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SUSTAINABLE ANTI-CORROSION ADDITIVES DERIVED FROM RECYCLED PLASTIC WASTE

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Abstract

Plastic waste valorization for corrosion control remains underexplored despite its potential to address both environmental pollution and material degradation. This study evaluates the corrosion inhibition performance of molten waste plastic sachets (WPS) as a novel coating material for mild steel, benchmarked against conventional red oxide paint and their combined application. Mild steel coupons were coated and exposed to hydrochloric acid, sodium chloride, and magnesium chloride media over 24 to 72 hours, with corrosion rates determined via weight-loss measurements. The combined WPS/red oxide system consistently exhibited enhanced inhibition performance relative to individual coatings, achieving a maximum inhibition efficiency of 99.77 %, 98.97 %, and 100 % in acidic, sodium chloride and magnesium chloride conditions respectively after 72 hours. The improved performance is attributed to the formation of a compact, hydrophobic barrier that limits electrolyte penetration and surface reactivity. These findings demonstrate a synergistic interaction between WPS and conventional coatings, highlighting a viable pathway for integrating recycled plastic into corrosion protection strategies. This approach offers a cost-effective and sustainable alternative for mitigating steel degradation while contributing to plastic waste management.

Keywords: corrosion inhibition; waste plastic sachets; mild steel; protective coatings; sustainability; acid corrosion

Introduction

Corrosion of metallic materials remains a persistent challenge in modern industry, particularly in sectors such as oil and gas, marine engineering, and chemical processing where metals are routinely exposed to aggressive environments. As an electrochemical process, corrosion leads to the gradual degradation of metals, compromising structural integrity, operational safety, and economic value over time [1,2]. Although thermodynamically inevitable, corrosion can be controlled through appropriate mitigation strategies that reduce its rate and severity [3–5]. The economic implications are substantial, with global losses attributed to corrosion amounting to billions of dollars annually through maintenance, equipment failure, and production downtime [6]. These realities underscore the continued need for efficient, durable, and economically viable corrosion protection approaches.

Among the various corrosion control strategies, the use of protective coatings and chemical inhibitors has gained widespread acceptance due to their practicality and cost-effectiveness. Corrosion inhibitors function primarily by adsorbing onto metal surfaces to form protective films that limit contact between the substrate and corrosive species [7,8]. Conventional systems often rely on inorganic pigments and heavy metal-based additives, which, while effective, pose environmental and health concerns due to their toxicity and persistence [9,10]. Increasing regulatory pressure and growing environmental awareness have therefore accelerated the search for alternative materials that combine high inhibition efficiency with reduced ecological impact.

In this context, polymer-based materials have emerged as promising candidates for corrosion protection. Their ability to form cohesive, adherent, and chemically resistant films makes them particularly suitable for coating applications. Furthermore, the structural versatility of polymers allows for the incorporation of functional groups that enhance adsorption and barrier properties [11–13]. Recent studies have demonstrated that polymeric inhibitors can achieve significant corrosion resistance across a range of environments, including acidic and saline media [14,15]. However, the synthesis and processing of such materials often involve additional costs and environmental burdens, which can limit their large-scale applicability.

Parallel to the challenges of corrosion is the escalating global issue of plastic waste accumulation. The widespread use of synthetic polymers, combined with inadequate waste management practices, has resulted in the persistent buildup of plastic

materials in terrestrial and aquatic environments. These materials are characterized by high chemical stability and resistance to degradation, properties that contribute to environmental pollution but also suggest potential for reuse in durable applications. Consequently, recent research has begun to explore the valorisation of plastic waste as a resource for developing functional materials, including corrosion inhibitors and coating additives [16–18].

The concept of utilizing recycled plastic waste in corrosion protection is particularly attractive, as it addresses two critical challenges simultaneously: reducing environmental pollution and enhancing material performance. Previous studies have reported the conversion of waste polymers, such as polyethylene terephthalate (PET), into functional derivatives capable of inhibiting corrosion through adsorption and film formation mechanisms [19,20]. While these findings highlight the feasibility of plastic-derived inhibitors, existing research has largely focused on chemically modified products or narrowly defined experimental conditions. There remains limited understanding of how minimally processed plastic waste can be directly integrated into coating systems and how such materials perform across different corrosive environments.

Moreover, the potential for synergistic interactions between recycled plastic materials and conventional protective coatings has not been adequately explored. Combining waste-derived polymers with established coating systems may enhance barrier properties, improve adhesion, and extend service life, yet systematic evaluations of such hybrid approaches are scarce. This gap is particularly relevant for mild steel, a widely used engineering material that is highly susceptible to corrosion in acidic and chloride-rich environments commonly encountered in industrial applications.

