



Corrosion of Dockyard Infrastructural Materials: a Peep into its Causes, Effects and Mitigation Strategies.

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Abstract

Corrosion of dockyard infrastructural materials is a pervasive issue affecting the durability, safety, and economic viability of marine structures. This paper explores the sources, impacts, and mitigation strategies for corrosion in dockyards. The corrosive environment in dockyards, characterized by seawater exposure, high humidity, and mechanical stress, accelerates degradation of materials like steel, concrete, and coatings. Sources of corrosion include seawater, atmospheric conditions, and microbiological activity. Impacts range from structural weakening and equipment failure to environmental contamination and economic losses. Effective mitigation strategies include materials selection, coatings, cathodic protection, and regular maintenance. This review highlights the importance of proactive corrosion management in dockyards, providing insights for stakeholders to optimize infrastructure lifespan and minimize environmental risks.

Keywords: Corrosion, dockyard infrastructures, degradation, sacrificial protection.

Introduction

Corrosion as the name implies is the gradual deterioration of metals and metal containing materials due to chemical reactions with their environment. It is usually defined as the degradation of metals due to an electrochemical process. In this context, it means electrochemical oxidation of metallic materials in reaction with an oxidant such as oxygen. Hence, examples of corrosion in dockyards infrastructures include the steel ship hulls and structures; piers and jetties; pipelines and fuel storage tanks; Cranes and lifting equipment; fencing and gates structures; and electrical and mechanical systems (Collinsdictionary.com, 2022). Corrosion produces lots of damage causing heavy production of oxides or salts of the original material. However, corrosion can also occur in materials other than metals, such as polymers and or ceramics. It is worthy to note that corrosion degrades the useful properties of materials and structures including strength, permeability to liquid and gases and also appearance (Bassil, 2017).

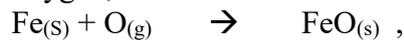
A dockyard (also called a shipyard) is a facility where ships are built, repaired and maintained. These can be yachts, military vessels, cruise liners or other cargo or passenger ships. According to Ronald, & Ronald, (2004) dockyards are sometimes more associated with maintenance and basic activities than shipyards, which are sometimes associated, more with initial construction. Dockyard contains so many infrastructural materials that involve daily activities. These materials are liable to corrosion due to items such as metal that made them up. It is therefore imperative to

know the causes, effects and prevention of this all-important scientific process called corrosion as it affects daily activity of a dockyard.

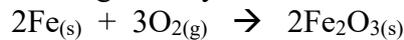
Corrosion is very destructive process to shipyard infrastructural materials. It is therefore worth knowing, the nature of damage, how corrosion affects dockyard materials and their lifespan or durability. So much economic waste has resulted in dockyard operation due to corrosion of valuable infrastructural materials found in dockyard and hence, there is the need to foster solution through regular review of modern development.

The Chemistry of Corrosion

Corrosion as a scientific process is an electrochemical phenomenon which involves degradation of metal due to electrochemical reactions with their environment. When steel is exposed to oxygen, it leads to formation of iron oxides (FeO) as in



which gradually increases to iron (III) Oxide as in



Mild steel which is made up of 99% iron and 0.02% of carbon is the major constituent of infrastructural materials found in dockyards (Barbara, Shaw and Robert, 2016). Corrosion in mild steel takes place by the displacement of carbon by Oxygen.

Types of Corrosion

Corrosion of materials in shipyards comes in various types. The following are some types of corrosion that can be identified in marine environment.

