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INVESTIGATING THE CORROSION INHIBITION EFFECTS OF TAGETES ERECTA L. LEAF EXTRACT ON ALUMINIUM IN ACIDIC MEDIUM

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ABSTRACT

The corrosion inhibitive effect of *Tagetes erecta L* as an eco-friendly inhibitor for the corrosion control of Aluminium in 0.5 Molar solution of HCl acid have been investigated using the weight loss method which is considered best informative than other laboratory methods. The study was carried out using 0.5m - 4.8ml of the *Tagetes erecta L* leaf extract respectively. Aluminum sheets of purity 97.9% were used in this study. Each sheet was 0.14cm thick and was mechanically cut into rectangular coupons of dimension 3 cm x 2 cm. The total surface area of the coupon used was 20 cm^2. These coupons were used without further polishing. However, surface treatment of the coupon involved degreasing in absolute ethanol and drying in acetone. The test coupons were totally immersed in the corroding 0.5M HCl containing various concentration of the inhibitor African marigold (*Tagetes erecta L*) at the time intervals of 5 - 25 hours. Maximum inhibition efficiency of 72.2% was obtained at the concentration of 4.8ml .The corrosion effect was investigated thoroughly and the corrosion rate was found to decrease while the inhibitive efficiency increases as the inhibitor concentration was increased. The study showed that *Tagetes erecta L* possesses inhibiting properties for reducing the corrosion rate of aluminium in 0.5M HCl acid.

KEYWORDS: Aluminium coupon, Corrosion rate, 0.5M HCl, Inhibitive effect, *Tagetes erecta L*.

1. INTRODUCTION

Corrosion can be defined as the gradual destruction of materials (usually metals) by chemical and/or electrochemical reaction with their environment. Or corrosion is defined as the natural process which covert a pure metal to a more stable form (ores), such as its sulfide, oxides and hydroxides. Corrosion has caused so many damages that an engineer, while selecting a metal for an application has to take into consideration the corrosion resistance of the metal/alloy in that specific environment .Corrosion is like an enemy to man because of its major effect and damages to modern technological products. Corrosion is not only dangerous, but also causes annual damages in billions of dollars due to the replacement of corroded equipment, product contamination, product loss from a vessel that has corroded, Process upsets resulting from corrosion etc. The United State of America, estimated annual cost of corrosion damages of over $376 billion per year, while Japan and China estimated to be 5258 trillion Yen per year. While the economic costs are frightening, we must consider them to be of secondary importance to the potential loss of life and damage to the environment problems, which can have widespread effects upon modern industrial businesses. Therefore, scientist looks into this problem and fined possible solution for controlling corrosion which are mentioned below.

Metallic structures can be protected from corrosion in many ways. A common method involves the application of protective coatings made from paints, plastics or films of noble metals on the structure itself (e.g., the coating on tin cans). These coatings form an impervious barrier between the metal and the oxidant but are only effective when the coating completely covers the structure. Flaws in the coating have been found to produce accelerated corrosion of the metal.

Another method of reducing corrosion is to polarize or shift the potential of the metal enabling it to act as a cathode (rather than an anode) in an electrochemical cell. One example is the galvanizing of steel with a coating of zinc. The iron and zinc then function as the electrodes of a cell. Zinc is the more readily oxidized metal of the pair and functions as the anode and corrodes, while the iron functions as the cathode. The zinc is used up and protection is effective as long as some zinc remains. Sacrificial anodes work on the same principle but use an external electrode made from a readily oxidized metal; this form of protection is commonly used on buried pipelines.

Another way of preventing corrosion is the Cathodic protection using an impressed current derived from an external power supply, is a form of protection in which the metal is forced to be the cathode in an electrochemical cell. For example, most cars now use the negative terminal on their batteries as the ground. Besides being a convenient way to carry electricity, this process shifts the electrical potential of the chassis of the car, thereby reducing (somewhat) its tendency to rust. But problem with all this numerous methods is that they are very expensive to practice that even the average man cannot afford.

The use of plant extracts to prevent corrosion has become important because they are environmentally acceptable and readily available with low cost. Plant extracts are rich source of naturally synthesized chemical compounds that can be extracted by simple methods with low cost (Abdel-Gaber et al., (2008).

