# Efficacy of Two Plant Extracts in inhibiting corrosion of mild steel under different media.

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**Abstract**
The study evaluated the efficacy of plant extracts as inhibitors of corrosion in mild steel using different environments, namely hydrochloric acid (HCl), tetraoxosulphate (VI) acid ($H_2SO_4$), atmosphere, distilled and sea water. Thirty six (36) mild steel coupons smeared with *Vernonia amygdalina* (bitter leaf) leaf extract and another set with *Azadirachta indica* (neem) leaf extract) were used for the study. Similar set of coupons unsmeared with either of the above extracts (control) was used for the investigation. Descriptive statistics were used in statistical analysis of collected data. Results showed that *Azadirachta* and *Vernonia* extracts recorded inhibitory efficiencies of 92.5% and 55.3%, respectively. Both plant extracts were more efficient in inhibiting corrosion of mild steel in $H_2SO_4$ medium. Corrosion rate on mild steel was a function of time, type of inhibitor and environment. Further studies should embark on other tropical plant extracts for purpose of comparison with known plant inhibitors.
**Keywords**: corrosion, metal, inhibition, plant extract.

## Introduction

Mild steel which is widely used in industries are often exposed to the action of acid solutions. This is particularly seen in industrial processes involving picking, and acid cleaning. Consequently, the mild steel corrodes easily, requiring the use of inhibitors to slow down the decline in quality (Eddy *et al*., 2008). Inhibitors create a barrier to corroding attack (El Ashry *et al*., 2006). A good number of these inhibitors are toxic and expensive, calling for the need to explore alternative, environmental friendly and cheap inhibitors.

Popular alternatives are plant extracts as they are eco-friendly(Abiola *et al*.,2007; Umoren,2008) including use of some plant derivatives(Wang *et al*.,2007). Plant extracts as inhibitors of corrosion are biodegradable and free from toxicants (Eddy and Odoemelam, 2009). Utilization of plant extract for inhibition of corrosion was reported in different environments (Oguzie, 2006). Neem (*Azadirachta indica*) and bitter leaf (*Vernonia amygdalina*) are plants found to possess phytochemicals such as saponins, tannins, flavonoids and anthraquinones. These phytochemicals are known to possess inhibitory properties. Nwabanne and Okafor (2001) found all the above phytochemicals in bitterleaf (*Vernonia amygdalina*). However, in a similar study, Eddy and Mamza, 2009) reported that tannins, saponins, flavonoids and anthraquinones) are constituents in Neem (*Azadirachta indica*). Apart from the use of these plants in human and farm animal health, their use in suppressing corrosion was the focus of this study. However, the level of efficacy of the plants is necessary to enable end users to make a wise choice of one of the two options in minimizing corrosion of mild steel especially under different environments.

Based on the above, the major objective of the study was to estimate which one of the two plant extracts is most suitable for inhibiting corrosion of mild steel under different environment.

## Materials and methods

Mild steel from universal steel company, Lagos with percentage composition of 0.0292 C, 0.0062 Si, 0.0152 S, 0.2529 Mn, 0.0096 P, 0.0261 Ni, 0.0125 Cr, 0.0869 Cu, 0.0047 Mo, 0.10060 As, 0.0101 Sn, 0.0030 Co, 0.0071 Al, 0.0005 Zn and 99.5350 Fe was used for the study. Solutions used were analytical grade reagent tetraoxosulphate (VI) acid (98% pure) to obtain 2.5 molar solution, 2.5 molar solution of hydrochloric acid, 2.5 molar solution of trioxonitrate (V) acid, distilled water, and sea water from the Atlantic ocean shore at Port Harcourt. Other materials used in the study were silicon carbide, grinding paper (grids of 60, 120, 220), fresh leaves of *Vernonia amygdalina* and *Azadirachta indica*. The study was conducted in confined room temperature.

Equipment used were electrons weighing scale balance, bench vice, plastic containers, measuring glass cylinders, funnels, small grinding machine, copper wires and sever net material.

## Sample preparation

The mild steel was cut to form different coupons, each of dimension 50 x 40 x 11mm with 0.75mm hole and drilled for hanger and easy access of the coupons during removal (Fig. 1). Each coupon was decreased by washing with ethanol rinsed with acetone and allowed to dry in air. This was smeared with the inhibitor extracts of vernornia amygdalina and Azadriachta indica before it was allowed to dry in a dessicator at $40^0$C for prescrivation till it is used. Dried coupon were tagged with white cellophone tape.

The leaves of *Vernonia* and *Azadirachta* were obtained from the Federal University of Technology Owerri, Nigeria, where they were grinded and squeezed out on a bench vice from a sever net material before its use on the mild steel.

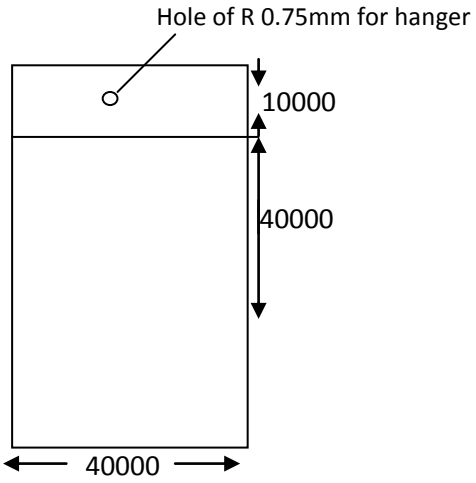


**Fig. 1: Coupon dimension**

**Experiment**

Thirty six (36) mild steel coupons smeared with *Vernonia amygdalina* were tagged $BM^1$ to $BM^{36}$. The same operation was done for *Azadirachta indica* to obtain $DM_1$ to $DM_{36}$. Then 36 mild steel coupons were not smeared but tagged $NM_1$ to $Nm_{36}$ to represent control. These specimens were weighed on electron mass balance in the Department of Materials and Metallurgical Engineering Laboratory, Federal University of Technology, Owerri, Nigeria, and readings were recorded. Slots were cut on the cover of plastic containers (with a litre capacity) to accommodate 3 rows and six columns of coupons. The heights of containers were such that they accommodate the entire height of the coupon except the hanger which was above for easy access of coupons during removal. The experiment was arranged in 3 series viz;

Series A (Acid test on specimen), Series B (Test on sea and distilled water) and Series C (Exposure to the atmosphere).

In series A, the specimens were immersed in each of the acid solution used in the study, name HCl, $HNO_3$ and $H_2SO_4$ at a concentration of 2.5M for each. Eighteen coupons were arranged in three rows and six columns. Two columns contained coupons smeared with a particular plant extract inhibitor while the last row was unsmeared. The acids were poured into the containers carrying the coupons and monitored at intervals of 4 hours for 24 hours.

In series B, the coupons were immersed in sea water and distilled water placed in separate transparent plastic containers. The same set-up as in Series A was put up, except for the timing and the duration of the test. The test was timed at 7 days interval for 42 days on mild steel coupons.

In series C, test was carried out by exposing the specimens to the atmosphere with the same duration as in Series B. The set-up was a little different. The coupons were tied to their holders and hung in an open place where only the atmospheric air came in contact with them. Care was taken not to allow rain water to come in contact with the coupons.

