Diethanolamine: An Inhibitor of Mild Steel Corrosion in Cassava Fluid Extract

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***Abstract*: - The effect of diethanolamine on the corrosion inhibition of mild steel in cassava fluid was investigated by weight loss measurements. The investigation was conducted at temperatures of 298K and 333K at concentration of 0.5M, 1.0M, 1.5M and 2.0M concentrations of diethanolamine in cassava fluid. The results showed that weight loss recorded decreased with concentration and temperature. Weight loss decrease from 0.0503mm, blank solution to 0.0101mm in 2.0M concentration at 298K and a decrease in corrosion rate of 0.0789mm/yr to 0.0411mm/yr under the same conditions on the 3rd day. Weight loss also decreased from 0.0243mm blank solution to 0.0002mm in 2.0M concentration and corrosion rate also decreased from 0.0380mm/yr to 0.0003mm/yr under the same concentration at 333K, on the 3rd day. Further decrease was also recorded as the day progresses to the 9th day. The highest efficiencies recorded were 98.01% at 0.5M concentration at 298K and 9918% at 2.0M concentration at 333K. The recorded values showed that diethanolamine is an efficient corrosion inhibitor of mild steel in cassava fluid.**

***Keywords:* Cassava fluid, weight loss, diethanolamine, mild steel, corrosion rate, metal coupon.**

I. INTRODUCTION

The deterioration of materials made of steel which is widely used in the chemical, petrochemical and agricultural industries have created a lot of problems. The chemical, physical and even the structural states of these material equipment made of steel are greatly affected because of the reaction these materials undergo with the ambient environment. Such decay and wearing away of the physical/chemical nature of material of construction due to its reaction with the environment is known as corrosion (Osarolube et al., 2004). The corrosion that sets in at a certain period of time make the material of construction to perform and function ineffectively, there by affecting the whole industrial processes and resulting in equipment failure (Amuda et al., 2008).

Corrosion problem is associated with enormous cost and thereby affect the economy of any given nation. An estimated 5% income of industrialized nations such as the U.S is spent on difficulties that arises from corrosion attack on equipment (NACE, 2007). Due to the increase and rise in population, there is also increase and rise in agro processing industries, since there is a high demand for food. The challenge of material corrosion therefore arises in the sector and also call for solution to reduce and mitigate these associated problems in every stage of processing the agricultural produce.

Cassava is an important crop consumed in Nigeria. The extraction process of cassava tubers to bring out the important part of it results in releasing hydrogen cyanide, a volatile compound that easily attack the material used in the construction of the processing plant due to regular contact (Amuda, et al., 2006, CAC/RCP, 2013). When there is this constant contact, there is the possibility of equipment failure caused by hydrogen embrittlement. The result is stress corrosion cracking, contamination of processed products, food poisoning and wastage of materials. There is also the resultant overwhelming loses and processing targets never being met or materialized (Amuda et al., 2006).

The hydrogen cyanide present in cassava, attacks the material of construction during cassava processing processes and thereby lowering the potentials of process equipment due to degradation and deterioration effect on the metals used in constructing the process equipment (Igwe and Edori, 2020). Cassava fluid corrosion ability have been studied by Ajide et al., (2012), where prepared metal coupons for a period of 36 days were immersed in cassava, orange distilled water fluids, each in a 200ml volumetric flask, and the weight loss was recorded at a period of 3 days, interval. Thereafter, MCS and KS7SS were added to the various fluids to investigate their performances in the different fluids. The study observed that MCs was highly unstable in the cassava and orange fluid environments and that KS7SS has a far better corrosion inhibitory performance in the different fluid environments and therefore recommended KS7SS to be used as corrosion inhibitor in processing equipment that involve these fluids. The study of Igwe and Edori, (2020), observed that with increased concentration of potassium chromate in cassava fluid medium, corrosion rate of the metal coupons greatly reduced.

The present study aimed at examining the effectiveness of diethanolamine as corrosion inhibitor in cassava fluid extract medium for the protection of mild steel against corrosion attack, which can be of help in the process of cassava processing and equipment maintenance in cassava fluid mediums.

II. MATERIALS AND METHODS

Rectangular shaped mild steel specimen of dimension 4.0 × 2.0 × 0.i cm and a hole 0,2mm was made at the upper end of the metal coupon to allow the passage of glass hooks and glass rods. The percentage chemical composition of the steel used was C; 0.45, Mn; 0.09, P; 0.02, Ni; 0.03, Cr; 0.45, Mo; 0.002, Sn; 0.01 and Fe; the remainder. The mild steel specimens were cut out and properly cleaned to give a good finish at the University of Port Harcourt Engineering and Science Workshop. Emery papers of different grits were used to grind the coupon specimens. The finished specimens were then degreased in ethanol after surface treatment and then dried in acetone (Ita and Edem, 2000, Osarolube and James, 2014). Afterwards the steel coupons were weighed using an AD54 Mettler Toledo digital weighing balance and kept in a dessicator prior to exposure to avoid being contaminated before use in corrosion experiments.