- i. Crevice corrosion
- ii. Galvanic corrosion
- iii. Pitting corrosion
- iv. Grevile corrosion
- v. Uniform corrosion
- vi. Stress corrosion

i) Crevice corrosion

This type of corrosion is very common among dockyard infrastructural materials especially fiber glass boats. In this type of corrosion, water is trapped in crevices found around boats and dockyard materials. It is at the same time reduces air exposure to water/metal interface. Crevice corrosion is also called “closed cell” corrosion because little or no air is allowed to get to the interface (Cramer and Covino, 2012).

ii) Grevile corrosion

This type of corrosion is commonly found in stainless steel materials. It involves chromium interacting with oxygen to form a thin film known as Chromium oxide (Cr_2O_3) which automatically covers the surface of the steel. The presence of any dirt at any portion of the surface of the steel, may tends to reduction to occur leading to corrosion of that surface area, (EPA-Environmental Protection Agency, (2008),).

iii). Pitting Corrosion

This is a localized form of corrosion by which cavities or holes are formed in the material, hence it is known as pitting corrosion. This type of corrosion is common in vessel and other materials whose parts are found sitting in water. Pitting is usually initiated by presence of various shapes of pit made in steel materials, (Melchers. 2005).

iv) Galvanic corrosion

This type of corrosion is caused by the presence of a galvanic cell, essentially between two metals submerged in an electrolyte that results in the attack on the expense of the other (Kenish, 2020).

It is often found in marine environments due to salt water which act as the electrolyte. When galvanized materials are submerged in this type of water, galvanic corrosion occurs.

v) **Stress Corrosion**

This type of corrosion usually occurs when metal is under heavy stress. Presence of crevice corrosion commonly led to stress corrosion due to heavy loading. This kind of corrosion can be found to cause propeller shaft breakage.

Infrastructural Materials found in dockyards

These are equipment, vessels, buildings and technology use in day to activities in a shipyard. These materials include cranes, shipways, drydock/graving dock, synchronists, steel sheet pilings and sea floating dock. Others include generator buildings, fencing material, spare-parts, galvanized plates, nails and fiber glass to mention but few (Benjamin, Amir and Michael, 2011).

Causes of Corrosion of infrastructural Materials

Corrosion is a complex process and is caused by many factors. Some of these factors include:

i) Pollutants in the environment, high velocity water waves, sea wind, residual stress, water and air. Biological and chemical processes convert these substances into toxic and corrosive substances that result into corrosion of steel materials (Roberge, 2000).

Concentration of pollutants in river water containing industrial, agricultural and municipal wastes

Pollutant	Polluted (mg/l)
Total dissolved and suspended solid (TDS/TSS)	BOD (biological oxygen demand) COD (chemical Oxygen demand)
12.22	0.058

Table 1 *Concentration of Pollutants (source: EPA, 2008)*

ii) Another major causes of corrosion of dockyard materials include presence of high salinity in the seawater that continually flow to the seashore of the dockyard and also presence of heavy pollutants such as corrosive chemical, industrial effluents and agricultural waste which are commonly deposited in the river close to the dockyard.

Effects of corrosion on infrastructural materials including docked vessels.

Corrosion in dockyards can have significant effects on infrastructural materials which can be highlighted as follows;

i) **Effects on Metallic materials**

- One major effect of corrosion on Dockyard materials and vessel is reduction of lifespan as a result of deterioration cause by rusting and other factors. This include structural weakening of steel components found in piers, cranes and pipelines
- Pitting and crevice corrosion of stainless steel equipment such as vessel hand rails

ii) **Concrete materials:**

- Degradation of concrete structures such as foundations, walls, and floors.
- Reinforcement corrosion due to chloride ingress.
- Cracking and spalling of concrete surfaces.

iii) **Coatings and paints:**

- Degradation of protective coatings, exposing underlying materials
- Peeling, blistering, or cracking of paint surfaces.

Problems associated with Corrosion of Dockyard Infrastructural Materials.

- i) Safety risks: Structural failure can occur leading to accidents, injuries and even death.
- ii) Economic Losses; another consequences of this manner can lead to huge financial losses due to maintenance, repair and replacement of corroded materials.
- iii) Environmental Impact: the by-products of corrosion can results into further pollution of the environment.

Mitigation Strategies

One major and modern strategy for mitigating corrosion especially in dockyard infrastructural materials is surface coatings. Coatings are essential for improving the life cycle, property, and other consequences. There are three major protective coatings. They are metallic coating, organic coating and inorganic coating.

