhibitor pathway rather than its high laboratory efficiency.

OECD Test Guideline 301 contains established methods of ready biodegradability assessment. They provide the experimental basis for environmental claims that cannot be obtained through the corrosion measurements alone. Their significance becomes especially pronounced in case of modified amino acids, surfactant mixtures or polymers.

Chemical Characteristics and Inhibition Mechanisms

Functional Groups and Molecular Speciation

All amino acids contain amino and carboxyl groups, but their charged states depend on solution conditions. In the strongly acidic medium, the protonated molecules are mostly present, while other conditions allow for different ionic species. The surface charge, electrolyte ions and metal oxide influence the interaction of these species with the substrate.

The side chains modify this behavior. Cysteine has a thiol group, methionine a thioether, and tryptophan an indole group. Glycine and alanine can be regarded as reference points due to the simpler structures.

Table 1. Features Important for Inhibitor Evaluation

Compound or family	Distinguishing feature	Main question for evaluation
Glycine and alanine	Small molecular structure	Is surface coverage sufficient at practical dosage?
Leucine	Larger aliphatic side chain	Does side-chain character improve film organisation?
Cysteine	Thiol functionality	Does adsorption provide protection or promote dissolution?
Methionine	Thioether functionality	How do electrolyte and temperature affect protection?
Tryptophan	Aromatic indole group	Does aromatic interaction improve surface retention?
Amino-acid derivatives	Additional functional groups	Does modification improve performance without unacceptable environmental cost?
Amino-acid-containing polymers	Multiple interacting segments	How do molecular size and backbone chemistry affect transport and degradation?

These features help to formulate the questions but cannot determine the universal efficiency order.

Adsorption and Protective Films

The adsorption reduces the accessibility of the reactive surface sites and influences the anodic dissolution or cathodic reactions. Depending on conditions, the electrostatic interaction, coordination, surface complex formation and film organization can contribute.

The protective film has to be sufficient in its continuity and stability during the exposure. Strong interaction with the dissolved metal ions can result in soluble complexes rather than protective surface film. This explains the difference in the behavior of the same molecule under different metals and electrolytes.

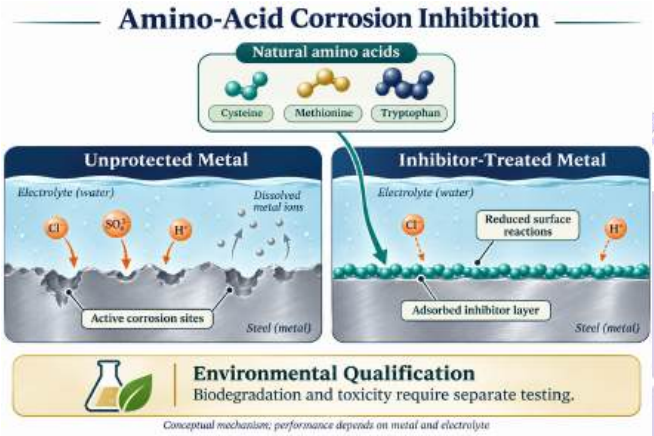
The reviewed studies suggest the diversity of the mechanisms. A simple term like physical adsorption or chemical adsorption often oversimplifies the changing metal–solution interface.

© 2026. This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0).

Vol. 14, Issue 11, November 2026
ISSN(P) 2347-5404 ISSN(O)2320 771X

Adsorption Isotherms and Computational Interpretation

The Langmuir-type fit can be found in several studies of amino acids. However, the good fit just indicates compatibility with the model under the investigated concentrations and does not validate all the assumptions made by the model.



Similarly, the calculated orbital energies or simulated adsorption geometry can support the hypotheses but cannot replace the corrosion measurements. The protonation state, solvent, surface oxidation and competitive ions have to be considered properly.

The mechanistic conclusions become stronger when the electrochemical measurements, surface chemistry and molecular modeling are converging.

Results of Evidence Synthesis

Published Quantitative Evidence

The literature shows the condition-dependent protection and not the consistent efficiency applicable in all the systems.

