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To cite this article: R. Elewa *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1107** 012073

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DNA as an Inhibitor for Corrosion Mitigation of Metallic Materials

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Abstract

Recently, the widespread of the applications of metallic materials in various spheres and fields or discipline in material science and engineering cannot be overemphasized. Alongside this great progression in the adoption of these material for use, the corrosion problems associated with these metals are also gradually becoming alarming which has birthed a call to action for immediate and sustainable efforts to salvage the problem. Several inhibitors have been developed in a bid to mitigate this corrosive ordeal facing a lot of industries, but inorganic inhibitors have some vital some shortcomings in form of poisonous substances which on the long run affects the surrounding. The pitfalls from non-organic inhibitors poised the drive of other researchers to develop a better, non-poisonous and organic inhibitive substances like Deoxyribonucleic Acid (DNA) that will mitigate corrosion without any negative residual effect on either the metallic materials or the environment. The DNA corrosion inhibitors have very good potential and economic owing to the source of extraction which is plant and animal waste which is in line with wealth generation prospect from waste product.

Keywords; Non-organic inhibitors, Metallic materials, DNA, Corrosion

1. Introduction

Corrosion occurs when chemical processes or oxidation erodes the surface of metals and their alloys [1]. A scholar defined corrosion as surface attack on the operating metals owing to the ambient conditions and other reactions between metals which is also referred to electrochemical reaction because of the mode of the attack on the metal surface [2-4]. This process causes gradual and progressively severe degradation of metals and the properties poses a lot of problems in the pipeline industries, chemical, marine and petrochemical industries. The surrounding environment of metallic materials really play very significant role on the corrosion effect on the metals [5-7]. To a notable extent, every environment corrosively affects metals, but their effects are varying magnitudes. For instance, acidic environments corrode metals more than environments with distilled water [8-10]. More also, areas with high level humidity and other humid atmospheres relatively initiates corrosion [11]. Owing to the wide application and usage of metals, corrosion has negatively affected several operational machineries, facilities and equipment which has caused a lot of financial and safety problems all over the world. The cost implication for corrosion runs into billions of dollars every year, this is due to the replacement of metal parts in various equipment, machines and structures [12-15]. Apart from the replacement costs, the cost of maintenance and other procedures needed to be performed to monitor corrosion and prevent complete breakdown of equipment and structure is also involved. Also cost of production down time



when equipment fail cannot be over emphasized [16-18]. Apart from the cost, the dangers that corrosion present is also a major source of concern. Sudden failure of various structures like bridges or even equipment poses a major threat to human life. Although corrosion has very damaging effects, the principle of galvanic corrosion is used in batteries to generate electricity. As a result of this incessant degradation of metallic materials, researchers and several academic scholars have intensified efforts to develop coatings in form of inhibitors to combat the effect of corrosion on metals in different environments [19-22]

2. Inhibition of Corrosive Metallic Degradation

An inhibitor for corrosion a substance in form of a chemical that decreases that rate of corrosion when added very little concentration into the surrounding ambience of any materials. Corrosion related problems have cost the United State of America over a sum of \$200 billion per annum. There are several common measures of protection for metals against corrosion like galvanization, cathodic protection, treatment for metal surfaces, use of metals that are corrosion resistant and use of inhibitors [11]. Amongst all the methods for corrosion control and metallic protection, using corrosion inhibitors, has ever been promising and has been the most viable protective method thus far due to ease of handling, very low cost and good inhibition effect for corrosion of metals [14]. Although the adoption of inhibitors is quite attractive due to their relative cost effectiveness and simplicity, the eventualities around their supposed long-term affects the corrosive processes on metals while posing some limitations to their scope of applications. Inhibitors for corrosion are generally categorized into cathodic inhibitors [19], anodic inhibitors [1], and mixed and volatile inhibitors [21]. Generally, the efficiency of most inhibitors increases with relative increase in the concentration of the inhibitors. For instance, a suitable inhibitor with a concentration of 0.004% and 0.008% will make about 90% and 95% efficiency respectively. To further justify the rationale for efficiency, [8] conducted a research to investigate the corrosive behavior of mild steel with six heterocyclic synthesized compound in 0.5M HCl acid and over 95% efficiency was recorded as the inhibition outcome. Moreover, some really vital things should be considered like toxicity, cost, eco-friendliness and availability. Most research findings reported that a vital challenge of frequently utilized volatile composite inhibitors with organic substances containing nitrogen is that they become very poisonous. Another shortcoming of a volatile inhibitor is that the powder is inflammable with potentials to explode when suspended in the air. Hence, this birthed the need for non-poisonous I the form of mixed and organic inhibitors like zincates, aldehydes and amines [9]. with long-term effect, sustainability and applicability without advert or toxic effects. There are notable difficulties encountered during the removal of volatile corrosion inhibitors after the shelf life of use. Furthermore, vapor that prevent corrosion could be non-toxic, and the powders can be toxic if and when inhalation occurs in dust form [13]. According to [16], several inhibitors of corrosion have served for certain applications, but they have also shown some consequential detriments with destructive effects on the environments.