The present study addresses these limitations by investigating the use of recycled waste plastic sachets (WPS) as a sustainable anti-corrosion additive for mild steel protection. Unlike many prior approaches that rely on chemical modification, this work explores the direct utilization of molten plastic waste as a coating material, both independently and in combination with conventional red oxide paint. The performance of these coatings is evaluated in multiple corrosive media, including hydrochloric acid, sodium chloride, and magnesium chloride solutions, to provide a broader assessment of their effectiveness under varied conditions.

In addition to quantifying corrosion inhibition efficiency through weight-loss measurements, this study seeks to elucidate the underlying protective behavior of plastic-based coatings in terms of barrier formation and resistance to electrolyte penetration. By examining the interaction between recycled plastic and traditional coating systems, the research aims to identify potential synergistic effects that could enhance corrosion resistance beyond that achievable with individual components.

Through this approach, the study contributes to the growing body of work on sustainable corrosion protection by demonstrating a practical pathway for integrating waste-derived materials into functional coating systems. The findings are expected to advance current understanding of polymer-based inhibitors, while offering an environmentally responsible and cost-effective alternative for mitigating corrosion in industrial applications.

Experimental

Preparation of Waste Plastic Sachets (WPS)

Discarded plastic sachets were collected locally and processed prior to use. The preparation involved a sequence of steps to ensure material consistency and cleanliness. Initially, the plastics were manually sorted to remove non-polymeric contaminants. This was followed by thorough washing with water to eliminate adhering dirt, grease, and other residues. The cleaned plastics were then air-dried and mechanically shredded into smaller fragments to facilitate uniform melting. The shredded material was subsequently heated to obtain a homogeneous molten phase suitable for coating application (Fig. 1).



Fig. 1. Converting plastic waste to useful anticorrosion material

Preparation of Mild Steel Coupons

Mild steel specimens were cut into uniform dimensions of approximately 4 cm × 2 cm × 0.2 cm. Prior to coating the coupon surfaces, they were mechanically polished using abrasive paper to remove pre-existing corrosion products and surface irregularities. The polished samples were degreased in acetone for 15 min, rinsed with distilled water, and air-dried. Each coupon was weighed accurately before coating to obtain the initial mass (Fig. 2).

Coating Application

Prepared steel coupons were divided into four (4) groups corresponding to different coating conditions: Molten WPS coating, red oxide paint coating, WPS underlayer followed by red oxide topcoat, and red oxide underlayer followed by WPS topcoat. Coatings were applied uniformly to ensure adequate surface coverage, after which the samples were allowed to dry and stabilize under ambient conditions prior to immersion testing (Fig. 2).

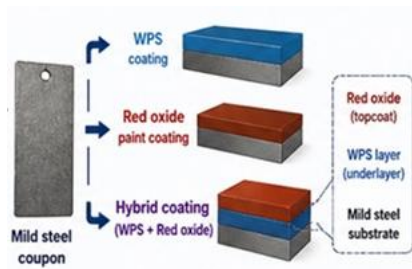


Fig. 2. Coating systems on mild steel coupons

Corrosive Media and Exposure Conditions

Corrosion tests were conducted in three aqueous environments representing acidic and saline conditions commonly encountered in industrial systems. These included 0.5 M hydrochloric acid (HCl), 0.5 M sodium chloride (NaCl), and 0.5 M magnesium chloride (MgCl₂) solutions, all prepared using analytical-grade reagents and distilled water. Each coated coupon was suspended in 250 mL glass containers containing the test solution, ensuring complete immersion without contact with the container walls. The experiments were carried out under static, non-aerated conditions at room temperature. For each coating system and medium, multiple specimens were evaluated over exposure periods of 24, 48, and 72 h (Fig. 3).

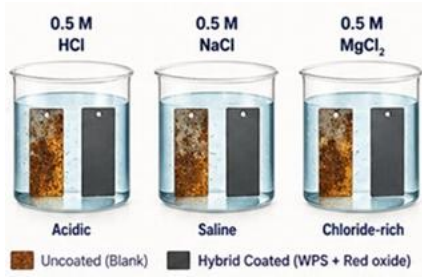


Fig. 3. Exposure of coated systems in aggressive media (24-72 h)

Gravimetric Analysis (Weight-Loss Measurement)

Corrosion behavior was assessed using the weight-loss technique, a widely accepted method for determining corrosion rates in metallic systems. At the end of each immersion period, coupons were retrieved, rinsed with distilled water, gently cleaned to remove corrosion products, dried, and reweighed to determine weight loss and other parameters.

The determination of weight loss (Δ), and corrosion rate (R_{corr}) were made from the following relation [26].

$$\Delta = m_i - m_f \quad (1)$$

$$R_{\text{corr}} = \frac{m_i - m_f}{A t} \quad (2)$$

Where Δ (g) is the weight loss, R_{corr} ($\text{mg} \cdot \text{cm}^{-2} \cdot \text{h}^{-1}$) is the corrosion rate, m_i (g) and m_f (g) represent mass before and after exposure to test solution, respectively, A (cm^2) is the surface area of specimen, and t (time) is the immersion time.