The use of plant extracts as an inhibitors is one of the most common practical techniques for protection against corrosion in closed systems, especially in acidic media and which are not expensive inhibitors, can be added to solutions in contact with metals. These compounds can prevent either the anode or the cathode reaction of corrosion cells; one way that they can do this is by forming insoluble films over the anode or cathode sites of the cell. Some of the methods employed to reduce corrosion of aluminium is application of sulphur, oxygen or nitrogen containing organic compounds as corrosion inhibitors to hinder corrosion reaction and thus reduce corrosion rate (Moussa et al., 1998; Madkour et al., 1999; Ebenso et al., 2001; Aytac et al., 2005). Naturally occurring substances have been used successfully as corrosion inhibitor for metals in corrosive environment (Eddy and Ebenso, 2008; Okafor et *al.*, 2005, 2007; Okafor and Ebenso, 2007; Abiola *et al.*, 2007; Umoren and Ebenso, 2008; Rajendran *et al.*, 2005; Oguzie, 2005; Oguzie *et al.*, 2006, 2007: Bendahou *et al.*, 2005). A lot of works have been reported on the inhibition of acid corrosion of metals using economic plants such as *coconut water (Obruche et al., 2018a)*, *Zenthoxylum alatum* plant (Chauhara and Gunasekara, 2006), the juice of *Cocos nucifera* (Abiola *et al.*, 2002), *Fenugreek* (Ehteram, 2007), seeds extract of *Strychnos nuxvomica* (Ambrish Singh *et al*, 2010), *Gossipium hirsutum* Liquid extract (Abiola *et al*., 2009), *Areca catechu* (Vinod Kumar *et al*, 2011), African marigold flower extracts (Obruche et al., 2018b).

The aim of this study is to investigate the effect of the leaf extract of *Tagetes Patula L*. on aluminum corrosion in 0.5M HCl solution.

There are two basic types of Marigold (Tagetes) with varieties of species: the large-flowered African (also called to as American) Marigold with the botanical names as *Tagetes erecta L* and the smaller-flowered French marigold with botanical names as *Tagetes patula L.* The inhibitor (*Tagetes erecta L*) have varieties species belonging to family Asteraceae, belonging to plant kingdom, which is used in different areas like corrosion prevention, cosmetic preparation, medicines use etc. the plant marigold spread quickly because of the ease in cultivation, ease in adaptation, longer blooming periods, very light and with excellent life cycle. Tagetes erecta L. has been used for the treatment of wide variety of diseases and ailments. the infusion of the plant has been used against rheumatism, cold and bronchitis, juice of leaves for earache, leaves and florets as emmenagogue and their infusion prescribed as a vermifuge, diuretic and carminative(Anonymous, 1976). Because of its great scent the oil has been mainly used for the compounding of hige quality perfumes.the essential oil acts as antihaemorrhagic, anti-inflammatory,antiseptic,antispasmodic,astringent,diaphoretic and emmenagogue and is valuable in aromatherapy for its powerful skin healing properties, Shiva et al., (2002). According to research, Tagetes species contained flavonoids, terpenoids,thiophenes, phenolic and carotenoids compounds.

Aluminum is the most abundant metal and the third most abundant element in the earth's crust, after oxygen and silicon. It makes up about 8% by weight of the earth's solid surface. The most important ore of aluminum is bauxite, a mixture of hydrated aluminum oxide ($Al_2O_3 \cdot xH_2O$). Another mineral important in the production of aluminum metal is cryolite (Na_3AlF_6). However, cryolite is not used as an ore because the aluminum is not extracted from it. Aluminum is a silvery-white light metal with many valuable/applicable properties. It has a density of 2.70 g/cm3, non-toxic, and can be easily machined.

Aluminium has its standard reduction potential of –1.66 volts, indicating that it is a very good reducing agent. Aluminum adapts to weathers conditions far better than iron, however, because the product of its corrosion, Al2O3, adheres strongly to the metal's surface, protecting it from further reaction. This is quite different from the behavior of iron's corrosion product, rust. Rust flakes off the surface of iron, exposing the surface to further corrosion.

Aluminium is used in varieties of applications due to its light weight, very high strength, good thermal and electrical conductivities, good heat and light reflectivity, its non-rusty nature, non-toxicity and attractive appearance and strong corrosion resistant properties. The surface film is amphoteric; hence, the metal could react with both acid and alkaline media. Despite all these great physical and chemicals properties of aluminium, it is not a perfect material for engineering applications in all environments as they suffer corrosion caused by chemical interactions with their surroundings Khandelwal *et al.*, (2010).