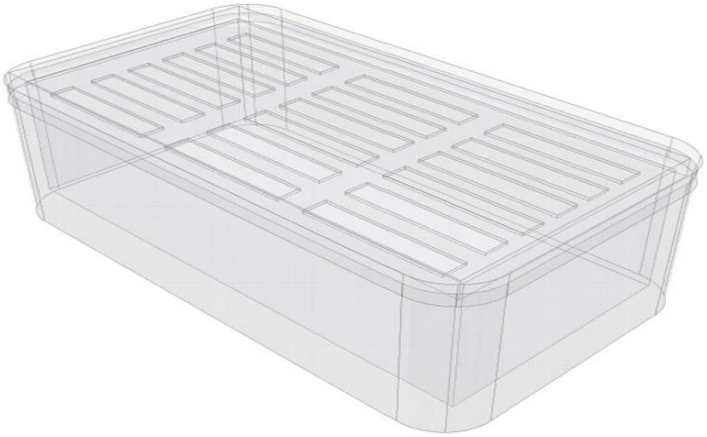

**Fig 2: A fully sliced container**

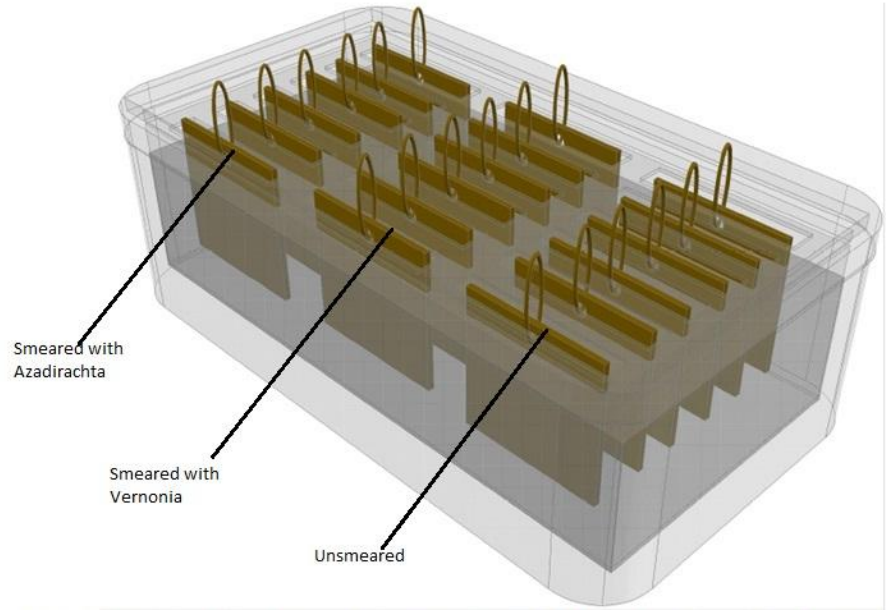


**Fig.3: Container with coupons smeared with inhibitors, arranged and immersed in a medium**

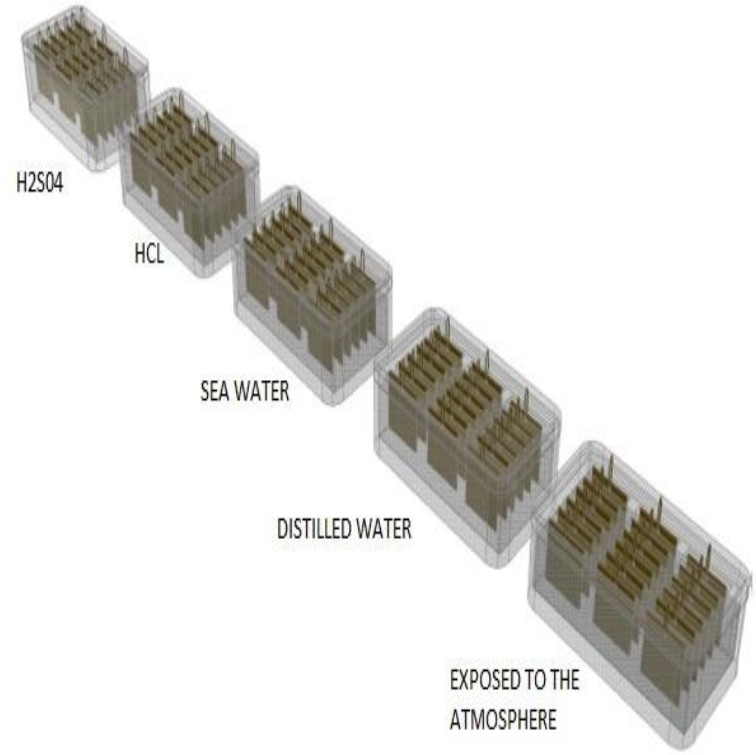


**Fig.4: Arrangement of coupons in different media**

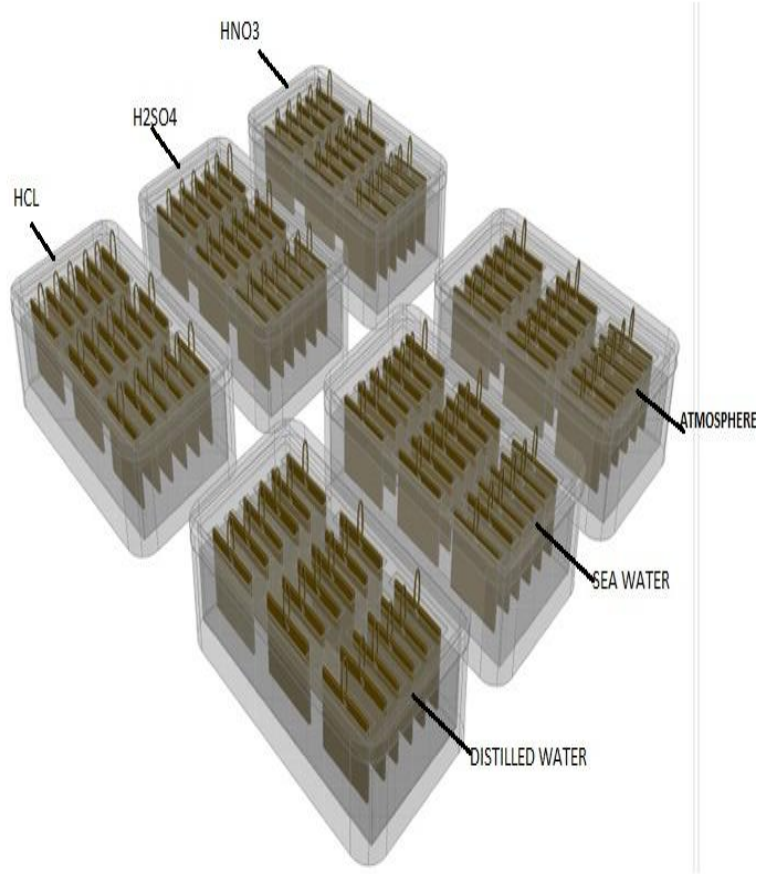


**Fig.5: Final arrangement of coupons both smeared and un-smeared in different media**

**Measurements**

Each sample was withdrawn from the test solutions, washed in a solution containing 50% sodium hydroxide and 100 grams per litre of zinc dust after every time interval (4 hours for series A, and 7 days for series B and C).