The inhibition efficiency, IE (%) and the surface coverage (θ), which represents the part of the metal surface covered by the inhibitor molecules, were calculated according to the following equations:

$$\% IE = \frac{[W_0 - W] \times 100}{W_0} \quad (3)$$

$$\theta = \frac{W_0 - W}{W_0} \quad (4)$$

Where W_0 and W represent the corrosion rates in the absence and presence of the inhibitors, respectively. The R_{corr} was calculated based on the mass difference before and after exposure, normalized by surface area and immersion time. $IE\%$ and θ were

evaluated to quantify the protective performance of the coatings relative to uncoated samples.

Data Analysis

All measurements were conducted in triplicate and under identical conditions to ensure consistency. The results obtained were compared across four (4) coating systems, three (3) exposure times, and three (3) corrosive media to evaluate trends in corrosion resistance and identify possible synergistic effects between WPS and conventional coatings.

Results and Discussion

The experimental data presented in Tables 1 and 2 provide comprehensive insights into the corrosion behaviour of inhibited and uninhibited mild steel samples in different aggressive media (0.5 M HCl, 0.5 M MgCl₂, and 0.5 M NaCl), and the inhibitory effects of recycled plastic-derived coatings. Figs. (4-5) present graphical details of the corrosion rate and percentage inhibition in the different media.

Weight Loss Analysis

Gravimetric techniques [27] were used in determination of the corrosion rate and corrosion inhibition efficiency of the inhibitors for the various corrosion media. Table 1 presents the weight changes of mild steel samples exposed to fixed concentrations (0.5 M) of acidic (HCl), saline (NaCl), and chloride-rich (MgCl₂) environments, respectively.

Table 1. Weight loss, Δ (g) of Inhibited and Uninhibited Mild Steel

Time	Inhibitors				
	Blank (Uninhibited)	Red Oxide Paint Only	Molten WPS Only	Red Oxide Paint Beneath, Molten WPS Above	WPS Beneath, Red Oxide Paint Above
	In 0.5 M of HCl				
24 hrs	0.653 ± 0.025	0.021 ± 0.020	0.012 ± 0.007	0.190 ± 0.03	0.001 ± 0.006
48 hrs	5.844 ± 0.395	0.015 ± 0.000	0.022 ± 0.003	1.263 ± 0.428	0.012 ± 0.003
72 hrs	2.181 ± 0.011	0.187 ± 0.038	0.115 ± 0.047	0.015 ± 0.010	0.005 ± 0.005
Time	In 0.5 M of NaCl				
	Blank (Uninhibited)	Red Oxide Paint Only	Molten WPS Only	Red Oxide Paint Beneath, Molten WPS Above	WPS Beneath, Red Oxide Paint Above
	In 0.5 M of NaCl				
24 hrs	0.510 ± 0.000	0.002 ± 0.001	0.354 ± 0.045	0.003 ± 0.000	0.013 ± 0.012
48 hrs	0.210 ± 0.000	0.006 ± 0.001	0.150 ± 0.003	0.005 ± 0.000	0.010 ± 0.007

72 hrs	0.290 ± 0.000	0.008 ± 0.003	0.219 ± 0.068	0.029 ± 0.026	0.003 ± 0.000
	In 0.5 M MgCl₂				
24 hrs	0.180 ± 0.000	0.003 ± 0.001	0.001 ± 0.000	0.002 ± 0.001	0.017 ± 0.010
48 hrs	0.290 ± 0.000	0.001 ± 0.001	0.003 ± 0.000	0.004 ± 0.001	0.011 ± 0.011
72 hrs	2.730 ± 0.000	0.008 ± 0.001	0.217 ± 0.040	0.015 ± 0.019	0.000 ± 0.000

Across all media, the blank (uncoated) samples exhibited the highest weight loss, indicative of severe corrosion. For instance, in 0.5 M HCl, the blank samples lost 0.653 ± 0.025 , 5.844 ± 0.395 , and 2.181 ± 0.011 g in 24, 48 and 72 hours respectively, reflecting the aggressive nature of the acidic medium. Conversely, samples coated with recycled plastic and combinations of red oxide paint with plastic demonstrated markedly lower weight losses (Table 1). In 0.5 M NaCl, the “WPS beneath, red oxide paint on top” combination exhibited a weight loss of 0.013 ± 0.012 , 0.010 ± 0.007 , and 0.003 ± 0.000 g in 24, 48 and 72 hours respectively, compared to the blank and when used separately. Similarly, in 0.5 M MgCl₂, the combined coating of WPS and red oxide paint reduced weight loss, emphasizing the protective effect of the polymeric barrier and synergistic coatings.

The results of the experiment showed that corrosion occurred because weight loss corrosion rate over time changed after immersion in an aggressive medium (Fig. 4 (a-c)).