Aluminium is used in many industries like chemicals industries, shipping, offshore petroleum exploration, power and coastal industrial plants (for cooling), fire-fighting, oil fuel water injection and desalination plants etc.

Corrosion occurs because of the natural tendency for most metals to return to their natural state (reverse of metallurgy); For instance, iron is made from hematite (common ore of iron) by heating with carbon. Iron corrodes and reverts to rust. The hematite and rust have the same composition Obruche et al., (2018b)

Figure 1: corrosion attack on an old bicycle

2 MATERIALS AND METHODOLGY

2.1 Materials

Materials used for this study were Aluminium sheets of purity 98.98%, ethanol, acetone, desiccator, distilled water, bristle brush, analytical weighing balance, beakers, 0.5M HCl and cutter.

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2.1.1 Preparation of Extract of *Tagetes Erecta L*

Tagetes patula L. leaf were dried at room temperature and grind to fine powder, 2g of the sample was mixed (refluxed) for 5hours in 100 ml of 0.5 M HCl solution. The refluxed solution was allowed to stand for 8 hours, filtered and stored. The filtrate obtained was used to prepare different concentrations of 0.5 M HCl solution for weight lost measurement

Figure 2: Matured *Tagetes erecta L* plant with fresh leaves

2.3 METHODOLOGY

2.3.1 Weight Loss Techniques.

The Previously pre weighed aluminium coupons were totally immersed in 50 ml of 0.5 M HCl solutions (in open beakers) in the absence and presence of different concentrations of the extract at room temperature for total period of 25 h immersion period. The variation of weight loss was monitored at interval of 5 h progressively for 25 h per coupon at room temperature (27^0C), the specimens (aluminium coupons) were carefully were retrieved from the solution after 5hrs of immersion time, scrubbed with a bristle brush, wash with ethanol and dried in acetone and reweighed. The difference in weight of the coupons was taken as the weight loss .i.e the initial (before immersion in the solution) and final weights (after immersion time) of the aluminium coupons. The experimental results were recorded using Mettler digital analytical balance (digital analytical balance with sensitivity of ±1 mg). Triplicate experiments were run for each concentration of inhibitor.

The inhibition efficiency (I %) was calculated for the interval of 5h of immense time using equation (1) below

Inhibition Efficiency (I %)

$$\frac{Q_O - Q_I}{Q_O} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where Q_O is the uninhibited (absence of inhibitor) and Q_I is the inhibited (with inhibitor) weight losses, respectively.

3. RESULTS AND DISCUSSION.

Targetes erecta L. Leaf extract as non-toxic corrosion inhibitor for acid corrosion of aluminium in HCl solution was studied in different concentrations (0.5 ml, 1.0 ml, 1.9 ml, 2.9 ml, 3.8 ml, and 4.8 ml, respectively). The data obtained for the corrosion behaviour of the aluminium coupons with and without inhibitors is given in the tables below.

Table 1: Aluminium coupon in 0.5M HCl without inhibitor

Time (hrs)	Initial weight of Specimen, W_F(g)	Final weight of Specimen, W_F(g)	weight Loss, ΔW(g)
5	1.7430	1.6397	0.1033
10	1.7430	1.6124	0.1306
15	1.7430	1.5998	0.1432
20	1.7430	1.5761	0.1669
25	1.7430	1.5485	0.1945

Table 2: Aluminium coupon in 0.5M HCl without inhibitor

Time (hrs)	Initial weight of Specimen, W_F(g)	Final weight of Specimen, W_F(g)	weight Loss, ΔW(g)
5	1.7113	1.5861	0.1252
10	1.7113	1.5573	0.1540
15	1.7113	1.5417	0.1696
20	1.7113	1.5205	0.1908
25	1.7113	1.4893	0.2223

Table 3: Aluminium coupon in 0.5 M HCl containing 0.5ml of inhibitor

Time (hrs)	Initial weight of Specimen, W_I(g)	Final weight of Specimen W_F(g)	Weight Loss, ΔW (g)	Inhibition Efficiency (%)
5	1.7019	1.6478	0.0541	52.6
10	1.7019	1.6291	1.6291	48.9
15	1.7019	1.6188	0.0831	64.9
20	1.7019	1.6070	0.0949	46.9
25	1.7019	1.5682	0.1337	35.8

