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The potency of Indian snakeroot, Rauvolfia serpentine, as an anti-corrosion spray

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Abstract

This study evaluates the effectiveness of Rauvolfia serpentine (Indian Snakeroot) as an anti-corrosion spray on mild steel sheets using gravimetric analysis and comparative tests. The tests were performed in selected environments, including freshwater, and saltwater, but focused more on the results in freshwater. Three pieces of mild steel sheets measuring 5.5cm² surface area were used for this experiment and studied in weighing and re-immersing. It was observed that the corrosion rate increases with time exposure to the corrosive medium in the presence and absence of the extract. If the surface was completely sprayed and the percentage of adsorption rose simultaneously, the Rauvolfia serpentina extract would result in a retardation of the mild steel's corrosion rate.

Keywords: Anti-corrosion; corrosion; green inhibitor; Indian snakeroot; Rauvolfia serpentina; spray.

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1. Introduction

Corrosion is defined as a chemical or electro-chemical reaction between a material (usually a metal) and its environment, causing deterioration of the material and its properties (Xing et al., 2023). It is found in air, water, soil, and any environment and often affects most substances. This event is considered catastrophic, and its economic effects have the potential to degrade the metal's look and, in certain situations, cause equipment failure. Apart from material loss, corrosion affects human safety, disrupts industrial activities, and poses a danger to the environment (Odio, et al., 2014).

Corrosion concerns in industry are notable, particularly in the marine area. Corrosion in the marine environment depends on coastline topography, wave action at surf currents, prevailing winds, and relative humidity. The marine atmosphere is filled with fine wind-carried sea salt particles deposited on exposed surfaces causing severe corrosion (Fishman & Crowe, 1977; Wang et al., 2022).

According to the NACE IMPACT study (2016), global corrosion costs are estimated at US $2.5 trillion, which is 3.4% of global GDP in 2013. For example, the United States, a highly developed country, has corrosion costs in its industry of $303.2 billion. This is 20% of the corrosion cost in the economic sector alone. It is recommended to save 15-35% on corrosion costs by using available corrosion control techniques or much like between $375 billion and $875 billion annually on a global basis (NACE IMPACT Report, 2016). A third-world country like the Philippines will gain corrosion control if ever, workers use organic corrosion inhibitors. Moreover, according to Dr. Baccay's study, the country's high humidity and temperature are also critical factors because this speed up the corrosion rate (Fresco, 2016). The other factor that is assumed is that the country is an archipelago; the islands are surrounded by an aqueous environment and most of them are seas.

Mild steel, a high carbon metal, is commonly used in industry and several engineering applications for the production of some automobile components, structural shapes (I beam and angle iron), and sheets that are used in pipelines, buildings, plants, bridges, and tin cans but its susceptibility to corrosion in moist air, water, acids, and other environments is a major barrier limiting its large-scale use (Callister, 1997; So, et al., 2020). Problems caused by corrosion can be mitigated or minimized in a variety of ways, including metal conditioning with coatings, cathodic protection, or the use of corrosion inhibitors (Bradford, 1993).

The use of corrosion inhibitors is widely and industrially accepted as a means of preventing corrosion. Corrosion inhibitors can be defined as chemicals that delay corrosion when added to the environment at low concentrations without significantly changing the concentration of other corrosives (Bradford, 1993). Organic corrosion inhibitors are highly recommended for metal coating. The advantages of using natural products are that they are environmentally friendly, have a low risk of environmental pollution (Nofrizal, et. al, 2012; Jahan et al., 2022), are effective over a wide temperature range, and are compatible with protected materials. It is being studied because it has excellent inhibitory activity, good water solubility, low cost, and low toxicity (Brycki, et al., 2018).

Some plants such as Solanum nigrum, Kappaphycus alvarezii, Piper nigrum, Strychnos nux-vomica, Datura stramonium, Solanum tuberosum, Datura metel, Spirulina platensis, Hydroclathrus clathratus, Caulerpa racemosa, Ervatamia coronary, and Rauvolfia serpentina are good corrosion inhibitors for many metals and alloy, which have shown excellent corrosion inhibition results (Loganayagi, et al., 2014). The present research addresses the potentiality of *Rauvolfia serpentine* as an anti-corrosion spray. The said plant’s phytochemical content is various kinds of alkaloids, flavonoids, saponins, phenols, and tannins (Mittal et al., 2012). R. serpentine indicates 2% fat, 12.4% alkaloid, and 7.35% saponin in plant samples (Malviya & Sason, 2016). The root extract of R. serpentina showed the presence of tannins, saponins, flavonoids, alkaloids, and starch in Deskmukh & Sharma's 1978 qualitative investigation, whereas the leaf extract tested positive for sugar, tannins, alkaloids, flavonoids, and starch. Studies show that green inhibitors include alkaloids, tannins, flavonoids, and other active compounds that contribute to their inhibitory properties (Chowdhary et al., 2004). It is believed that about 10% of plant species produce alkaloids (Okwu & Okwu, 2004). It was previously reported that the entire plant of R. serpentina is rich in alkaloids (Rajeev, et al., 2011). The main alkaloids are present in the roots, stems, and leaves of plants and vary from 1.7 to 3.0%. The bark of the roots contains more than 90% of the total alkaloids of the roots (Malviya & Sason, 2016).