The washed samples were dried with acetone before re-weighing. The difference in weight for the interval was taken as the weight loss from the weight loss due to corrosion rate. Inhibition efficiency was thereafter calculated.

**Calculations**

Weight loss of the coupon ($W_{loss}$) was computed as follows:

$W_{loss}$ = Wi – Wf

Where $W_{loss}$ = weight loss(g)

Wi = initial weight(g)

Wf = final weight(g)

Corrosion rate of the acid on the coupon (C.R) was calculated as:

C.R = W/A.T

Where C.R = Corrosion rate

W = Weight loss (mg)

A = area ($mm^2$)

T = time (hrs)

Efficiency of the inhibitors (E1) was computed as:

Where C.Rs = {(C.Rus – C.Rs)/C.Rus} x 100/1

Where C.Rs = Corrosion rate of smeared (inhibitor)

C.Rus = Corrosion rate of unsmeared (control)

**Results and Discussion**

Weight loss of mild steel smeared with *Vernonia amygdalina* and *Azadirachta indica* on exposure for 24 hrs are shown on Table 1. Mean values of weight loss for the two plant extracts were 0.2098g (*Vernonia*), 0.448g (*Azadirachta*) and 0.1765g (control). However, weight loss ranged from 0.088 – 0.552 g (*Vernonia*), 0.081 – 1.182 g (*Azadirachta*) and 0.143 – 0.228 g (control). These values were under the medium of hydrochloric acid (2.5 mol). But, under the medium of tetraoxosulphate (VI) acid, mean values of weight loss were least in mild steel treated with plant extract as follows: 0.720g (*Vernonia*), 0.613 g (*Azadirachta*) and 1.082 g (Control) (Table 2). Values of weight loss ranged from 0.404 – 1.589 g (*Vernonia*), 0.031 – 1.509 g (*Azadirachta*) and 0.327 – 1.783 g (Control). The plant extracts were more effective in reducing corrosion of mild steel using tetra-oxo-sulphate (VI) medium.

**Table 1.** Variation of weight loss in grams(g) with exposure time(days) mild steel smeared with *Vernonia amydgalina* and *Azadirachta indica* juices immersed in acid

| S/N | Test medium | Exposure time (Hours) | coupon Notation | Inhibitors | Initial weight (g) | Final weight (g) | weight loss (g) |
|---|---|---|---|---|---|---|---|
| 1 | | 4 | BM1 | *Vernonia* | 13.662 | 13.574 | 0.088 |
| 2 | | | | *amygdalina* | 13.168 | | |
| 3 | | 12 | BM3 | | 14.062 | 13.888 | 0.174 |
| 4 | | 16 | BM4 | | 13.706 | 13.503 | 0.203 |
| 5 | | 20 | BM5 | | 14.008 | 13.766 | 0.242 |
| 6 | | 24 | BM6 | | 14.006 | 13.454 | 0.552 |
| | | | | *Azadiracta* | | | |
| | | | | *indica* | | | |
| 7 | | 4 | DM1 | | 14.101 | 14.02 | 0.081 |
| 8 | | 8 | DM2 | | 14.113 | 13.959 | 0.154 |
| 9 | HCl (2.5mol) | 12 | DM3 | | 13.99 | 13.824 | 0.166 |
| 10 | | 16 | DM4 | | 14.463 | 13.984 | 0.479 |
| 11 | | 20 | DM5 | | 13.969 | 13.362 | 0.607 |
| 12 | | 24 | DM6 | | 14.939 | 13.757 | 1.182 |
| | | | | Non | | | |
| | | | | Coated | | | |
| 13 | | 4 | NM1 | (Control) | **14.071** | **13.928** | 0.143 |
| 14 | | 8 | NM2 | | 14.277 | 14.126 | 0.151 |
| 15 | | 12 | NM3 | | 14.506 | 14.339 | 0.167 |
| 16 | | 16 | NM4 | | 14.189 | 14.01 | 0.179 |
| 17 | | 20 | NM5 | | 13.883 | 13.692 | 0.191 |
| 18 | | 24 | NM6 | | 13.897 | 13.669 | 0.228 |

**Table 2. Variation of weight loss in grams(g) with exposure time(days) of mild steel smeared with *Vernonia amydgalina* and *Azadirachta indica* juices immersed in acid**

| S/N | Test medium | Exposure time (HOURS) | Coupon notation | Inhibitors | Weight loss (g) | Corrosion rate (mg/mm^2/yr) | Efficiency (%) |
|---|---|---|---|---|---|---|---|
| 1 | | 4 | BM7 | Vernonia | 0.314 | 204.662 | 3.976 |
| 2 | | 8 | BM8 | Amygdalina | 0.404 | 263.323 | 28.114 |
| 3 | | 12 | BM9 | | 0.559 | 364.351 | 30.299 |
| 4 | | 16 | BM10 | | 0.622 | 405.413 | 55.284 |
| 5 | | 20 | BM11 | | 0.743 | 484.280 | 54.333 |
| 6 | | 24 | BM12 | | 1.589 | 1035.694 | 10.881 |
| | $H_2S0_4$ | | | Azadirachta | | | |
| | | | | Indica | | | |
| 7 | | 4 | DM7 | | 0.031 | 20.205 | 90.520 |
| 8 | | 8 | DM8 | | 0.355 | 231.385 | 36.833 |
| 9 | | 12 | DM9 | | 0.394 | 256.805 | 50.873 |
| 10 | | 16 | DM10 | | 0.626 | 408.021 | 54.996 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | 20 | DM11 | | 0.763 | 497.316 | 53.104 |
| 12 | 24 | DM12 | | 1.509 | 983.551 | 15.367 |
| | | | Non Coated | | | |
| 13 | 4 | NM7 | (Control) | 0.327 | 213.135 | |
| 14 | 8 | NM8 | | 0.562 | 366.306 | |
| 15 | 12 | NM9 | | 0.802 | 522.736 | |
| 16 | 16 | NM10 | | 1.391 | 906.640 | |
| 17 | 20 | NM11 | | 1.627 | 1060.462 | |
| 18 | 24 | NM12 | | 1.783 | 1162.142 | |

Weight loss in mild steel treated with the plant extracts using seawater as the environment showed that the extracts especially from *Azadirachta indica* (mean= 0.486 g) was ineffective in inhibiting corrosion in 42 days(Table 3). Mean values were as follows: 0.282g (*Vernonia*), 0.486 g (*Azadirachta*) and 0.210 g (control) (Table 3). In Table 3, weight loss of mild steel ranged from 0.155 – 0.453 g (*Vernonia*), 0.154 – 1.504 g (*Azadirachta*) and 0.09 – 384 g (Control).

Table 4 shows results of weight loss in mild steel smeared with both plant extracts for 42 days in distilled water. Mean values of weight losses using plant extracts were 0.362 g (*Vernonia*), 0.409 g (*Azadirachta*) and 0.172 g (control) under distilled water environment. Values of weight loss in mild steel ranged from 0.112 – 0.848 g (*Vernonia*), 0.152 – 0.867 g (*Azadirachta*) and 0.052 – 0.315 g (control).