Table 4: Aluminium coupon in 0.5M HCl containing 1.0ml of inhibitor

Time (hrs)	Initial weight of Specimen, W_I(g)	Final weight of Specimen W_F (g)	Weight Loss, Δ W (g)	Inhibition Efficiency (%)
5	1.7377	1.6920	0.0457	60.0
10	1.7377	1.6759	0.0618	56.6
15	1.7377	1.6684	0.0693	55.7
20	1.7377	1.6543	0.0834	53.4
25	1.7377	1.6201	0.1176	43.6

Table 5: Aluminium coupon in 0.5M HCl containing 1.9ml of inhibitor

Time (hrs)	Initial weight of Specimen, W_I(g)	Final weight of Specimen W_F(g)	Weight Loss, ΔW (g)	Inhibition Efficiency (%)
5	**1.7247**	**1.6833**	**0.0414**	**63.8**
10	**1.7247**	**1.6723**	**0.0524**	**63.2**
15	**1.7247**	**1.6646**	**0.0601**	**61.6**
20	**1.7247**	**1.6517**	**0.0731**	**59.1**
25	**1.7247**	**1.6206**	**0.1041**	**50.0**

Table 6: Aluminium coupon in 0.5M HCl containing 2.9ml of inhibitor

Time (hrs)	Initial weight of Specimen, W_I(g)	Final weight of Specimen W_F(g)	Weight Loss, $\triangle$W (g)	Inhibition Efficiency (%)
5	1.6824	1.6479	0.0348	69.6
10	1.6824	1.6344	0.0483	66.1
15	1.6824	1.6257	0.0570	63.6
20	1.6824	1.6100	0.0727	59.4
25	1.6824	1.5919	0.0908	56.4

Table 7: Aluminium coupon in 0.5M HCl containing 3.8ml of inhibitor

Time (hrs)	Initial weight of Specimen, W_I(g)	Final weight of Specimen W_F (g)	Weight Loss, $\triangle$W (g)	Inhibition Efficiency (%)
5	1.7222	1.6900	0.0322	71.8
10	1.7222	1.6763	0.0459	67.7
15	1.7222	1.6681	0.0541	65.4
20	1.7222	1.6493	0.0729	59.6
25	1.7222	1.6320	0.0902	56.7

Table 8: Aluminium coupon in 0.5M HCl containing 4.8ml of inhibitor

Time (hrs)	Initial weight of Specimen, W_I(g)	Final weight of Specimen W_F (g)	Weight Loss, $\triangle$W (g)	Inhibition Efficiency (%)
5	1.7180	1.6862	0.0318	72.2
10	1.7180	1.6708	0.0872	66.8
15	1.7180	1.6609	0.0571	63.5
20	1.7180	1.6496	0.0684	61.8
25	1.7180	1.6286	0.0894	57.1

Where:

W_i = Initial Weight

W_f = Final weight

Weight loss = $W_i - W_f$

3.1 Effect of Concentration on Inhibition Efficiency

The inhibition efficiency increases with increase in concentration.

Table 9: Inhibition Efficiency and weight loss of Aluminium after 5 hrs

Concentration g/L	Weight Loss, ΔW (g)	Inhibition Efficiency (%)
0.5	0.0541	52.6
1.0	0.0457	60.0
1.9	0.0414	63.8
2.9	0.0348	69.6
3.8	0.0322	71.8
4.8	0.0318	72.2