In the study of Bothi Raja and Sethuraman in 2010 the R. serpentina alkaloid extract was tested on sweet steel dissolved in acid solution. It was found that the inhibition efficiency reached up to 95% in the HCl solution and 96% in the H2SO4 solution, with a concentration of 50 ppm of an inhaler at a temperature of 323 K (Bothi Raja & Sethuraman, 2010).

1.1. *Theoretical background*

Two contrary theories were shown in the study.

1.1.1. *The theory of degradation*

The theory of degradation describes gradual the deterioration of an object over time. The article describes the main provisions of the theory of degradation. The theory is built on the energy approach and shows the interaction of the energy of the object and the energy of the external environment (Varlamov, et al., 2018).

1.1.2. *The theory of metal corrosion degradation*

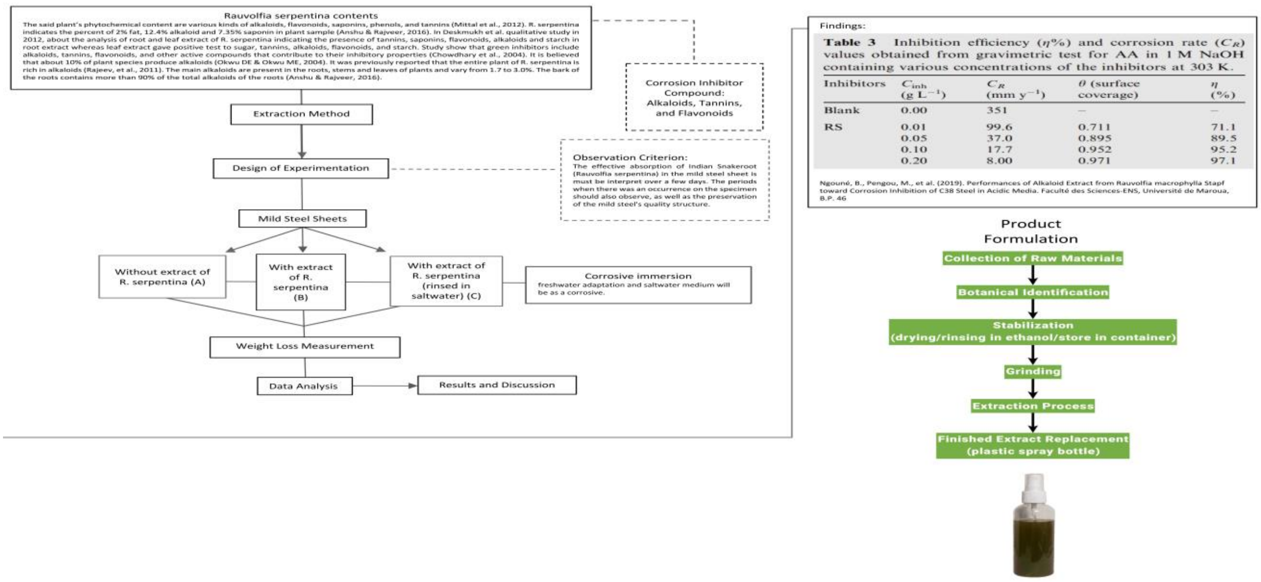
Based on the hypothetical study by Svintradze and Pidaparti in 2010, the equation for correcting the corrosion attenuation due to pitting corrosion behavior is derived from solid-state physics, and some solutions and simulations are presented and discussed (Svintradze & Pidaparti, 2010).

1.2. *Conceptual model*

The conceptual model for this study is seen in Figure 1

Figure 1

Conceptual model



1.3. *Purpose of study*

In this study, the potency of Rauvolfia serpentina extract as an anti-corrosion spray and its inhibition effect on the reinforced steel sheets in water adaptation and the saltwater corrosive medium was evaluated using gravimetric and comparative analysis. The questions the study aims to answer are as follows:

1. Is there a significant weight loss in every time of interval?
2. Is there a significant difference in the corrosion rate of the three samples?
3. Is there significant differences between the three samples beyond comparative analysis?

The hypothesis of the study is: If the amount of adsorption of R. serpentina components to the surface of the sample increases in corrosive immersion, then the rate of corrosion will decrease, and if the weight of the sample (with the extract) is maintained, the inhibition efficiency of R. serpentina components increases.