Weight loss in mild steel treated with plant extracts for 42 days kept exposed to atmosphere varied with mean values of 0.376 g *(Vernonia*), 0.152 g (*Azadirachta*) and 0.223 g (Control)(Table 5). Ranges of weight in mild steel were 0.102 – 1.268 g (*Vernonia*), 0.117 – 0.186 g *(Azadirachta*) and 0.016 – 1.115 g (Control).

**Table 3. Variation of weight loss in grams (g) with exposure time (days) of mild steel smeared with *Vernonia amydgalina* and *Azadirachta indica* juices immersed in sea water.**

| S/N | Test medium | Dates of removal | Exposure time (DAYS) | Coupon notation | Inhibitors | Initial weight (g) | Final weight (g) | Weight loss (g) |
|---|---|---|---|---|---|---|---|---|
| 1 | SEAWATER | 9/7/2011 | 7 | BM25 | *Vernonia* | 13.952 | 13.797 | 0.155 |
| 2 | | 16/7/2011 | 14 | BM26 | *amygdalina* | 13.937 | 13.703 | 0.234 |
| 3 | | 23/7/2011 | 21 | BM27 | | 14.274 | 14.037 | 0.237 |
| 4 | | 30/7/2011 | 28 | BM28 | | 14.346 | 14.07 | 0.276 |
| 5 | | 6/8/2011 | 35 | BM29 | | 14.483 | 14.144 | 0.339 |
| 6 | | 13/8/2011 | 42 | BM30 | | 13.926 | 13.473 | 0.453 |
| | | | | | *Azadirachta indica* | | | |
| 7 | | 9/7/2011 | 7 | DM25 | | 14.234 | 14.08 | 0.154 |
| 8 | | 16/7/2011 | 14 | DM26 | | 13.646 | 13.427 | 0.219 |
| 9 | | 23/7/2011 | 21 | DM27 | | 13.795 | 13.527 | 0.268 |
| 10 | | 30/7/2011 | 28 | DM28 | | 14.521 | 14.198 | 0.323 |
| 11 | | 6/8/2011 | 35 | DM29 | | 14.146 | 13.698 | 0.448 |
| 12 | | 13/8/2011 | 42 | DM30 | | 14.553 | 13.049 | 1.504 |
| | | | | | Non Coated | | | |
| 13 | | 9/7/2011 | 7 | NM25 | (Control) | 13.794 | 13.704 | 0.09 |
| 14 | | 16/7/2011 | 14 | NM26 | | 14.006 | 13.863 | 0.143 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 15 | | 23/7/2011 | 21 | NM27 | 13.593 | 13.431 | 0.162 |
| 16 | | 30/7/2011 | 28 | NM28 | 13.7 | 13.487 | 0.213 |
| 17 | | 6/8/2011 | 35 | NM29 | 14.379 | 14.109 | 0.27 |
| 18 | | 13/8/2011 | 42 | NM30 | 14.276 | 13.892 | 0.384 |

**Table 4.Variation of weight loss in grams (g) with exposure time (days) of mild steel smeared with *Vernonia amydgalina* and *Azadirachta indica* juices immersed in distilled water.**

| S/n | Test medium | Dates of removal | Exposure time (DAYS) | Coupon notation | Inhibitors | Initial weight (g) | Final weight (g) | Weight loss (g) |
|---|---|---|---|---|---|---|---|---|
| 1 | DISTILLED WATER | 9/7/2011 | 7 | BM19 | *Vernonia* | 14.512 | 14.4 | 0.112 |
| 2 | | 16/7/2011 | 14 | BM20 | *Amygdalina* | 14.854 | 14.704 | 0.15 |
| 3 | | 23/7/2011 | 21 | BM21 | | 14.34 | 14.049 | 0.291 |
| 4 | | 30/7/2011 | 28 | BM22 | | 13.626 | 13.322 | 0.304 |
| 5 | | 6/8/2011 | 35 | BM23 | | 14.226 | 13.378 | 0.848 |
| 6 | | 13/8/2011 | 42 | BM24 | | 14.115 | 13.65 | 0.465 |
| | | | | | *Azadirachta Indica* | | | |
| 7 | | 9/7/2011 | 7 | DM19 | | 14.565 | 14.413 | 0.152 |
| 8 | | 16/7/2011 | 14 | DM20 | | 13.832 | 13.64 | 0.192 |
| 9 | | 23/7/2011 | 21 | DM21 | | 14.675 | 14.366 | 0.309 |
| 10 | | 30/7/2011 | 28 | DM22 | | 13.995 | 13.589 | 0.406 |
| 11 | | 6/8/2011 | 35 | DM23 | | 13.959 | 13.432 | 0.527 |
| 12 | | 13/8/2011 | 42 | DM24 | | 14.934 | 14.067 | 0.867 |
| | | | | | Non Coated | | | |
| 13 | | 9/7/2011 | 7 | NM19 | (Control) | 14.091 | 14.039 | 0.052 |
| 14 | | 16/7/2011 | 14 | NM20 | | 13.831 | 13.748 | 0.083 |
| 15 | | 23/7/2011 | 21 | NM21 | | 13.345 | 13.246 | 0.099 |
| 16 | | 30/7/2011 | 28 | NM22 | | 13.756 | 13.558 | 0.198 |
| 17 | | 6/8/2011 | 35 | NM23 | | 14.365 | 14.082 | 0.283 |
| 18 | | 13/8/2011 | 42 | NM24 | | 14.445 | 14.13 | 0.315 |

**Table 5. variation of weight loss in grams(g) with exposure time(days) of mild steel smeared with *Vernonia amydgalina* and *Azadirachta indica* juices exposed to the atmosphere**

| S/N | Test medium | Dates of removal | Exposure time (Days) | Coupon notation | Inhibitors | Weight loss (g) | Corrosion rate (mg/mm^2/yr) | Efficiency (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | **ATMOSPHERE** | 9/7/2011 | 7 | BM31 | Vernonia | 0.102 | 1.271 | -537.500 |
| 2 | | 16/7/2011 | 14 | BM32 | Amygdalina | 0.138 | 1.719 | -375.862 |
| 3 | | 23/7/2011 | 21 | BM33 | | 0.185 | 2.305 | -374.359 |
| 4 | | 30/7/2011 | 28 | BM34 | | 0.243 | 3.028 | -395.918 |
| 5 | | 6/8/2011 | 35 | BM35 | | 0.321 | 4.000 | -248.913 |
| 6 | | 13/8/2011 | 42 | BM36 | | 1.268 | 15.799 | -13.722 |
| | | | | | Azadirachta | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | Indica | | | |
| 7 | | 9/7/2011 | 7 | DM31 | | 0.117 | 1.458 | -631.250 |
| 8 | | 16/7/2011 | 14 | DM32 | | 0.124 | 1.545 | -327.586 |
| 9 | | 23/7/2011 | 21 | DM33 | | 0.147 | 1.832 | -276.923 |
| 10 | | 30/7/2011 | 28 | DM34 | | 0.164 | 2.043 | -234.694 |
| 11 | | 6/8/2011 | 35 | DM35 | | 0.174 | 2.168 | -89.130 |
| 12 | | 13/8/2011 | 42 | DM36 | | 0.186 | 2.318 | 83.318 |
| | | | | Non Coated | | | |
| 13 | | 9/7/2011 | 7 | NM31 | (Control) | 0.016 | 0.199 | |
| 14 | | 16/7/2011 | 14 | NM32 | | 0.029 | 0.361 | |
| 15 | | 23/7/2011 | 21 | NM33 | | 0.039 | 0.486 | |
| 16 | | 30/7/2011 | 28 | NM34 | | 0.049 | 0.611 | |
| 17 | | 6/8/2011 | 35 | NM35 | | 0.092 | 1.146 | |
| 18 | | 13/8/201 | 42 | NM36 | | 1.115 | 13.893 | |