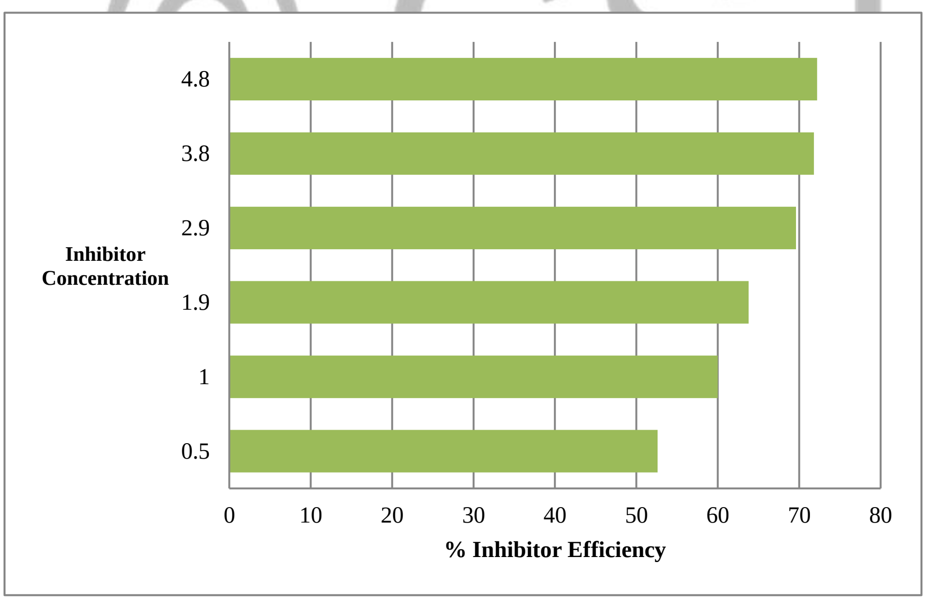

Figure 3: Effect of different concentration on Inhibition Efficiency (%) after 5hours in 0.5M HCl

Table 10: Inhibition Efficiency and weight loss of Aluminium after 10 hrs

Concentration (g/L)	Weight Loss, △W (g)	Inhibition Efficiency (%)
0.5	0.0728	48.9
1.0	0.0618	56.6
1.9	0.0524	63.2
2.9	0.0483	66.1
3.8	0.0459	67.7
4.8	0.0872	66.8

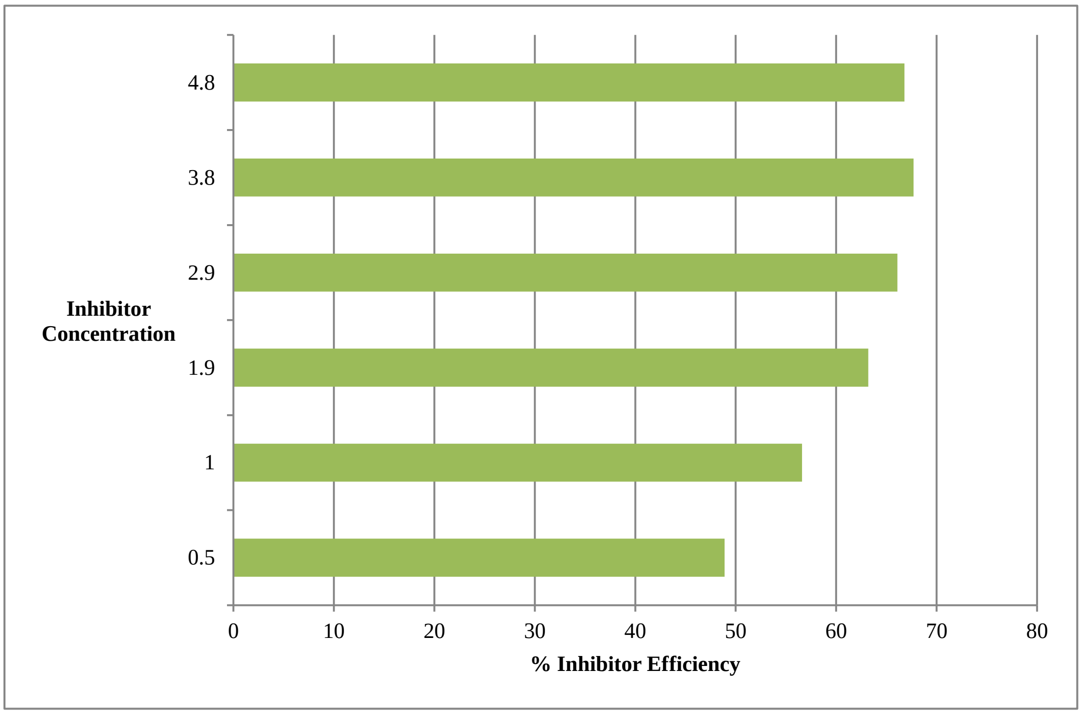

Figure 4: Effect of different concentration on Inhibition Efficiency (%) after 10hours in 0.5M HCl

Table 11: Inhibition Efficiency and weight loss of Aluminium after 15 hrs

Concentration (g/L)	Weight Loss, ΔW (g)	Inhibition Efficiency (%)
0.5	0.0831	64.9
1.0	0.0693	55.7
1.9	0.0601	61.6
2.9	0.0541	65.4
3.8	0.0571	63.5
4.8	0.0831	64.9