Table 2. Selected Verified Quantitative Findings

Publication	System	Published quantitative finding	Interpretation boundary
Ashassi-Sorkhabi et al. (2004)	Steel in HCl; alanine, glycine, and leucine	Reported inhibition range: 28–91%	Covers different investigated conditions
Fu et al. (2010)	Low-carbon steel in 1 M HCl; tryptophan	Most effective tested concentration: 0.01 mol/L; temperature range: 298–328 K	Does not establish performance outside that range
Morad (2008)	Mild steel in sulfamic acid; sulfur-containing compounds	Tests conducted in 5% sulfamic acid at 40°C	Compound ranking is specific to this system
Mobin et al. (2016)	Mild steel in 1 M HCl; cysteine and surfactants	Temperature range: 30–60°C	Mixtures require separate attribution and assessment

The numerical entries here describe the conditions and findings reported in the literature. They are not the pooled dataset and cannot be averaged to generate the average inhibition efficiency.

Electrolyte Dependence

Elabbasy et al. reported the following maximum efficiencies for the concentration of 0.01 M of cysteine.

Table 3. Efficiency of Cysteine Under Different Acidic Electrolytes

Electrolyte	Reported maximum inhibition efficiency
1 M HCl	97.3%
1 M H_3PO_4	89.7%
1 M H_2SO_4	84.4%

Within-study, the difference between hydrochloric acid and sulfuric acid equals 12.9 percentage points. These numbers are the maximums reported by the authors and

© 2026. This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0).

Vol. 14, Issue 11, November 2026
ISSN(P) 2347-5404 ISSN(O)2320 771X

cannot be interpreted as the efficiencies recalculated from another electrochemical endpoint.

The comparison demonstrates why the concentration is insufficient for evaluation of inhibitors. The electrolyte composition and measurement basis have to be reported alongside the efficiency claim.

Consistency Across Measurement Methods

Weight loss measurements integrate the metal loss during the exposure period. Polarization experiments estimate the corrosion-related electrochemical behavior near the measurement conditions. The impedance measurements characterize the interface using the selected interpretation model.

For weight-loss measurements, efficiency is usually expressed as:

$$IE_WL = [(CR_0 - CR_i) / CR_0] \times 100$$

For the interpretation with the charge-transfer resistance:

$$IE_EIS = [(R_ct,i - R_ct,0) / R_ct,i] \times 100$$

These are related but not identical measures. Agreement between the methods increases the confidence in results; disagreement may reveal the time-dependent development of the film, changes in surface or limitations in data fitting.

Thus, the review has to preserve the method names and avoid the selection of the measurement giving higher percentage.

Biodegradability and Environmental Assessment

Biological Origin Versus Measured Degradation

Natural amino acids have proven biological functions; however, the environmental assessment concerns the released substance and conditions of its release. The industrial solutions can contain salts, corrosion products, residual acid, co-inhibitors and transformation products.

Biodegradation of an isolated parent compound does not necessarily characterize the formulated product. The chemical modification can change solubility, microbial availability or degradation pathways. Alternatively, the negative results can be explained by test inhibition or inappropriate conditions.

The conclusion is that amino acids constitute a promising starting chemistry, while environmental claims require the compound-specific evidence.

Recognized Criteria of Biodegradability

OECD 301 contains six aerobic screening methods conducted over 28 days with the pass criteria of 70% removal of dissolved organic carbon or 60% of theoretical oxygen demand or theoretical carbon dioxide production, depending on the method. The guideline also establishes the ten-day window and additional validity criteria. [OECD](https://www.oecd.org/en/publications/test-no-301-ready-biodegradability_9789264070349-en.html?utm_source=chatgpt.com)

These numbers serve as classification criteria and not the universal results obtained for every inhibitor mentioned above.