**Table 5. variation of weight loss in grams(g) with exposure time(days) of mild steel smeared with *Vernonia amydgalina* and *Azadirachta indica* juices exposed to the atmosphere**

| S/N | Test medium | Dates of removal | Exposure time (Days) | Coupon notation | Inhibitors | Weight loss (g) | Corrosion rate (mg/mm^2/yr) | Efficiency (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | **ATMOSPHERE** | 9/7/2011 | 7 | BM31 | Vernonia | 0.102 | 1.271 | -537.500 |
| 2 | | 16/7/2011 | 14 | BM32 | Amygdalina | 0.138 | 1.719 | -375.862 |
| 3 | | 23/7/2011 | 21 | BM33 | | 0.185 | 2.305 | -374.359 |
| 4 | | 30/7/2011 | 28 | BM34 | | 0.243 | 3.028 | -395.918 |
| 5 | | 6/8/2011 | 35 | BM35 | | 0.321 | 4.000 | -248.913 |
| 6 | | 13/8/2011 | 42 | BM36 | | 1.268 | 15.799 | -13.722 |
| | | | | | Azadirachta Indica | | | |
| 7 | | 9/7/2011 | 7 | DM31 | | 0.117 | 1.458 | -631.250 |
| 8 | | 16/7/2011 | 14 | DM32 | | 0.124 | 1.545 | -327.586 |
| 9 | | 23/7/2011 | 21 | DM33 | | 0.147 | 1.832 | -276.923 |
| 10 | | 30/7/2011 | 28 | DM34 | | 0.164 | 2.043 | -234.694 |
| 11 | | 6/8/2011 | 35 | DM35 | | 0.174 | 2.168 | -89.130 |
| 12 | | 13/8/2011 | 42 | DM36 | | 0.186 | 2.318 | 83.318 |
| | | | | | Non Coated | | | |
| 13 | | 9/7/2011 | 7 | NM31 | (Control) | 0.016 | 0.199 | |
| 14 | | 16/7/2011 | 14 | NM32 | | 0.029 | 0.361 | |
| 15 | | 23/7/2011 | 21 | NM33 | | 0.039 | 0.486 | |
| 16 | | 30/7/2011 | 28 | NM34 | | 0.049 | 0.611 | |
| 17 | | 6/8/2011 | 35 | NM35 | | 0.092 | 1.146 | |
| 18 | | 13/8/201 | 42 | NM36 | | 1.115 | 13.893 | |

**Figure 6 indicates weight loss with exposure time of coupon in HCl smeared with plant extracts from *Vernonia* and *Azadirachta* together with the control (unsmeared coupon). There was progressive loss in weight in the three different coupons irrespective of treatment.**

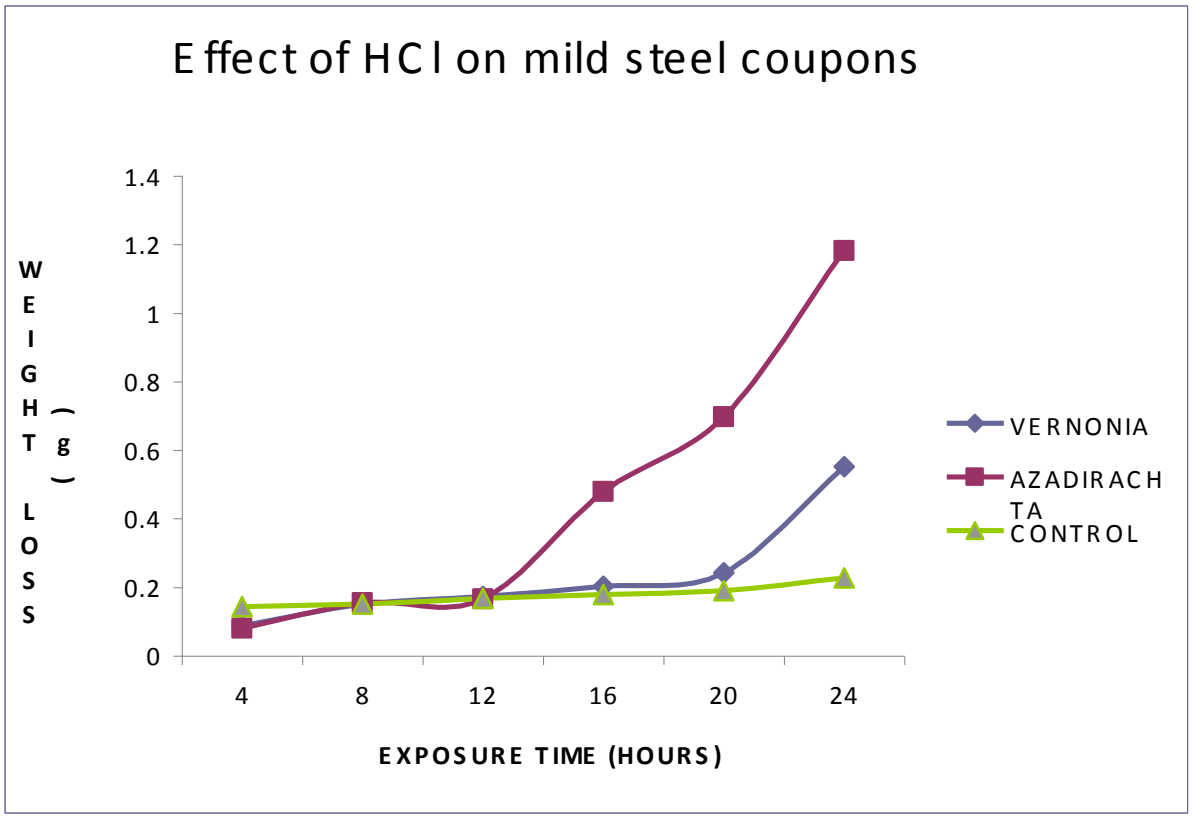


**Fig. 6: Weight loss versus exposure time of coupons in HCl**

The weight loss recorded in *Azadirachta indica* after 12 hours was rapid followed by *Vernonia* after 24 hours while weight loss in mild steel remained low in the control. This can be attributed to high concentration of chloride ion in the environment similar to the study earlier conducted by Phanasgaonkar *et al.* (1996).

There was more weight loss of mild steel from the un-smeared coupon (control) and those of smeared coupons under HCl (Fig. 6).Similar pattern was followed by the plant extracts under $H_2SO_4$ medium. An initial decrease in weight loss with *Azadirachta* occurred at the commencement of the experiment, indicating that absorption took place initially. However, it was observed that coupon smeared with *Vernonia* had higher weight loss than that with *Azadirachta*. Corrosion rate of coupon with exposure time using $H_2SO_4$ environment is shown in Fig 9. Similar distribution was recorded in Fig. 8.