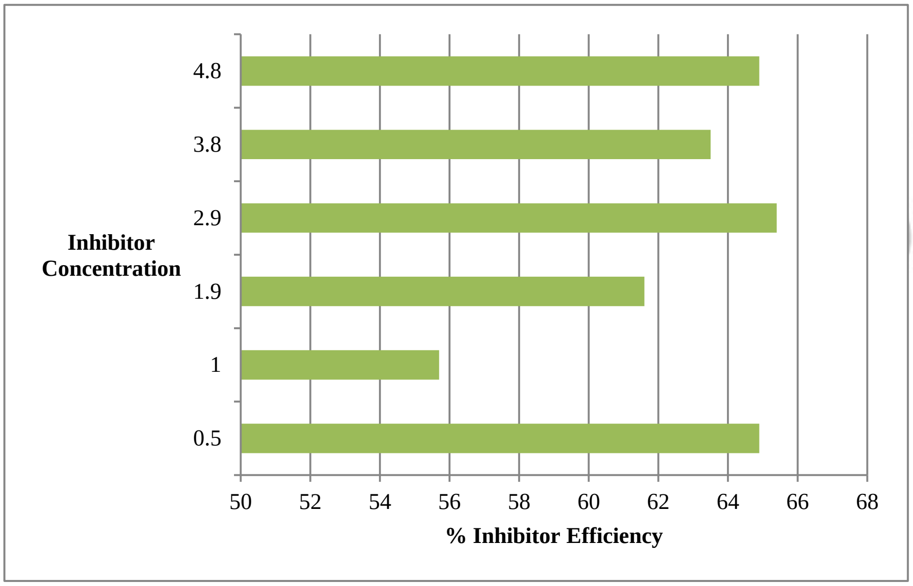

Figure 5: Effect of different concentration on Inhibition Efficiency (%) after 15hours in 0.5M HCl

Table 12: Inhibition Efficiency and weight loss of Aluminium after 20 hrs

Concentration (g/L)	Weight Loss, ΔW (g)	Inhibition Efficiency (%)
0.5	0.0949	46.9
1.0	0.0834	53.4
1.9	0.0731	59.1
2.9	0.0727	59.4
3.8	0.0729	59.6
4.8	0.0684	61.8

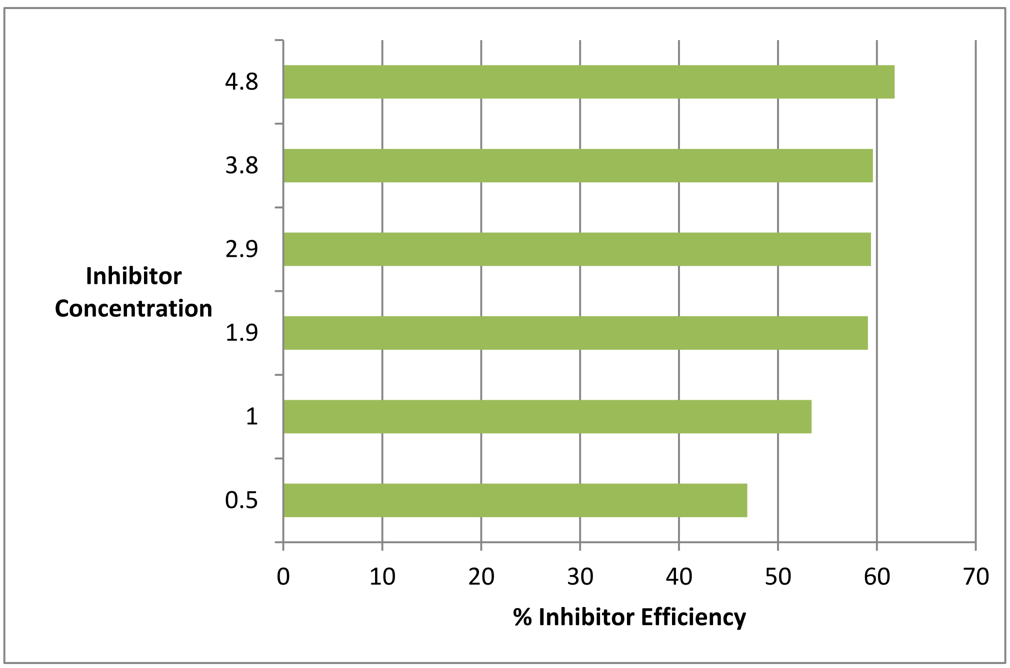

Figure 6: Effect of different concentration on Inhibition Efficiency (%) after 20hours in 0.5M HCl