Table 4. Evidence Needed for Environmental Claims

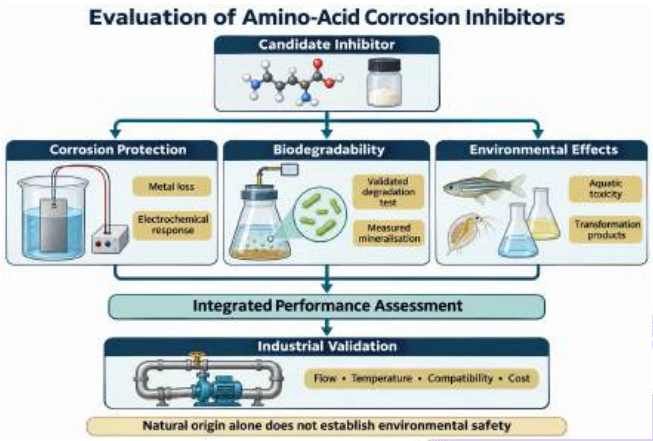
Claim	Evidence needed	Insufficient substitute
Effective inhibitor	Reproducible corrosion measurements	Molecular structure alone
Readily biodegradable	Applicable validated degradation test	Natural origin
Low aquatic toxicity	Relevant organism-level testing	Pharmaceutical or biological use
Environmentally preferable formulation	Assessment of all components and treatment needs	Performance of the amino-acid component alone
Industrially suitable	Relevant operational and compatibility testing	Short static laboratory exposure

Biodegradability and toxicity have to be evaluated separately. Degradability does not mean non-toxicity

© 2026. This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0).

Vol. 14, Issue 11, November 2026
ISSN(P) 2347-5404 ISSN(O)2320 771X

and rapid microbial consumption may increase oxygen demand in the receiving water.



Discussion

Performance–Environment Trade-Offs

Sulfur-containing and aromatic amino acids provide valuable molecular features; however, their effectiveness depends on concentration and environment. Modification can improve the film formation or surface retention, but increase the synthesis complexity.

Thus, the goal should be the achievement of sufficient protection under feasible dosage with acceptable environmental profile. The maximization of inhibition percentage may favor the complicated formulation underperforming in terms of cost, treatment or environment.

Mixtures have to be considered with special attention. The surfactant may improve the coverage, while the formulated product has to be evaluated. The environmental characteristics of the parent amino acid cannot be generalized to the every additive.

Industrial Implementation

Laboratory results have to be followed with testing under the representative flow conditions, temperature cycling, contamination and exposure duration. Such factors as the steel grade, surface preparation, dissolved oxygen, and corrosion products accumulation may influence the performance.

The inhibitor suitable for short acid cleaning may not be suitable for continuous circulation. The storage stability, foam formation, adhesion of the downstream coating and compatibility with the other treatment chemicals have to be taken into account.

Cost comparison has to be based on the effective treatment concentration and service duration and not on the raw-material price alone. The inexpensive compound requiring frequent dosing may prove to be economically inferior to more durable one.

Research Quality and Reporting

Future researches have to report the absolute corrosion rates in combination with inhibition percentage. High relative efficiency may hide the unacceptable corrosion rate.

The replication, uncertainty estimates, material composition, exposed area, cleaning procedure and solution conditions have to be disclosed. The environmental tests have to specify the chemical form and formulation of the inhibitor.

The negative results have the value as well. The reports of the corrosion acceleration or unstable protective behavior help to establish the limitations and prevent overgeneralization.

Limitations

The present review is a focused narrative and not a comprehensive systematic analysis. The access to some publications was limited to the abstract or selectively available full text and prevented the detailed comparison of all the experimental endpoints.

The reviewed studies employ various metals, electrolytes, concentrations and measurement methodologies. Therefore, no pooled efficiency estimate, general ranking of compounds, or claim of statistical significance can be made.

Biodegradation studies were not performed independently and the present review does not endorse any commercial product based on such.

Conclusion

Natural amino acids provide an abundant basis for the development of corrosion inhibitors due to functional groups and varied side chain chemistries. From published reports, there is evidence of efficient protection under certain conditions but also of a significant dependence on electrolyte composition, concentration, temperature, and substrate.

Biological source, efficiency of corrosion inhibition, and biodegradability must be viewed as separate results.

© 2026. This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0).

Vol. 14, Issue 11, November 2026
ISSN(P) 2347-5404 ISSN(O)2320 771X

A combination of reproducible corrosion tests, surface characterisation, environmental tests on formulations, and practical validation is a strong development strategy.