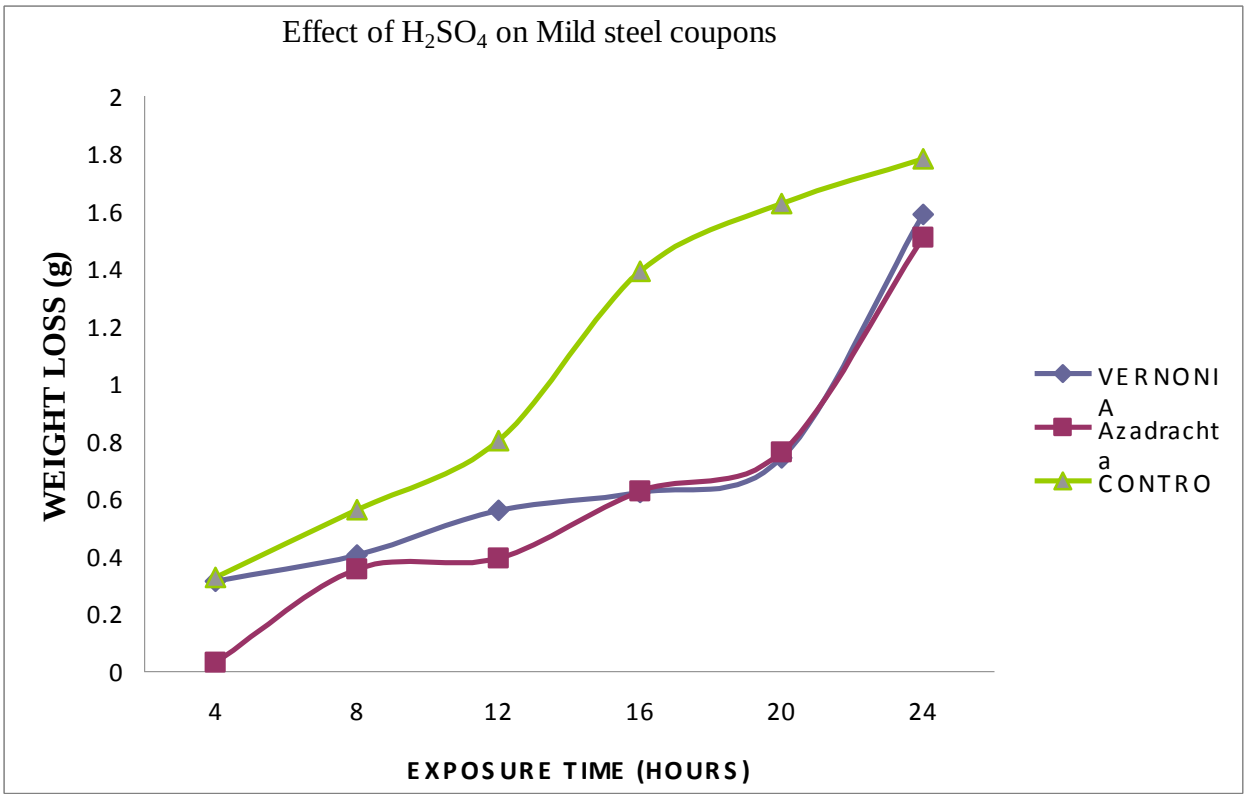


**Fig 7: Weight loss versus exposure time in $H_2SO_4$**

Initially, corrosion rate was low for *Azadirachta* followed by *Vernonia* than control with first 8 hours (Fig. 8). All the coupons had almost the same rate of corrosion at the 12th hour, but, the corrosion rate of *Azadirachta indica* rose rapidly after 12 hours (Fig. 8). However, *Vernonia* rose above the control at 20th hour while the control maintained low rate of corrosion throughout the experiment. Low corrosion at the beginning of the experiment indicates absorption of plant extracts.