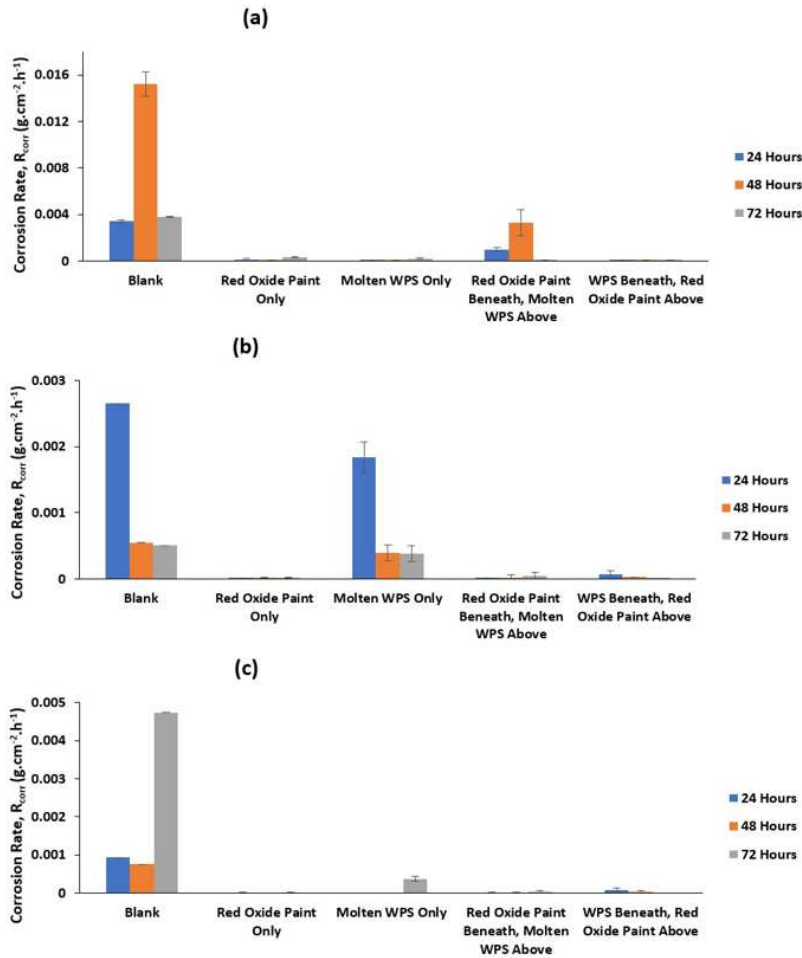


Fig. 4. Corrosion Rate R_{corr} of Inhibited and Uninhibited Mild Steel in Various Media (a) 0.5 M Hydrochloric Acid; (b) 0.5 M Sodium Chloride; and (c) 0.5 M Magnesium Chloride

However, the rate of corrosion varied increasingly in the following trend: HCl, NaCl and MgCl_2 . When mild steel is exposed to hydrochloric acid, it is subjected to what is commonly referred to in the literature as chloride-induced aggressiveness. Halide ions, particularly chlorides, are highly reactive and can disrupt any protective passive films on the metal surface, sometimes even preventing such films from forming altogether. This makes the steel more vulnerable to corrosion, as the natural barrier that would normally slow down metal degradation is compromised. From Fig. 4 (a-c), it is seen that corrosion rate varied with different inhibitors used, there was a significant difference of rate of corrosion (R_{corr}) between blank and coupons coated with inhibitors; the rate decreased subsequently from molten WPS; red oxide paint; and alternated applied inhibitors. This shows the effect of each inhibitors used to reduce corrosion rate.

Inhibitory efficiency (Fig. 5 (a-c)) was observed to increase through all inhibitors but at highest with coupons coated with WPS beneath and red oxide paint on-top.