3. DNA as an Organic Inhibitor for Corrosion

A study was conducted by [10] to investigate the effects of deoxyribonucleic acid also known as DNA on the properties of cement paste with corrosion induce by chloride for steel reinforcement in mortars of cement using the technique of electrochemical process with electrochemical independence spectroscopy which is known as (EIS) and linear polarization resistance also known as LPR. The study further reported the outcome of the effect of deoxyribonucleic acid cement paste's mechanical properties upon proper examinations. The distribution of the pore sizes and hydration products of the deoxyribonucleic acid infused in the cement pasted were discovered by the use of Mercury Intrusion Porosimetry (MIP) and

X-ray diffraction (XRD) respectively. The outcome of the study showed that the DNA had significant improvement in the corrosion resistance of the reinforced steel material and the 28d flexural strength. However, a pitfall was discovered from the study as the DNA incorporation affected the 3d compressive strength on a decrease.

In the year 2018, Tüzün & Kaya conducted an experiment to analyse the properties of the molecules of DNA and RNA as potential inhibitors of corrosion. The study was done on five DNA molecules which are uracil, cytosine, adenine, uracil and thymine. Using molecular docking and quantum chemical calculations. The various parameters used were chemical potential, electrophilicity, electronegativity, global softness, nucleophilicity chemical hardness and proton affinity with proper calculations and concise analysis. The outcome of the calculation from the chemical quantum revealed that the ranking of the corrosion inhibitors are in this descending order uracil > thymine > cytosine > adenine > uracil. The additional result theoretically gotten are very germane to the designing of new molecules for corrosion inhibition.

Another study by [4] carefully examined the effect of DNA as a corrosion inhibitor for stainless steel. The Deoxyribonucleic acid (DNA) was gotten through experimental extraction from a calf's thymus gland which forms part of the immune system of mammalian animals. The extracted DNA was used as a coating substance on stainless steel grade of 3CR12 in ambience of hydrochloric acid as the medium. At varying temperature conditions and concentrations, an understudy was carried out on the mechanism of the inhibitor in a bid to expressly elucidate the level of improvement on the corrosion resistance of metal initiated by the inhibitor. It was reported that the best inhibition efficiency from the incorporated DNA was achieved at 20mg/L and 10 °C. It was also revealed by the micrographs using scanning electron microscope (SEM) that the DNA's biomacromolecules got absorbed on the surface of the stainless steel. It was further reported that the demonstration of the Tafel polarization of the DNA inhibitors at varying concentrations outrightly implied mixed-type inhibitors. Results from the X-ray powder diffraction analysis revealed that the efficiency of the inhibition in the HCl medium was increased.

3.1 Economic Value of DNA Inhibitors

Generally, corrosion inhibitors are the trending panacea to curbing the incessant problem of corrosion in metals in various ambience of applications as they significantly help to reduce the rate of corrosion with a resultant effect of reduced losses that could arise from the damage caused by degradational effect of corrosive environments or activities. To a large extent, inorganic inhibitors have mitigated the effect of corrosion on metals but their residual effects like residual poisons in form of powder from coating a major disadvantage which decline the value adding prospect of the non-organic inhibitors. However, the organic inhibitors like DNA are not poisonous [2]. This will also initiate more economic values because the DNA corrosion inhibitors are developed from plant and animal waste which corroborates the waste to wealth philosophy of value addition [3].

Conclusion

The synopsis of the study is that the advent of DNAs as corrosion inhibitors is better than non-organic inhibitors because DNAs help to maintain the properties of the metallic materials in service with appreciable economic return in terms of added value which is gotten from waste conversion to useful products in various fields as a corrosion mitigating agent and not

degrade the metallic materials like other inorganic inhibitors initially mitigates corrosion efficiently but ends up depositing residues on the surface of the metals that gradually depreciates the properties of the materials which will still result into losses .

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