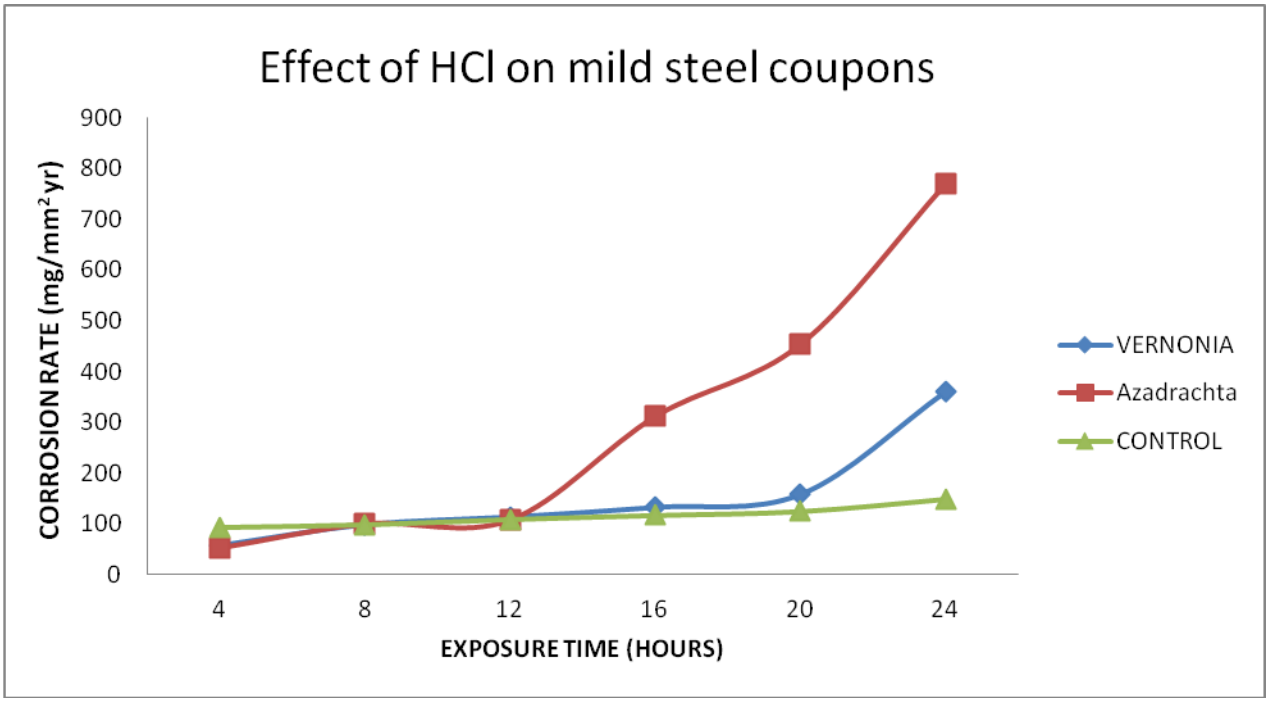


**Fig 8: Corrosion Rate versus exposure time for Mild Steel in HCl**

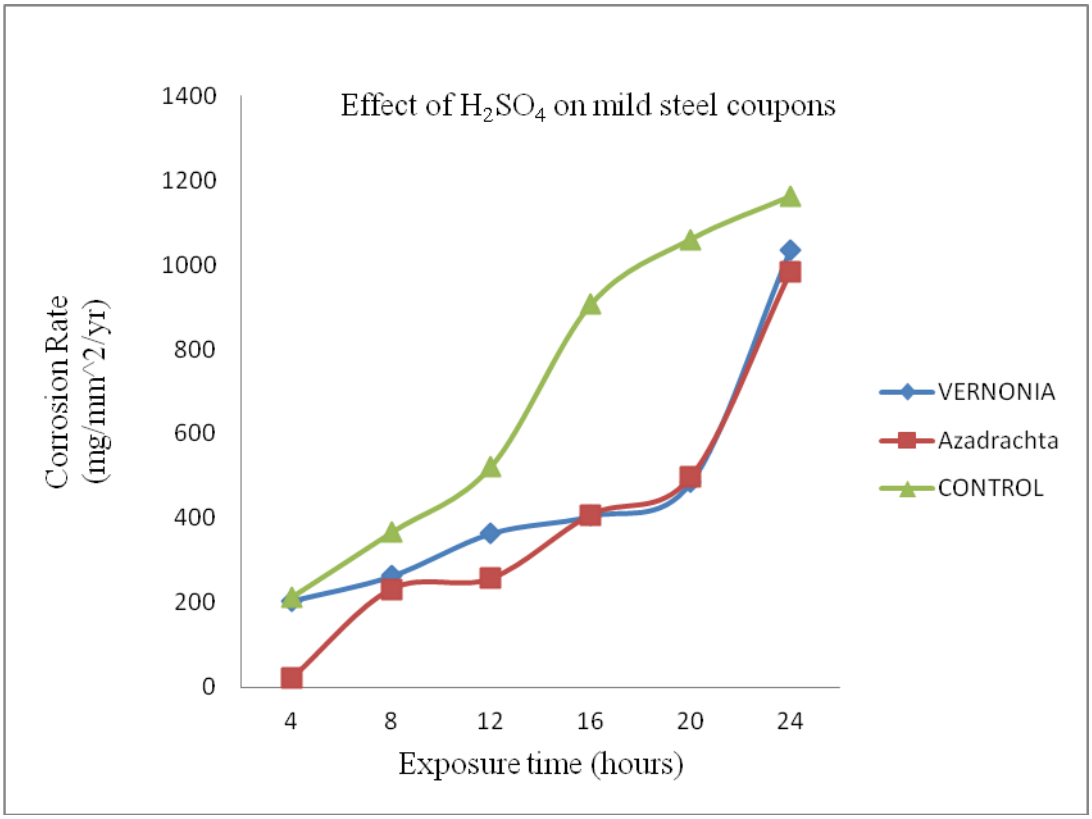


**Fig 9: Corrosion Rate versus exposure time in $H_2$ $SO_4$**

Inhibition efficiency is shown in Fig. 10 under the hydrochloric acid environment. The inhibition efficiency of *Azadirachta* was 43.36% while that of *Vernonia* stood at 38.46% at the first 4 hours. Inhibition efficiency of plant extracts decreased substantially due to the chloride environment. It could be that the plant extracts were damaged by the protective oxide hence are not good inhibitors in a chloride environment.