1) Protective Coatings:

Three protective coating methods have been found highly effective against corrosion of dockyard infrastructural materials.

- i) Metallic coating: in this type of coating, metallic materials are coated on dockyard materials by electroplating, deposition of vapor and by hot dipping process (ojo, Fayemi & Kunle, 2021). Such metallic materials used for this coating process include chromium, silver, copper and tin. It is worthy to note that metallic coating are renowned for their texture.
- ii) Inorganic Coating; this involves the use of chemical action in the presence of electricity or no electricity. It makes use of film deposition of metallic oxide on concrete structure. This technique is often use in industrial application as an alternative to painting. Inorganic provides a better corrosion resistance metallic artifact. It is also use as a pre-coating prior to proper deposition (Ojo, and Kunle, 2021).
- iii) Organic Coating; this coating involves the use of epoxide, polyvinyl chloride (PVC) and polyurethane in coating metallic material such as pipes. Modern research has shown that this coating offers protection for environmental degradation of industrial equipment (Marcos, et al. 2006).

2) Electrodeposition:

This is a modernized old method of protecting metallic materials against corrosion. In this method is also known as electroplating. It involves adding a layer of another metal or composite alloy or an electrolytic oxide film to a metallic material to achieve a desired protection (Ojo, and Kunle, 2021). This can be demonstrated with the outline diagram shown in figure 1.0 below.

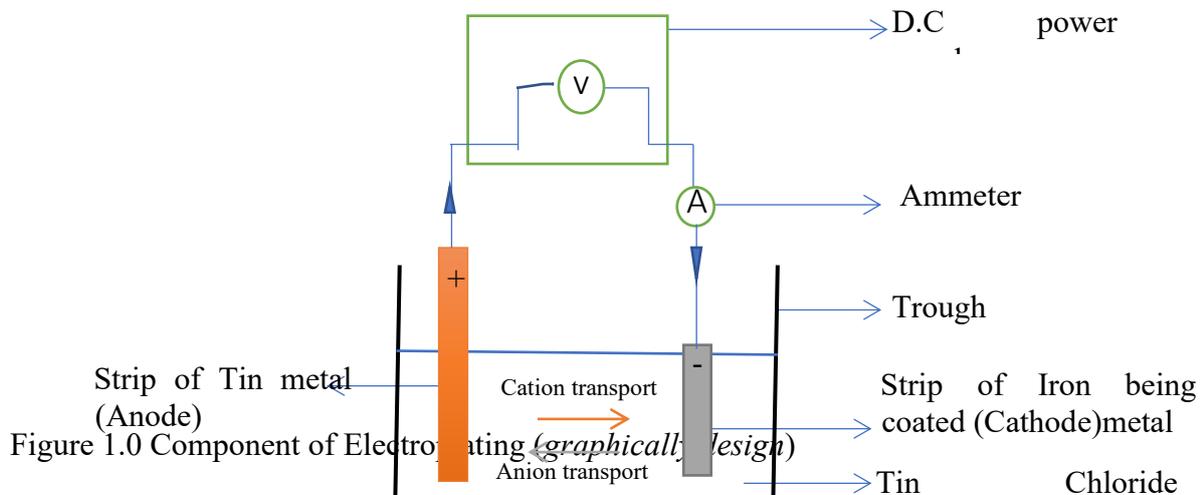


Figure 1.0 Component of Electroplating (*graphically design*)

- 3) Galvanization: this strategy is more or less like the electroplating. However, in this type of protection, steel is coated with Zinc (galvanizing). This causes the zinc to corrode first, thus, protecting the steel material.
- 4) Cathodic Protection (CP): this is a common but very effective strategy for mitigating corrosion. It uses an external electric current or sacrificial anodes to make the target metal a cathode, preventing corrosion. The method is an electrochemical which is used to prevent corrosion on metal structures such as pipelines, tanks, ship hull, docks and offshore platforms. In the process the entire structures are turned into cathode of a corrosion cell (ESC Group, 2021). It involves two strategies; either by using sacrificial anode also known as galvanic or the use of impressed current (ICCP) to supply electrons, for the structure to become resistance to oxidation, thus increasing the span of the material. This strategy prevents costly repairs, reduces maintenance frequency, and significantly extends the life of most dockyard infrastructural materials