Table 13: Inhibition Efficiency and weight loss of Aluminium after 25 hrs

Concentration (g/L)	Weight Loss,$\triangle$W (g)	Inhibition Efficiency (%)
0.5	0.1041	50.0
1.0	0.0908	56.4
1.9	0.0902	56.7
2.9	0.0894	57.1
3.8	0.1041	50.0
4.8	0.0908	56.4

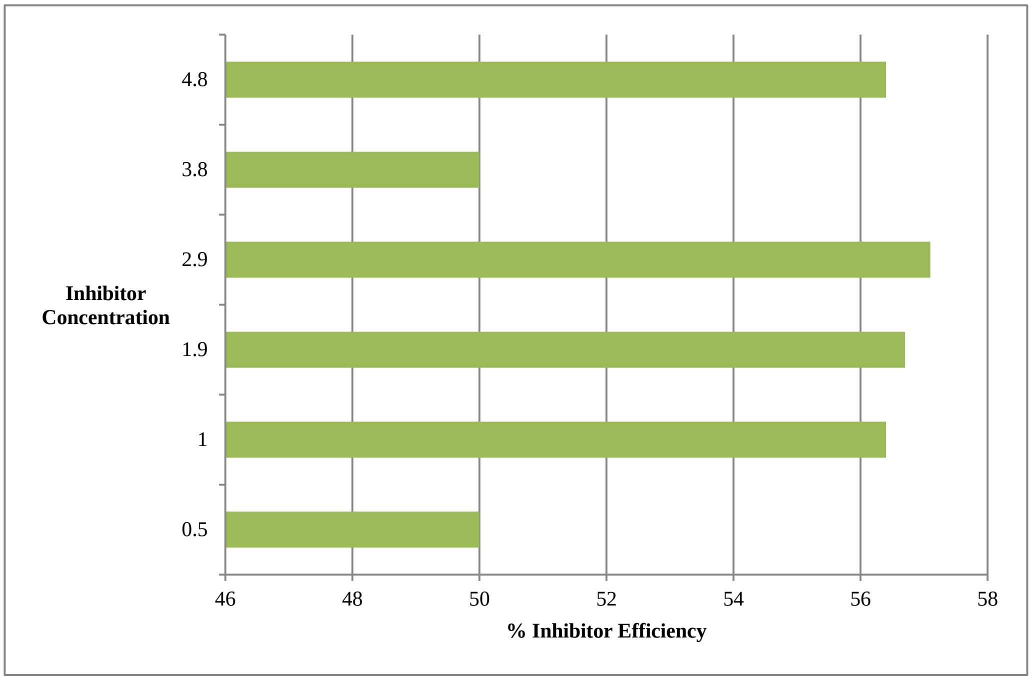

Figure 7: Effect of different concentration on Inhibition Efficiency (%) after 25hours in 0.5M HCl

Table 14: Weight loss (g) of aluminium coupon for control and different concentration of inhibitor at various times

Time (Hour)	Control 1	Control 2	0.5ml	1.0ml	1.9ml	2.9ml	3.8ml	4.8ml
5	0.1033	0.1252	0.0541	0.0457	0.0414	0.0348	0.0322	0.0318
10	0.1306	0.1540	0.0728	0.0618	0.0524	0.0483	0.0459	0.0872
15	0.1432	0.1696	0.0831	0.0693	0.0601	0.0570	0.0541	0.0571
20	0.1669	0.1908	0.0949	0.0834	0.0731	0.0727	0.0729	0.0684
25	0.1945	0.2223	0.1337	0.1176	0.1041	0.0908	0.0902	0.0894