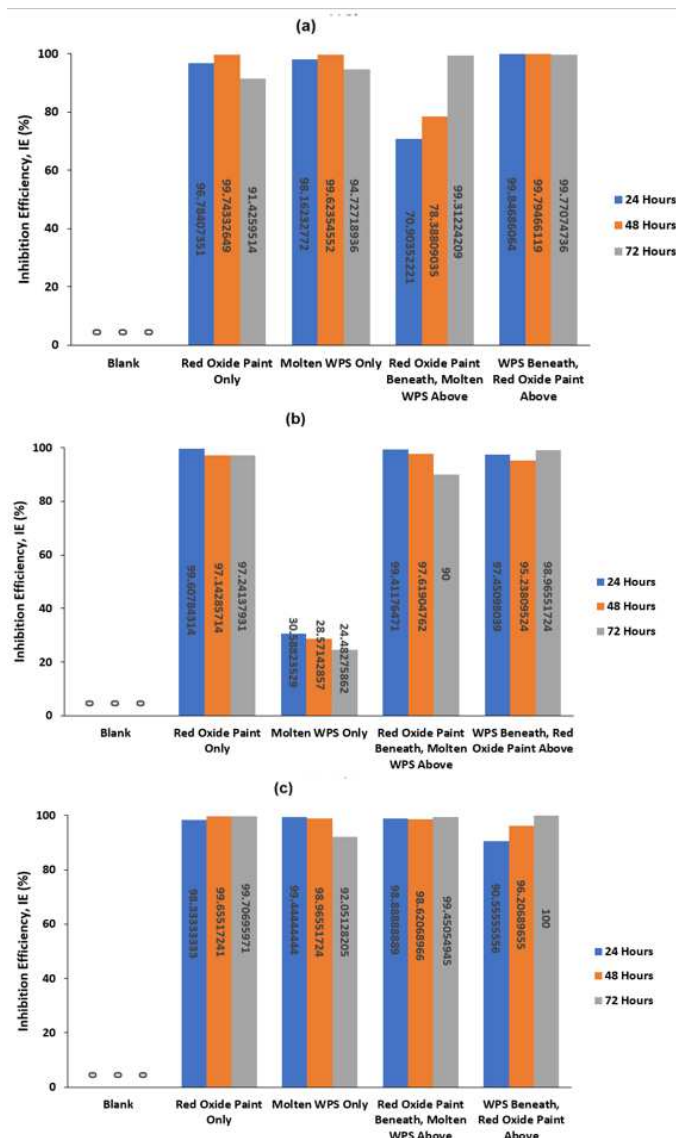


Fig. 5. Inhiition Efficiency of Inhibited and Uninhibitrd Mild Steel in (a) Hydrochloric Acid (HCl), (b) Sodium Chloride (NaCl), and (c) Magnesium Chloride (MgCl₂)

Therefore, it shows a linear decrease in corrosion rate and increase in inhibitory efficiency, IE (%) with time. In employing the gravimetric techniques to investigate the corrosion inhibition properties of aminic corrosion inhibitors on mild steel in HCl solutions, Singh et al., [28] showed that the inhibitors exhibited high inhibition efficiency, with values ranging from 85 % to 95 %. Similar research conducted by Aljourani et al., [29] using plant extract on aluminium in acidic solutions yielded

significant inhibition efficiency ranging from 70 % to 90 %. Electrochemically, NaCl had an enormous effect on the kinetics of corrosion process. Initially, NaCl accelerated the corrosion process by accelerating the dissolution of metal which increased the anodic reaction [30]. Fig. 4 (b), which presents the corrosion rates of the steel coupons after 24, 48, and 72 hours in sodium chloride, shows that metal dissolution occurs most rapidly during the initial 24 hours. After this period, the corrosion rate gradually decreases, likely due to the formation of passivating corrosion products that act as a protective layer on the metal surface. This trend is important because it indicates that prolonged exposure to the corrosive environment can lead to a self-limiting effect, where the metal becomes increasingly resistant to further corrosion. The observed behaviour can be attributed to the concept of passivity, where the formation of corrosion complexes reduces the effective corrosive strength of the surrounding solution over time [30]. Interestingly, this effect is not felt when WPS is used as the sole inhibitor. In $MgCl_2$ environment as shown in Fig. 4 (c), the R_{corr} was slow at 24 hours especially for the blank and the molten WPS, and then became rapid between 48 hours and 72 hours. This occurred when the passive films that were formed between 24 hours and 48 hours broke down and thus corrosion commenced. However, the higher rate of corrosion reflects the increased weight loss of coupons when compared to specimens exposed to HCl and NaCl environments.

The surface coverage (θ), which represents the part of the metal surface covered by the inhibitor molecules is presented in Table 2. The observed trend in coated samples consistently outperforming uncoated samples, aligns with prior studies highlighting the role of polymer-based films in forming physical and chemical barriers against corrosive agents [31,32]. The combination of red oxide paint with molten waste plastic seems to offer dual protection: physical isolation and chemical passivation, reducing the active surface area exposed to the electrolyte.

Table 2. Surface Coverage of Inhibitors in Various Media over 72-Hour Duration

Time	Blank	Red Oxide Paint Only	Molten WPS Only	Red Oxide Paint Beneath, Molten WPS Above	WPS Beneath, Red Oxide Paint Above
	surface coverage (θ) in 0.5 M of HCl				