Future Research

Key topics for future research are comparison under standard conditions, determination of degradation products, environmentally characterised mixture, and flow experiments. An integrated study would relate residual corrosion, required dose, environmental effects, and cost of treatment.

References

1. El Ibrahimi, B., Jmiai, A., Bazzi, L., and El Issami, S. (2020). Amino acids and their derivatives as corrosion inhibitors for metals and alloys. Arabian Journal of Chemistry, 13(1), 740–771. DOI: 10.1016/j.arabjc.2017.07.013.
2. Ashassi-Sorkhabi, H., Majidi, M. R., and Seyyedi, K. (2004). Investigation of inhibition effect of some amino acids against steel corrosion in HCl solution. Applied Surface Science, 225(1–4), 176–185. DOI: 10.1016/j.apsusc.2003.10.007.
3. Morad, M. S. (2008). Corrosion inhibition of mild steel in sulfamic acid solution by S-containing amino acids. Journal of Applied Electrochemistry, 38, 1509–1518. DOI: 10.1007/s10800-008-9595-2.
4. Fu, J.-J., Li, S.-N., Cao, L.-H., Wang, Y., Yan, L.-H., and Lu, L.-D. (2010). L-Tryptophan as green corrosion inhibitor for low carbon steel in hydrochloric acid solution. Journal of Materials Science, 45, 979–986. DOI: 10.1007/s10853-009-4028-0.
5. Mobin, M., Zehra, S., and Parveen, M. (2016). L-Cysteine as a corrosion inhibitor for mild steel in 1 M HCl and the synergistic effect of anionic, cationic, and non-ionic surfactants. Journal of Molecular Liquids, 216, 598–607. DOI: 10.1016/j.molliq.2016.01.087.
6. Mazumder, M. A. J. (2019). Synthesis, characterization, and electrochemical analysis of cysteine-modified polymers for the corrosion inhibition of mild steel in aqueous 1 M HCl. RSC Advances, 9, 4277–4294. DOI: 10.1039/C8RA09833F.
7. Marzorati, S., Verotta, L., and Trasatti, S. P. (2019). Green corrosion inhibitors derived from natural sources and biomass wastes. Molecules, 24(1), 48. DOI: 10.3390/molecules24010048.
8. Elabbasy, H. M., Toghan, A., and Gadow, H. S. (2024). Cysteine as an eco-friendly anticorrosion inhibitor for mild steel in various acidic solutions: Electrochemical, adsorption, surface analysis, and quantum chemical calculations. ACS Omega, 9(11), 13391–13411. DOI: 10.1021/acsomega.3c10522.
9. Verma, C., Chauhan, D. S., Aslam, R., Banerjee, P., Aslam, J., Quadri, T. W., Zehra, S., Verma, D. K., Quraishi, M. A., Dubey, S., AlFantazi, A., and Rasheed, T. (2024). Principles and theories of green chemistry for corrosion science and engineering: Design and application. Green Chemistry, 26(8), 4270–4357. DOI: 10.1039/D3GC05207A.
10. Organisation for Economic Co-operation and Development. (1992). Test No. 301: Ready Biodegradability. OECD Guidelines for the Testing of Chemicals, Section 3. OECD Publishing. DOI: 10.1787/9789264070349-en.
11. Abdul, R., Mohan, P., Kumar, P., Singh, N., Goel, P., & Goel, O. (2024). Reducing Supply Chain Constraints with Data-Driven PLM Processes. International Journal of Worldwide Engineering Research, 2(11), 302–317.
12. Balasubramaniam, V. S., Salunkhe, V., Agrawal, S., Goel, P., Gupta, V., & Gupta, A. (2024). Optimizing Cross Functional Team Collaboration in IT Project Management. Darpan International Research Analysis, 12(1), 140–179.
13. Bhatt, J., Bhardwaj, A., Jeyachandran, P., Goel, P., & Jain, A. (2024). The Impact of Standardized ELN Templates on GXP Compliance in Pre-Clinical Formulation Development. International Journal of Multidisciplinary Innovation and Research Methodology, 3(3), 476–505.
14. Gaikwad, A., Mahimkar, S., Gajbhiye, B., Jain, A., & Goel, P. (2024). Optimizing Reliability Testing Protocols for Electromechanical Components in Medical Devices. International Journal of Applied Mathematics & Statistical Sciences, 13(2), 13–52.