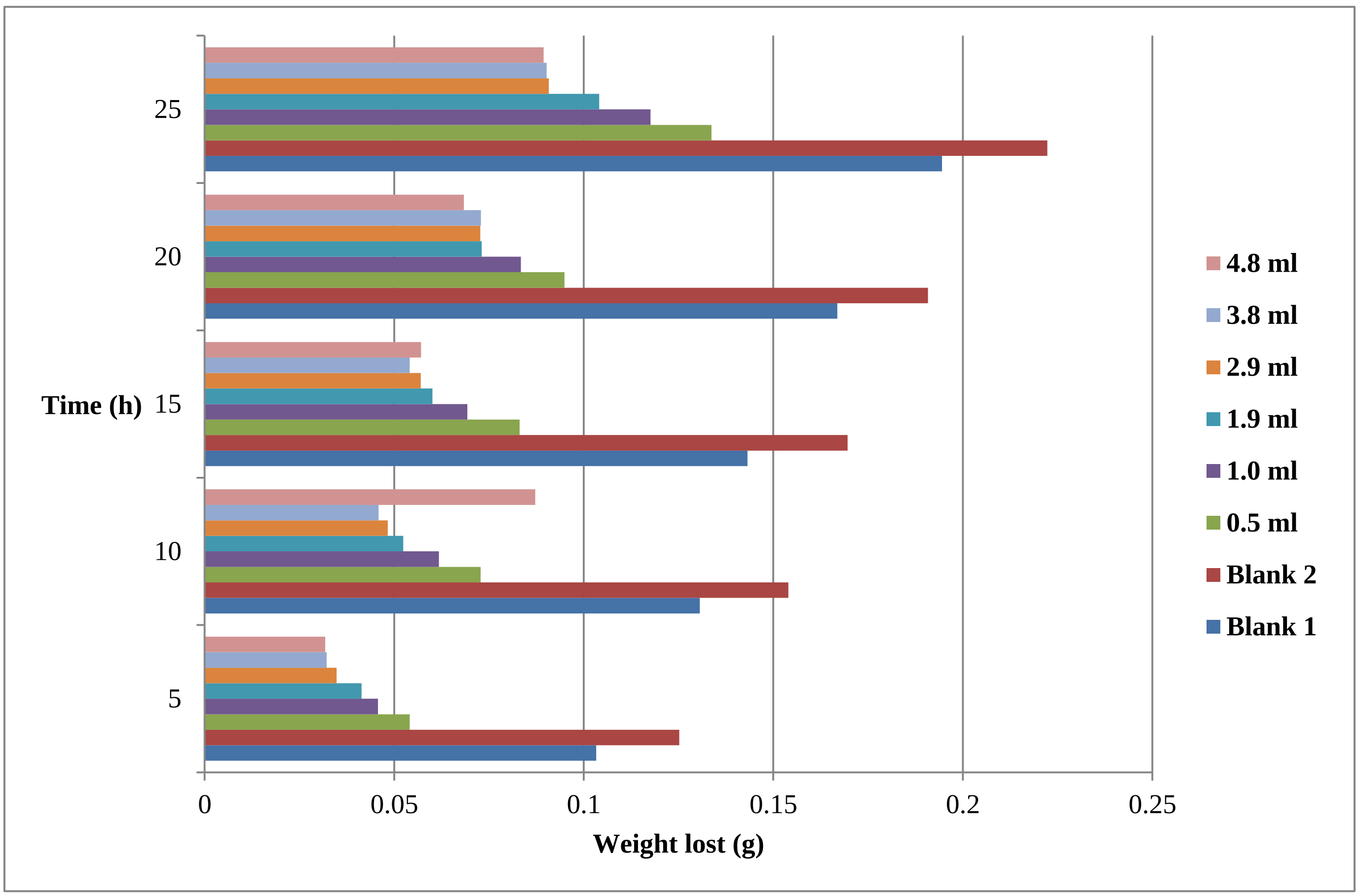

Figure 8: Effect of weight loss with time in the absence (blank or control) and presence of inhibitor in 0.5M HCl using different concentration of inhibitor.

4. CONCLUSION

In this study, the following conclusions can be drawn:

- The extracts from the leaves of *Tagetes erecta L* were found to be effective green inhibitors of aluminiun coupon in 0.5ml HCl.
- The corrosion rate was found to decrease.
- Inhibitive efficiency of the extract increases with increase in concentration of the inhibitor.
- The corrosion process was inhibited by adsorption of the extracts organic matter on the aluminium coupon surface and blocking its active sites.
- Therefore, the research showed that *Tagetes erecta L* leaves extract possesses the inhibitive properties of corrosion in 0.5ml HCl and is therefore recommended to homes, public and private industries as a corrosion inhibitor.

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