24	0.000 ± 0.000	0.968 ± 0.200	0.982 ± 0.720	0.709 ± 0.200	0.999 ± 0.760
48	0.000 ± 0.000	0.997 ± 0.997	0.996 ± 0.992	0.784 ± 0.084	0.998 ± 0.992
72	0.000 ± 0.000	0.914 ± 0.454	0.947 ± 0.272	0.993 ± 0.091	0.999 ± 0.545
surface coverage (θ) in 0.5 M of NaCl					
24	0.000 ± 0.000	0.996 ± 0.000	0.306 ± 0.000	0.994 ± 0.000	0.975 ± 0.000
48	0.000 ± 0.000	0.971 ± 0.000	0.286 ± 0.000	0.976 ± 0.000	0.952 ± 0.000
72	0.000 ± 0.000	0.972 ± 0.000	0.245 ± 0.000	0.900 ± 0.000	0.990 ± 0.000
surface coverage (θ) in 0.5 M MgCl₂					
24	0.000 ± 0.000	0.983 ± 0.000	0.994 ± 0.000	0.989 ± 0.000	0.906 ± 0.000
48	0.000 ± 0.000	0.997 ± 0.000	0.990 ± 0.000	0.986 ± 0.000	0.962 ± 0.000
72	0.000 ± 0.000	0.997 ± 0.000	0.921 ± 0.000	0.995 ± 0.000	1.000 ± 0.000

In 0.5 M MgCl₂ (Fig. 4 (c)), plastic coatings alone reduced the corrosion rate to 0.000052 g cm⁻² h⁻¹ at 24 hours, corresponding to a 99.44 % inhibition efficiency, whereas combined plastic and red oxide coatings reached 99.45 and 100 % inhibition at 72 hours (Fig. 5 (c)). This indicates that though chloride ions in MgCl₂ are aggressive, coating combinations can effectively mitigate localized corrosion. Similar trends were observed in 0.5 M NaCl, where the blank sample exhibited an R_{corr} of 0.0005 g cm⁻² h⁻¹ (Fig. 4 (b)), whereas the combined coating achieved inhibition 95 to 98 % (Fig. 5 (b)) in 72 hours.

McMahon et al. [35] conducted a comprehensive review which discusses advanced techniques for evaluating the performance of metal and metal-oxide-based primers in corrosion protection. They examined various assessment methods, and also highlighted the importance of comprehending corrosion inhibition mechanisms and the role of material composition in enhancing substrate protection. The study by Emira et al. [36] evaluated the anticorrosive performance of various paint systems on carbon steel. They prepared an array of paint formulations based on chlorinated rubber and incorporated inorganic materials serving as pigments such as zinc chromate, zinc phosphate, red iron oxide, and treated iron industry waste powder. The study found that the type and concentration of pigments significantly affected the anticorrosive properties of the pigment systems, especially the treated iron industry waste powder.

Rajasekharan and Manisankar [37] investigates the development of a polymer-based red oxide primer for improved corrosion inhibition. They synthesized polyaniline-based (PANI-based) red oxide composite by incorporating PANI into a red oxide base. The composite's performance was evaluated through electrochemical tests, and the study concluded that the PANI-modified red oxide primer exhibited improved corrosion inhibition compared to conventional primers, attributing the appreciable anticorrosion performance to the synergistic effect of PANI and red oxide. Overall, the data in this study suggest that while single plastic coatings provide substantial protection, optimal inhibition occurs when combined with metallic oxide layers, supporting findings by Quraishi et al., [38] who reported that multi-component coatings exhibit both sacrificial and barrier protection mechanisms.

Surface Coverage and Mechanistic Insights

The high inhibition efficiencies observed are indicative of effective surface coverage by the polymeric films. As Table 2 shows, surface coverage often exceeded 95% for the best-performing coatings. This supports the mechanism proposed by many authors, where adsorbed inhibitor molecules occupy active corrosion sites, forming a compact barrier that reduces metal dissolution [39,34]. The synergistic effect of plastic beneath red oxide paint likely arises from enhanced adhesion and decreased porosity, reducing the penetration of aggressive ions to the mild steel surface.

Implications for Sustainable Anti-Corrosion Strategies

These results demonstrate that recycled plastic waste can be valorised into effective corrosion inhibitors, aligning with sustainable material reuse principles. Incorporating such waste into hybrid coatings not only enhances the lifespan of mild steel structures in acidic and saline environments but also addresses plastic pollution. The study aligns with current research emphasizing circular economy approaches in materials engineering [40].

Conclusion

This study highlights the potential of recycled plastic-based coatings as sustainable, high-performance anti-corrosion strategies suitable for industrial applications in harsh environments. Uninhibited mild steel experienced the highest weight loss and corrosion rates across all media, confirming vulnerability to acidic and chloride-

containing solutions. Plastic coatings significantly reduced corrosion rates, achieving up to 99.77 %, 98.97 % and 100 % inhibition in HCl, NaCl and MgCl₂ respectively after 72 hours. Synergistic combinations of red oxide paint and plastic yielded the highest protection, with inhibition efficiencies of 99.54 % in HCl, 94.48 % in NaCl, and 99.72 in MgCl₂. Post analysis, corrosion rates for coated samples remained stable over time, demonstrating the durability of polymeric and hybrid coatings. Surface coverage values approaching 1 indicate effective adsorption and barrier formation, confirming the mechanistic basis of inhibition.

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Clinical Trial Number

Not applicable. This study was not a clinical trial.

Consent to Publish declaration

Not applicable.

Consent to Participate declaration

Not applicable. This study did not involve human participants.