Mechanism of sacrificial anode protection:

Sacrificial anodic protection also known as galvanic protection, is a corrosion control method where a more active, less noble metal such as Zinc, Aluminum, or Magnesium is electrically connected to a structural metal, such as steel. The active metal which represents the (anode) corrodes preferentially, sacrificing itself to protect the structure acting as the (cathode) by supplying electrons and reversing the corrosion process.

The mechanism of sacrificial anode protection involves the creation of a galvanic cell. The sacrificial anode has a more negative electrochemical potential than the cathode, causing it to oxidize and release electrons that flow to the cathodic structure, preventing it from losing its own electrons.

In figure 2,0 below, the bars of zinc are acting as the anode which are sacrificed for corrosion in place of the steel vessel hull

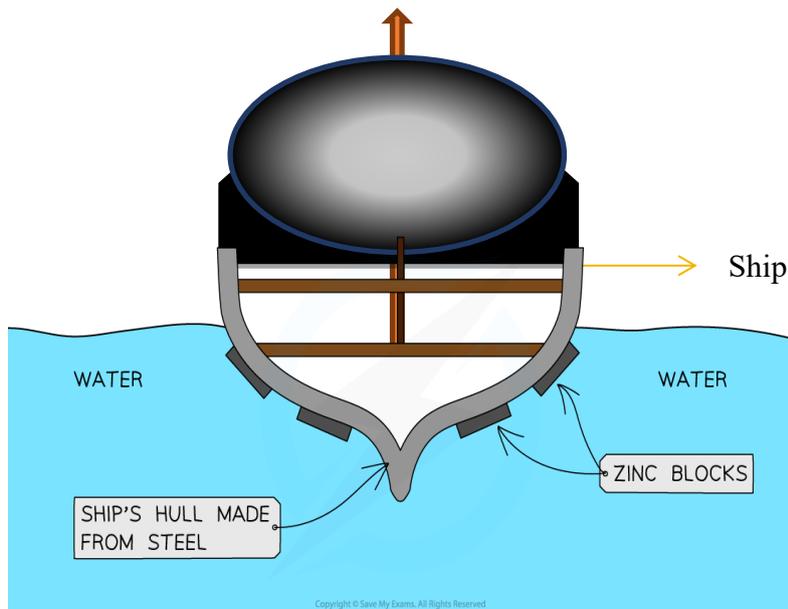


Figure 2.0 The use of zinc bars as anode which sacrificially corrode in place of the steel ship hull.

- 5) Corrosion Inhibitors: This involves the use of chemical compounds added to liquids or surfaces such as ship hulls, to form a protective film that impedes corrosion reactions. Some of these chemicals include oil, water, acids, etc. These chemicals are used in small amounts to create a protective molecular layer on metal surfaces or neutralize corrosive agents, thus, reducing corrosion rates and extending equipment life. Corrosion inhibitors are widely used in dockyard and oil/gas infrastructures and also in cooling system (Jane, and Les, 2025).

Types of Corrosion Inhibitors; there are four main types of corrosion inhibitors.

- Volatile corrosion Inhibitors (VCLs), They are transported in closed environments to the metal surface via volatilization.
- Organic Inhibitors: these are organic chemicals such as carboxylic acids and amines.
- Inorganic Inhibitors: examples include Nitrates, Phosphates, and Molybdates.
- Green Inhibitors: These are non-toxic biodegradable that are derived from plant and plants materials

Mechanisms of operation: these chemical and biological substances work by forming protective films blocking anodic or cathodic area to be protected. They can also increase the electrical resistance of the metal surface.