2. Methods and materials

2.1. Materials

2.1.1. Mild Steel Sheets

The mild steel sheets used for this study were sourced locally. The sheets were obtained by requisition in Taytay, Rizal, Philippines. The sheets were cut into three pieces before obtaining them. The details of steel sheets are presented in Table 1. Steel sheets were rinsed in ethanol, washed using distilled water, and then stored in the container.

Table 1

The Physical Composition of the Steel Sheets

Steel Sheet	Surface Area (cm^2)	Thickness (cm)	Weight (g)
A			5.783
B	5.5	0.02	5.551
C			5.984

2.1.2. Corrosives and reagents

160ml freshwater was used for the first two samples, sheets A and B; 80 saltwater of about 30% fine-grained salt was poured and mixed for the sample, sheet C. 250ml of 70% ethyl alcohol and 500ml of distilled water was used for reagents.

2.2. Formulation of Rauvolfia serpentina product

Fresh Rauvolfia serpentine roots, stem and leaves have been traditionally used for a very long time to cure snake bites, mental issues, type 2 diabetes, and hypertension (Dey et al., 2022; Isah & Zafar 2024; Natarajan et al., 2023; CT et al., 2020). The source of the fresh R. serpentine roots was a local garden in Taytay, Rizal, Philippines. The plants were washed, cut into pieces, pulverized using a blender with at least 40ml of distilled water to spin the blade, and then dried in the sun. The extract of R. serpentina is placed inside a container; the 160ml distilled water and 100 of 70% ethyl alcohol are poured. The container is then closed and kept for at least three days. The substance is stirred periodically, and if placed inside a bottle, it should be shaken from time to time to ensure complete extraction. At the end of extraction, the fine extract of R. serpentina is then separated from the residue by filtration using a cheesecloth and a funnel. The extract was put in the spray bottle combined with the solution of at least 10 ml of 70% ethyl alcohol for preservation.

2.3. Procedure

The process was started 10 minutes before noon. The whole surface of pre-weigh samples B (freshwater medium) and C (saltwater medium) was sprayed with R. serpentine solution, sample A (freshwater medium) was not sprayed and set aside for comparative analysis. The samples were placed in each plastic container. The sheet A and B were carried out in 80ml distilled water and the sheet C was carried out in 80ml saltwater with 30% fine salt on it. Samples then were set aside on a clean empty table, near the window.

After 24 hours of immersion, the samples were washed in distilled water, wiped using tissue paper, and re-weighed using a digital weighing scale (KA67/K1918B model [0.001-50g]). The difference in weight was taken as weight loss. The procedures were repeated after 48, 72, 96, and 120 hours of immersion.

2.4. Data analysis

From the weight modification and weight loss data, the corrosion rate (CR) and inhibition efficiency (IE%) of the plant extract were calculated using formulas 1 and 2 (Odusote, et al., 2016):

1. $CR = \Delta W / AT$; 2. $IE\% = (1 - CR_{inh} / CR_{blank}) \times 100$

where, CR = corrosion rate in (cm^2/hrs.); ΔW = weight loss in (g); A = area of the steel sheet in (cm^2); T = time; IE% = inhibition efficiency rate in (cm^2/yrs.); CR_{inh} = corrosion rate in the presence of the extract and; CR_{blank} = corrosion rate in the absence of the extract.

3. Results

The weight modification against the corrosive media is displayed in Table 2; the weight loss data (ΔW) is displayed in Table 3; the corrosion rate (CR) is displayed in Table 4 and; the inhibition efficiency (IE%) is displayed in Table 5. Corrosion rate against the time of immersion and the image of three samples before and after 120 hours of immersion are depicted in Figures 2 and 3.

Table 2

Weight Modification of the Samples (A, Without Spray of Extract in Freshwater; B, with Spray of Extract in Freshwater; C, with Spray of Extract in Saltwater) in each Time of Immersion.

Sample	24 hrs.	48 hrs.	72 hrs.	96 hrs.	120 hrs.
A	5.782	5.782	5.780	5.778	5.778
B	5.550	5.550	5.550	5.550	5.550
C	5.984	5.983	5.983	5.983	5.980

3.1. Is there a significant weight loss in every time of interval?

Table 3

Weight loss (ΔW) of Samples (A, Without Spray of Extract in Freshwater; B, with Spray of Extract in Freshwater; C, with Spray of Extract in Saltwater) in Each Time Intervals.