Ethics declaration

This study did not involve human participants, human biological materials, or live animals. Therefore, ethical approval or informed consent was not required.

Author contribution statement

All authors contributed to the study conception, preparation, and design. Material preparation, data collection was carried out by **Theresa Orieji Uchechukwu** and **Hamzah Audu Bawa**. Laboratory and data analysis were performed by **Faith Okwose Oghenekparobor** and **Hamzah Audu Bawa**. The draft of the manuscript was written by **Kenneth Abara Ibe**, and all authors commented on previous versions of the manuscript. The authors read and approved the final manuscript.

Competing Interests Policy

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

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Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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References

1. Wicks ZW Jr, Jones FN, Pappas SP, Wicks DA. Organic coatings: science and technology. 3rd ed. Hoboken (NJ): Wiley; 2007. <https://doi.org/10.1002/047007907X>
2. Roberge PR. Handbook of corrosion engineering. New York: McGraw-Hill; 1999.
3. Popov BN. Corrosion engineering: principles and solved problems. Amsterdam: Elsevier; 2015. <https://doi.org/10.1016/C2012-0-03070-0>
4. Yin J, Lu M, De Gyvez JP. Full-signature real-time corrosion detection of underground casing pipes. IEEE Trans Instrum Meas. 2000;49(1):120-8. <https://doi.org/10.1109/19.836321>
5. Fayomi OSI, Akande IG, Odigie S. Economic impact of corrosion in oil sectors and prevention: an overview. J Phys Conf Ser. 2019;1378(2):022037. <https://doi.org/10.1088/1742-6596/1378/2/022037>
6. Brondel D, Edwards R, Hayman A, Hill D, Mehta S, Semerad T. Corrosion in the oil industry. Oilfield Rev. 1994;6(2):4-18.
7. Nalli K. Appendix VI: corrosion and its mitigation in the oil and gas industries. In: Plant equipment and maintenance engineering handbook. Hoboken (NJ): Wiley; 2012. p. 673-9. <https://doi.org/10.1002/9781118162569.app6>
8. Ossai CI. Advances in asset management techniques: an overview of corrosion mechanisms and mitigation strategies for oil and gas pipelines. Int Sch Res Notices. 2012;2012:570143. <https://doi.org/10.5402/2012/570143>
9. Berntsen T, Seiersten M, Hemmingsen T. Effect of FeCO_3 supersaturation and carbide exposure on the CO_2 corrosion rate of carbon steel. Corrosion. 2013;69(6):601-13. <https://doi.org/10.5006/0553>
10. Eddy NO, Ebenso EE. Adsorption and inhibitive properties of ethanol extracts of *Musa sapientum* peels as a green corrosion inhibitor for mild steel in H_2SO_4 . Afr J Pure Appl Chem. 2008;2(6):46-54.

11. James AO, Oforka NC, Abiola OK. Inhibition of acid corrosion of mild steel by pyridoxal and pyridoxol hydrochlorides. *Int J Electrochem Sci.* 2007;2(3):278-84. [https://doi.org/10.1016/S1452-3981\(23\)17073-8](https://doi.org/10.1016/S1452-3981(23)17073-8)
12. Salami L, Fadayini O, Oso O, Samuel D. Biocorrosion study of mild steel in dumpsite leachates. *Br J Appl Sci Technol.* 2015;11(2):1-10.
13. Abiola OK, Oforka NC, Ebenso EE. The inhibition of mild steel corrosion in an acidic medium by fruit juice of *Citrus paradisi*. *J Corros Sci Eng.* 2003;5.
14. Wright G. Corrosion protection of metals. *Metals J Corros Prot.* 2006;8(2):1-10.
15. Ravikumar HR, Rao SS, Karigar CS. Biodegradation of paints: a current status. *Indian J Sci Technol.* 2012;5(1):1977-87. <https://doi.org/10.17485/ijst/2012/v5i1.33>
16. Turner A, Kearl ER, Solman KR. Lead and other toxic metals in playground paints from South West England. *Sci Total Environ.* 2016;544:460-6. <https://doi.org/10.1016/j.scitotenv.2015.11.078>
17. Milios L, Holm Christensen L, McKinnon D, Christensen C, Rasch MK, Hallstrøm Eriksen M. Plastic recycling in the Nordics: a value chain market analysis. *Waste Manag.* 2018;76:180-9. <https://doi.org/10.1016/j.wasman.2018.03.034>
18. Sy-Changco JA, Pornpitakpan C, Singh R, Bonilla CM. Managerial insights into sachet marketing strategies and popularity in the Philippines. *Asia Pac J Mark Logist.* 2011;23(5):755-72. <https://doi.org/10.1108/13555851111183129>
19. Eugenio FDT, Pajarito BB. Potential anti-corrosion additives derived from waste plastic sachets. *IOP Conf Ser Mater Sci Eng.* 2019;634(1):012039. <https://doi.org/10.1088/1757-899X/634/1/012039>
20. Zhang F, Ju P, Pan M, Zhang D, Huang Y, Li G, et al. Self-healing mechanisms in smart protective coatings: a review. *Corros Sci.* 2018;144:74-88. <https://doi.org/10.1016/j.corsci.2018.08.005>
21. Natarajan KA. Corrosion: introduction—definitions and types. NPTEL lecture. 2014. p. 1-9.