- 6) Material Selection and Design: This is another good strategy for corrosion abatement. This strategy plays a crucial role in mitigating corrosion in dockyards. Some of the material selections include;
- i) Choosing materials inherently resistant to corrosion, such as; stainless steel of the grade 316L and 304L; Titanium alloys and Fiberglass-reinforced polymers(FRP) (Johirul & Muhammad, 2022)
 - ii) Material compatibility: This is done to ensure materials are compatible with the environment and other materials to reduce galvanic corrosion risks (Bassil, J. 2017)..
 - iii) Design strategies: Some of the Design strategies include avoidance of crevice and dead spots, using corrosion resistant fasteners and application of protective coating.
- 7) Regular Maintenance of dockyard Infrastructural Materials. This can involve inspection and maintenance of the infrastructures regularly. Some maintenance strategies include;

- i. Regular Inspections: this help to identify corrosion signs like rust, cracks, or coating damage, allowing for prompt action.
 - ii. Cleaning: Removing dirt, debris and marine growth prevent moisture accumulation and reduces corrosion risk.
 - iii. Coating Maintenance: Re-applying protective coatings and repairing damaged areas shields materials from corrosive environments.
 - iv. Drainage and Ventilation: Ensuring proper drainage and ventilations reduces moisture buildup and slows corrosion.
- 8) Environmental Control: this involve using substances such as silanes/siloxanes on concrete to prevent moisture infiltration (Mohammad, et al, 2022)
 - 9) Design Strategies: in design and construction of dockyard, the following strategies should be followed to achieve a long-lasting lifespan:
 - Avoidance of crevices and dead spots: in this strategy, areas where water and debris may accumulate should be avoided.
 - Choosing a corrosion-resistant fasteners: this choice when properly taken will not compromise the integrity of the structure.
 - Design for disassembly: In constructing a dockyard, there is the need to allow for easy replacement or maintenance of corroded components, (Roberge, 2000).

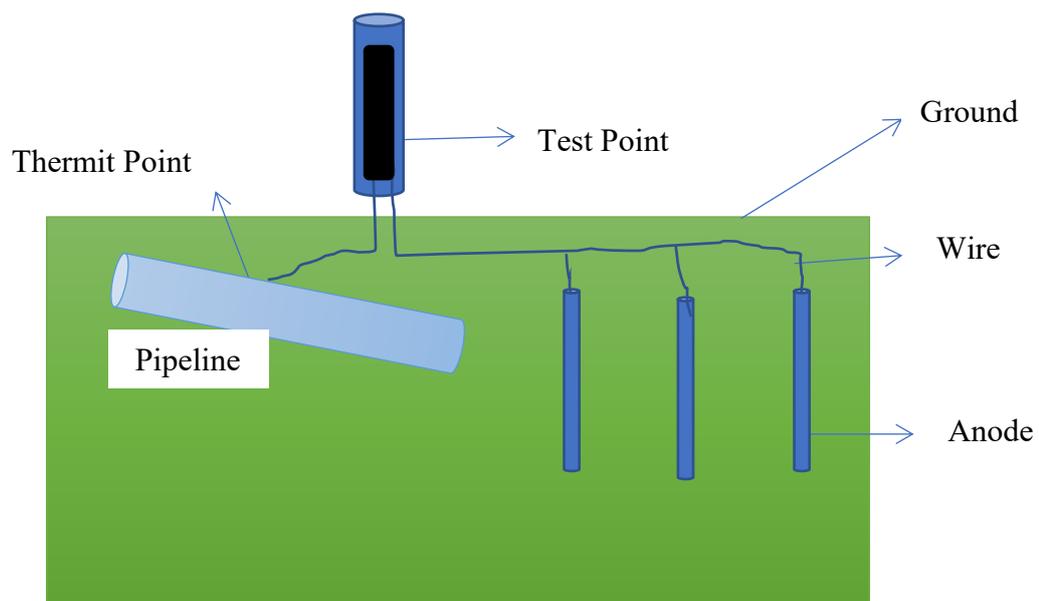


Figure 3.0 *Sacrificial Anode Protection System.*(Graphically design)

These strategies when properly implemented, dockyard infrastructure can be made more resistant to corrosion, reducing maintenance costs and improving safety.