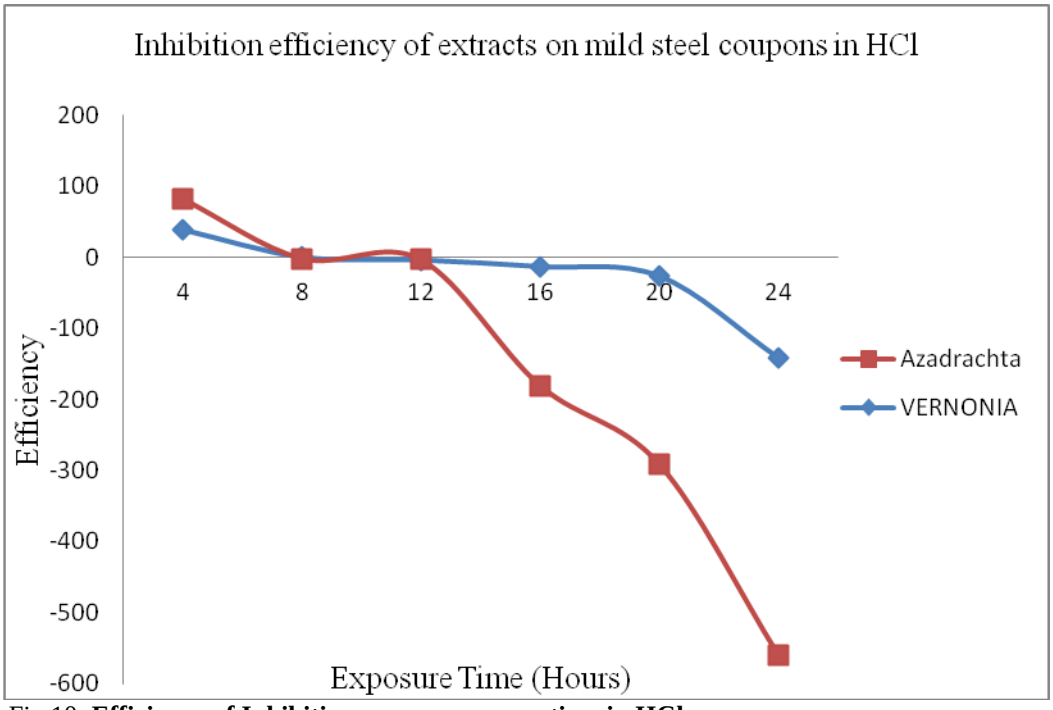


Fig 10: **Efficiency of Inhibition versus exposure time in HCl**

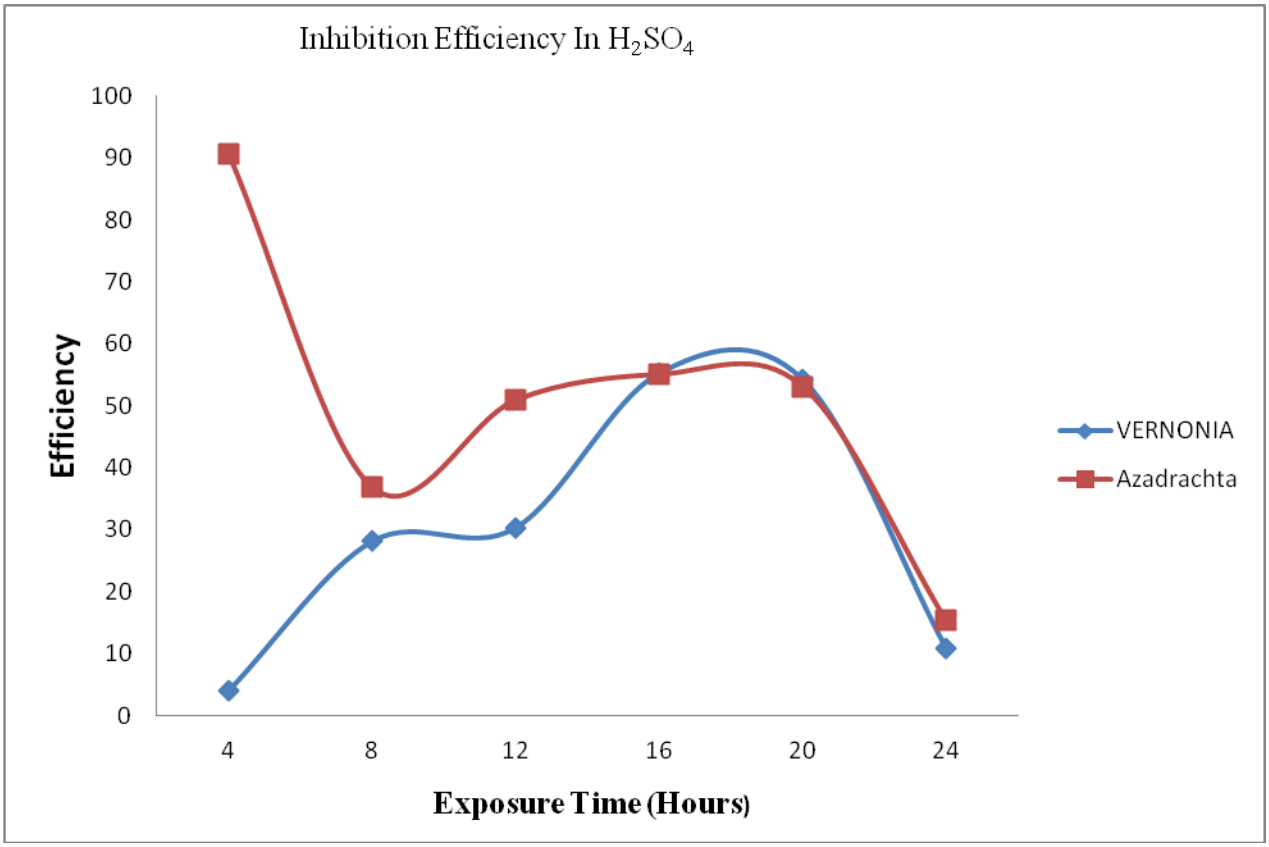


**Fig 11: Shows inhibitive efficiency versus exposure time in $H_2SQ_4$**

Inhibitive efficiency of plant extracts under $H_2SO_4$ over 24 hours is given in Fig. 11. Although both inhibitors are effective in $H_2SO_4$ medium, *Azadirachta* (92.5%) was found to the more efficient than *Vernonia* (55.28%).

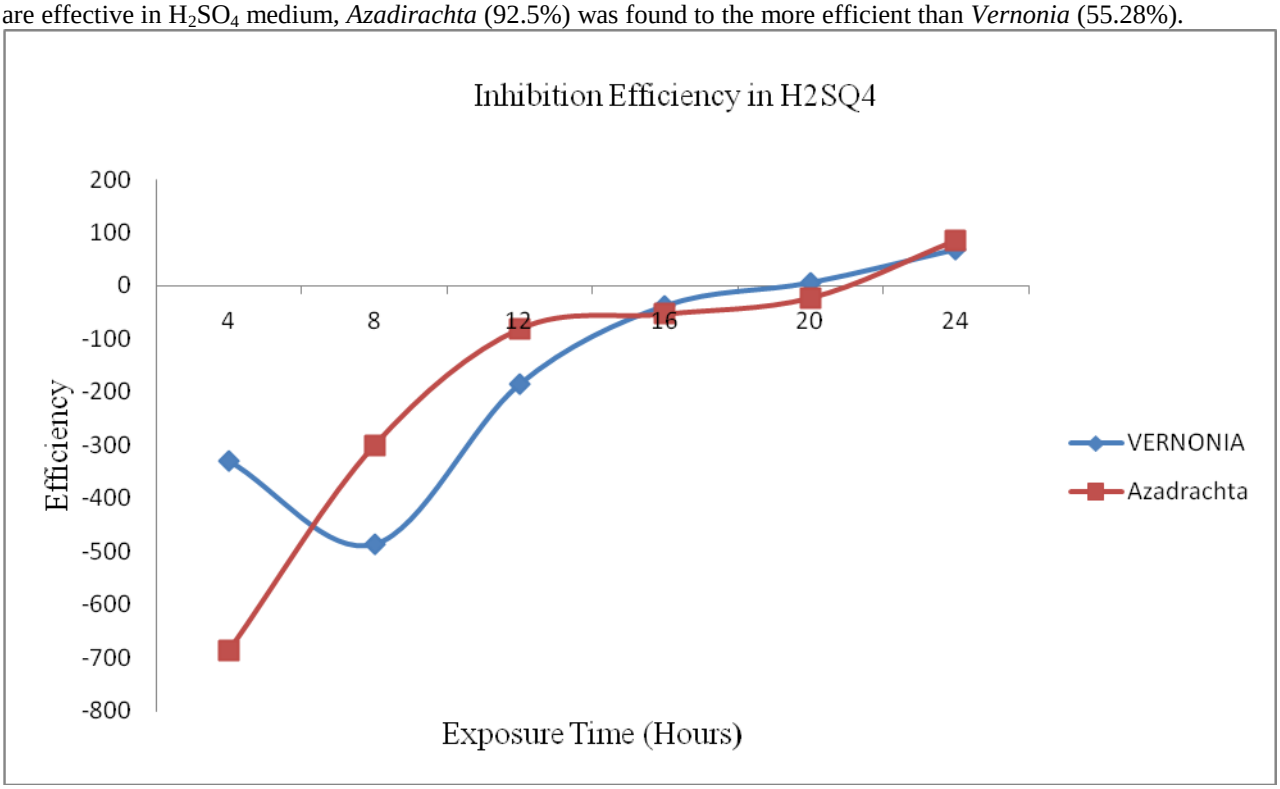


**Fig. 11: Inhibitive Efficiency versus exposure time in $H_2SO_4$**

The effectiveness of inhibitors depends on the relative concentration of chloride, inhibitor species and corrosion state of the steel at the time of treatment (Phanasgaonkar *et al.*, 1996). With the smearing of the plant extracts and drying, absorption has already taken place, and $H_2SO_4$ is believed to have strong affinity for water. Consequently, the inhibitors were able to inhibit corrosion of mild steel. In *Vernonia*, an increase in efficiency from a minimum of about 4% to 55.3% maximum after 20 hours is an indication that it reacted with the environment by electrochemical reduction to form product which is more effective. In *Azadirachta*, its decrease in efficiency is attributable to decrease in electrochemical reduction in line with findings of Thomas (1994).

Earlier studies showed that *Azadirachta* showed efficiency of 73.62% in $H_2SO_4$ (Eddy and Mamza, 2009) and 98.03% for *Vernonia* using alcohol extract (Odiongenyi, 2009). Given the result of inhibitory efficiency of 53.3% (*Vernonia*) and 92.5% (*Azadirachta*), one can deduce from this study that, both plant extracts can be used as inhibitors of corroding mild steel even without alcohol as the environment.

**Conclusion**

Plant extracts under $H_2SO_4$ medium exhibited greater inhibitory efficiency on corroding mild steel when compared other environments such as HCl and sea water. There was progressive loss in weight in mild steel coupons irrespective of treatment and medium. Corrosion rate differed with time among the plant extracts. Inhibition efficiency decreased substantially in HCl medium due to damage by chloride ions.

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