22. Popoola LT, Grema AS, Latinwo GK, Gutti B, Balogun AS. Corrosion problems during oil and gas production and its mitigation. *Int J Ind Chem*. 2013;4(1):35.
23. Grimes JW, Sonke J. Guidelines for corrosion inhibitor selection for oil and gas production. In: NACE Corrosion Conference; 2016. Paper no. 264017. p. 3-4.
24. Cai G, Wang H, Jiang D, Dong Z. Degradation of fluorinated polyurethane coating under UVA and salt spray. Part I: corrosion resistance and morphology. *Prog Org Coat*. 2018;123:337-49. <https://doi.org/10.1016/j.porgcoat.2018.07.025>
25. Armelin E, Oliver R, Liesa F, Iribarren JI, Estrany F, Alemán C. Marine paint formulations: conducting polymers as anticorrosive additives. *Prog Org Coat*. 2007;59(1):46-52. <https://doi.org/10.1016/j.porgcoat.2007.01.013>
26. Abdallah M, Al-Abdali FH, Kamar EM, El-Sayed R, Abdel Hameed RS. Corrosion inhibition of aluminum in 1.0 M HCl solution by some nonionic surfactant compounds containing five membered heterocyclic moiety. *Chem Data Collect*. 2020;28:100407. <https://doi.org/10.1016/j.cdc.2020.100407>
27. ASTM International. Standard practice for laboratory immersion corrosion testing of metals. ASTM G31-12a. West Conshohocken (PA): ASTM International; 2012.
28. Singh AK, Singh A, Quraishi MA. Corrosion inhibition of mild steel in hydrochloric acid solutions by aminic corrosion inhibitors. *J Alloys Compd*. 2017;723:725-36.
29. Aljourani W, Al-Abbas S, Al-Abbas F. Corrosion inhibition of aluminum in acidic solutions by plant extracts. *J Mater Sci*. 2019;54(10):7513-25.
30. Revie RW, Uhlig HH. Corrosion and corrosion control: an introduction to corrosion science and engineering. 4th ed. Hoboken (NJ): Wiley; 2008. <https://doi.org/10.1002/9780470277270>
31. Gao B, Fu Q, Su L, Yuan C, Zhang X. Preparation and electrochemical properties of polyaniline doped with benzenesulfonic functionalized multi-walled carbon nanotubes. *Electrochim Acta*. 2010;55(7):2311-318. <https://doi.org/10.1016/j.electacta.2009.11.068>

32. Rani BEA, Basu BBJ. Green inhibitors for corrosion protection of metals and alloys: an overview. *Int. J. Corr.* 2012;380217:1-15. <https://doi.org/10.1155/2012/380217>
33. Abiola OK, Ebenso EE, Otaigbe JO. Corrosion inhibition of mild steel in acidic medium by organic compounds. *J Appl Electrochem.* 2010;40(3):581-8.
34. Ebenso EE. Novel corrosion inhibitors for mild steel in acidic media. *Corros Sci.* 2003;45(5):813-28.
35. McMahon ME, Santucci RJ Jr, Glover CF, Kannan B, Walsh ZR, Scully JR. A review of modern assessment methods for metal and metal-oxide based primers for substrate corrosion protection. *Front Mater.* 2019;6:190. <https://doi.org/10.3389/fmats.2019.00190>
36. Emira HS, Shakour AA, Abd El Rehim SS, Saleh IA, El-Hashemy MA. Evaluation of corrosion protection of carbon steel by anticorrosive paints. *Anti-Corros Methods Mater.* 2012;59(5):255-62. <https://doi.org/10.1108/00035591211265677>
37. Rajasekharan V, Manisankar P. Polyaniline based red oxide primer paint for efficient corrosion protection. *Anti-Corros Methods Mater.* 2014;61(6):409-15. <https://doi.org/10.1108/ACMM-07-2013-1283>
38. Quraishi MA, Sardar R, Singh AK. Synergistic inhibition of mild steel corrosion in acid medium. *Mater Chem Phys.* 2007;104(1):1-8.
39. Umoren SA, Eduok UM. Adsorption and corrosion inhibition of steel using polymeric surfactants. *J Adhes Sci Technol.* 2011;25(16):2015-32.
40. Uttaravalli AN, Dinda S, Kalidindi P, Venkateshan KC. Preparation and characterization of ketonic polymer for coating applications. *Prog Org Coat.* 2016;99:251-62. <https://doi.org/10.1016/j.porgcoat.2016.06.004>