Conclusion:

Corrosion of dockyard infrastructural materials is a significant concern, but proactive maintenance and mitigation strategies can make a huge difference. By understanding the sources, impacts and prevention techniques, dockyard operations can extend infrastructures lifespan, reduce maintenance costs, enhance safety and minimize environmental risks.

Regular Inspections, cleaning, anodic and cathodic protection are key to preventing corrosion. By prioritizing corrosion management, dockyards can ensure structural integrity, operational efficiency and sustainability.

Recommendations

- i. There should be the needs to Implement Regular inspection
- ii. Use corrosion-resistant materials should be put into serious consideration while planning a dockyard.
- iii. Intending owners of dockyard should work on improvement of drainage and ventilation.
- iv. There is the need to provide regular training and awareness campaign.
- v. Stakeholders should develop a corrosion management plan and monitor environmental conditions.

References

- Barbara E.J, Shaw K and Robert L, (2016). Corrosion in mild steel. The 7th Israeli. Conference on Corrosion and Electrochemistry.
- Bassil, J. (2017). Introduction to Estuaries and Marine Pollution, CRC Press. www.researchgate.net cited January, 2026.
- Benjamin V, Amir E and Michael S, (2011). Corrosion control in desalination industry. Michael Schorr ed, ISBN 9789533073118
- Collinsdictionary.com, 2022 retrieved, 2025
- Cramer. S. D. and Covino. B.S. (2012), Corrosion: Environments and Industries eds. ASM Handbook, Vol. 13C, Ohio, 1137 pp
- EPA-Environmental Protection Agency, (2008), USA. Ship building and Repair Industries, www.epa.gov/oeca/sector. USA (accessed August, 2024). ,.
- ESC Group, (2021). Exploring Sacrificial anode cathodic Protection: Key Principles, Advantages, and Uses. A publication of the Marine Rubber Fender System, U.S.A.
- Jane L. and Les C., (2025). Unlocking and Managing the Effects of Corrosion. A publication of the Institute of corrosion.
- Johirul Mohammad , et al, (2022). Predicting biodiesel properties and its optimal fatty acid profile via explainable machines. Renewable Energy, vol. 189, pages 245-258. <https://doi.org/10.1016/j.renene>
- Kennish M.J., (2020), Estuaries and Marine Pollution, CRC Press, practical Handbook of Estuarine and Marine pollution. 1st edition of ebook. Ebook ISBN 9780203742488.
- Manahan S.E.(2020), Fundamentals of Environmental Chemistry, Lewis Publishers, Boca Raton.
- Marcos M. et al. (2006), Polución y Corrosión en Rios Contaminados, 3er. Congreso de Ingeniería Civil, Territorio y Medio Ambiente, Zaragoza.
- Melchers R.E. (2005), Effect of Nutrient-based Water Pollution on the Corrosion of Mild Steel in Marine Immersion Conditions, Corrosion, 61(3), 237-245,
- Ojo S.I.F. and Kunle O.B., (2021). Corrosion Mitigating Techniques and the Mechanisms: Comment. IOP Conference series material science and engineering. 1107(1). A researchGate publication.
- Ronald M. Atlas, Ronald M. Atlas, (2004). A handbook of Microbiological Media. Published by Boca Raton under Chemistry in the Environment. 3rd edition. ebook ISBN 9780429129032.
- Schorr M. and Valdez B.(2006), Pollution and Corrosion in the Kishon River, The 7th Israeli Conference on Corrosion and Electrochemistry.
- Roberge P. R. (2000), Handbook of Corrosion Engineering, Chapter 6: Corrosion Maintenance through Inspection and Monitoring, McGraw-Hill , N.J., 1130pp,.
- Schorr M. and Valdez B.(2005), Corrosion of the Marine Infrastructure in Polluted Seaports, Corrosion Engineering, Science and Technology, 40(2), 137-142,