15. Goel, P., Rajakumar, J., & Thason, M. (2025). Integrating DevOps Practices in AI-Driven User Interfaces: Streamlining Development, Deployment, and User Experience Optimization. Universal Research Reports, 12(2), 19.
16. Gupta, A. K., Govindankutty, S., Nandyala, A. R., Maria Thason, J. R., Pippal, S., & Gupta, G. K. (2025). AI-Driven Test Automation for Big Data Systems in Cloud Environments. In 2025 First International Conference on Advances in Computer Science, Electrical, Electronics, and Communication Technologies (CE2CT) (pp. 1354–1359). IEEE. https://doi.org/10.1109/CE2CT64011.2025.10941644
17. Jeyachandran, P., Bhardwaj, A., Bhatt, J., Goel, P., & Jain, A. (2024). Reducing Customer Reject Rates through Policy Optimization in Fraud Prevention. International Journal of Research Radicals in Multidisciplinary Fields, 3(2), 386–410.
18. Joshi, A., Salunkhe, V. R., Agrawal, S., Goel, P., & Gupta, V. (2022). Optimizing Ad Performance Through Direct Links and Native Browser Destinations. International Journal for Research Publication and Seminar, 13(5), 538–571.
19. Kankanampati, P. K., Salunkhe, V., Chopra, P., Shrivastav, A., Goel, P., & Goel, O. (2023). Ensuring Compliance in Global Procurement with Third Party Tax Solutions Integration. International Journal of Progressive Research in Engineering Management and Science, 3(12), 488–505. https://doi.org/10.58257/IJPREMS32319
20. Kumar, L., & Thason, J. R. M. (2025). Containerization in Modern Software Architectures: Optimizing Scalability, Portability, and Resource Efficiency. International Journal for Research Publication and Seminar, 16(2), 163–181. https://doi.org/10.36676/jrps.v16.i2.262
21. Maria Thason, J. R., & Prasad, M. S. R. (2025). Bridging the Gap: Integrating Security into DevOps Practices for Enhanced Software Delivery and Risk Mitigation. International Journal of Research in Modern Engineering & Emerging Technology, 13(5), 1–22. https://doi.org/10.63345/ijrmeet.org.v13.i5.130501
22. Maria Thason, J. R., & Rastogi, D. D. (2025). Orchestrating Complex Release Pipelines in DevOps: Strategies for Managing Dependencies, Automation, and Continuous Delivery. Journal of Quantum Science and Technology, 2(2), 6–28. https://doi.org/10.63345/jqst.v2i2.292
23. Murthy, K. K. K., Gupta, V., & Goel, P. (2021). Transforming Legacy Systems: Strategies for Successful ERP Implementations in Large Organizations. International Journal of Creative Research Thoughts, 9(6), h604–h618.
24. Rajakumar Maria Thason, J., & Solanki, S. (2025). Automated Canary Deployments in Continuous Delivery: Balancing Speed and Reliability. International Journal of Enhanced Research in Science, Technology & Engineering, 14(4), 426–448.
25. Saoji, M., Tangudu, A., Pagidi, R. K., Jain, A., & Goel, P. (2021). Virtual Reality in Surgery and Rehab: Changing the Game for Doctors and Patients. Universal Research Reports, 8(4), 169–191.
26. Thason, J. R. M., & Singh, R. K. (2025). Measuring DevOps Success with the DORA Metrics: A Comprehensive Analysis of Key Performance Indicators and Their Impact on Software Delivery. International Journal of Creative Research Thoughts, 13(5), i341–i358. https://ijcrt.org/papers/IJCRT2505957.pdf
27. Viswanatha Prasad, R., Khan, I., Vadlamani, S., Kumar, L., Goel, P., & Singh, S. P. (2020). Blockchain Applications in Enterprise Security and Scalability. International Journal of General Engineering and Technology, 9(1), 213–234.

© 2026. This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0).