Sample	24 hrs.	48 hrs.	72 hrs.	96 hrs.	120 hrs.
A	0.001	0.001	0.003	0.005	0.005
B	0.001	0.001	0.001	0.001	0.001
C	0	0.001	0.001	0.001	0.003

From Table 3, it can be estimated that the weight loss of the samples in the extracts of the absence and presence in different media is significantly reduced compared to the blank solution. Also, as the concentration of the extract increases, weight loss decreases. The decrease in weight loss may be due to the adsorption of tannins, alkaloids, and flavonoids. Adsorption of these compounds on the surface of the steel sheet forms a barrier to the dissolution of the metal in the corrosive medium (Chowdhary et al., 2004).

3.2. Is there a significant difference in the corrosion rate of the three samples?

Table 4

Corrosion rate (CR) of Samples (A, Without Spray of Extract in Freshwater; B, with Spray of Extract in Freshwater; C, With Spray of Extract in Saltwater).

Time Intervals (hours)	Corrosion Rate (CR)		
	A	B	C
24	0.00000138	0.00000138	-
48	0.00000069	0.00000069	0.00000069
72	0.00000138	0.00000046	0.00000046

96	0.00000172	0.00000034	0.00000034
120	0.00000162	0.00000032	0.00000097

From the result analyzed, the average weight loss is 0.005g (A),1.20g (B), and 0.003g (C) with corresponding corrosion rates of values 0.0000162, 0.00000032, and 0.00000097 (mm/yr). The sample B in the presence of extract in freshwater shows a lower corrosion rate when compared to the sample B (without spray of the extract in freshwater. Sample C in saltwater shows a lower amount of corrosion rate than sample A.

Table 5

The inhibition efficiency (IE%) of the Sample in Rauvolfia serpentina Extract Against Freshwater at Each Time of Immersion.

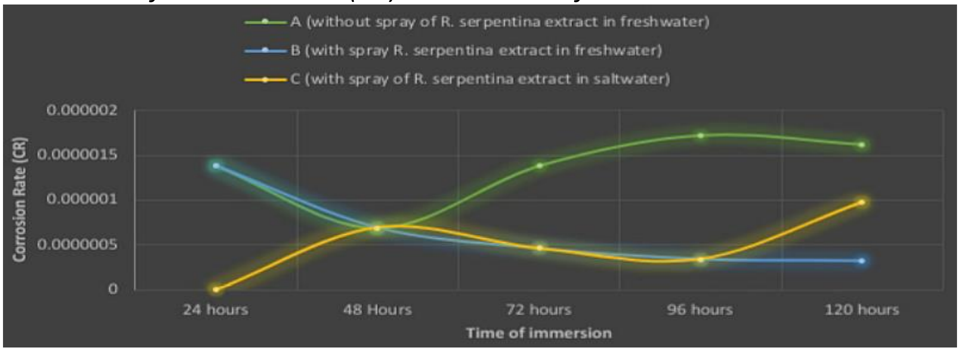
Time of Intervals (hours)	Inhibition Efficiency (IE%) B
24	0
48	0
72	66.67
96	80.23
120	80.25

The stability of the inhibition behavior of the extract was assessed by the passage of inhibition efficiency as a function of time.

3.3. Is there a significant difference in the corrosion rate of the three samples?

Figure 2

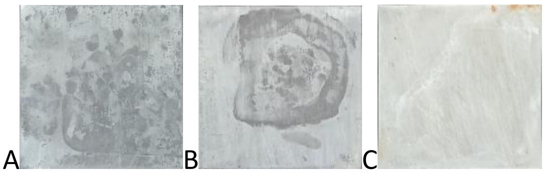
Line Chart of Corrosion Rate (CR) in Each Time of Immersion



3.4. Is there a significant difference between the three samples beyond comparative analysis?

Figure 3

After 120 Hours of Immersion of Samples (A, Without Spray of Extract in Freshwater; B, with Spray of Extract in Freshwater; C, with Spray of Extract in Saltwater).



A B C

By observation, there is a significant difference between the three samples. The amount of pitting corrosion from the B (with a spray of extract in freshwater) is less compared to the A (without a spray of extract in freshwater). It also shows less amount of corrosion present in sample C (spray of extract in saltwater) but the surface color becomes yellowish as it goes through the time of immersion.

4. Conclusions

The results and discussion supported the hypothesis that if the amount of adsorption of R. serpentina components to the surface of the sample increases in corrosive immersion, then the rate of corrosion will decrease, and if the weight of the sample (with the extract) is maintained, the inhibition efficiency of R. serpentina components increases.

It has been found that spraying Rauvolfia serpentina extract onto freshwater and saltwater media reduces the rate of corrosion of steel sheets as the concentration of Rauvolfia serpentina extract increases. Increased inhibition efficiency and weight loss of Rauvolfia serpentina extract showed sample stability in the freshwater medium. From this, we can conclude that it is an extract of R. serpentina can act as an effective anti-corrosion spray for mild steel in both freshwater and saltwater media.

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