Locally produced cassava tubers were peeled and crushed in a grating machine and then cassava fluids were squeezed out to obtain the fluid extract for the experiment. Different concentrations of 0.5, 1.0, 1.5 and 2.0M of diethanolamine were prepared for use as inhibitor. All the solutions used in the experiment were of analytical grade.

Experimental Process

The corrosion of mild steel was determined using the weight loss method (James et al.,2007, James and Akaranta, 2009). Local breed cassava tubers obtained from the farm ware washed, peeled and crushed by the use of grating machine and the fluid extracted through the application of pressure of the prepared cassava mass in a permeable sack bag, and a clean basin used in collect in the extract (Igwe and Edori, 2020). The already prepared inhibitors of (0.5, 1.0, 1.5 and 2.0M) concentrations of diethanolamine were introduced into the cassava fluid extracted into a volumetric flask of 100ml. The volumetric flask containing the pure cassava fluid extracted was used in the experiment as control.

Determination of Weight Loss

The corrosion of mild steel in cassava extract containing different concentrations of diethanolamine as inhibitor was studied using the weight loss determination method. The different concentrations of diethanolamine as inhibitor were mixed with the cassava fluid extracted in beakers of 250ml capacity. The temperature of the experiment was maintained at 298K and 333K using a thermo stated water bath (Orubite-Okosaye et al., 2007). The corrosion coupons were removed from the solution at intervals of 3 days progressively for 9 days and washed in a distilled water to stop the reaction. The corrosion products in the metal coupons were removed by brushing with brittle brush and thoroughly scrubbed and then washed in a distilled water to erase the product created as a result of corrosion reaction. The steel coupons were then weighed in a balance after being dried in acetone in order to quantify loss due to corrosion activities (reactions). The weight loss that resulted due to the chemical reaction that took place was then calculated using the expression

$W = \frac{\Delta m}{At}$ (Rajappa and Venkatesha, 2003).

Where, Δm = mass loss due to corrosion reaction

t = the period within which the coupons were exposed (days)

A = total surface area of the coupons.

The difference in weight measured in grams (g) is the difference in weight before and after the removal of corrosion reaction product. The rate of corrosion of the metal coupons are then converted to millimeter per year (mm/yr), using the expression of Fontana (1987), given as:

$$CR = \frac{87.6W}{DAT}$$

Where,

CR = corrosion rate

W = weight loss due to corrosion reaction = ΔW

D = density of coupon specimen in g/cm^3

A = total surface area of the coupon exposed to the solution measured in cm^2

T = the period of exposure of metal coupons in days.

Efficiency of Corrosion Inhibitor

The efficiency of the corrosion inhibitor is calculated in percentages using the formula,

$$\%\,Efficiency = \frac{\Delta WB - \Delta Wi}{\Delta WB} \times \frac{100}{1}$$

Where,

ΔW_B = weight loss recorded in steel coupon without inhibitor

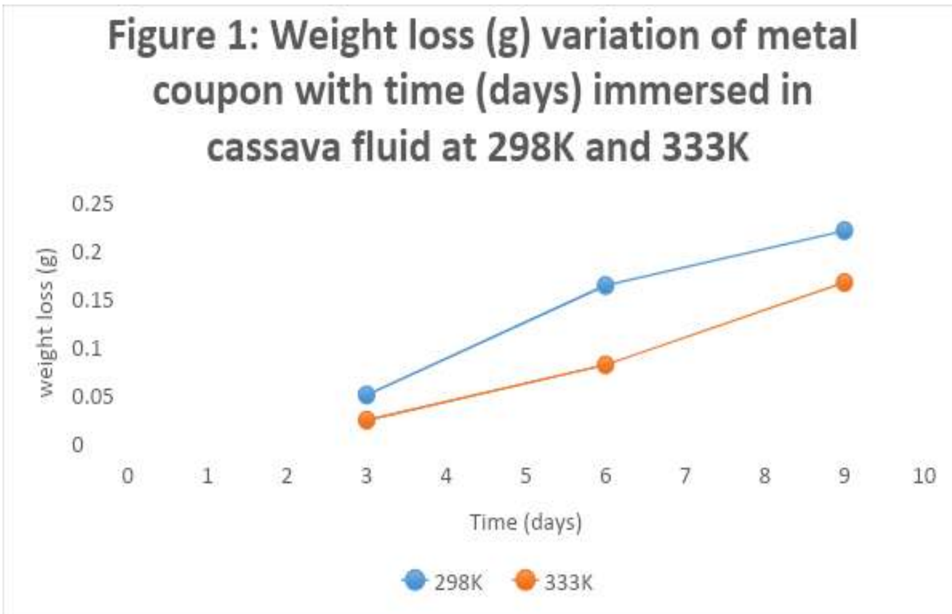
ΔW_i = weight loss recorded in steel coupon with the presence of inhibitor (Abiola et al., 2004).

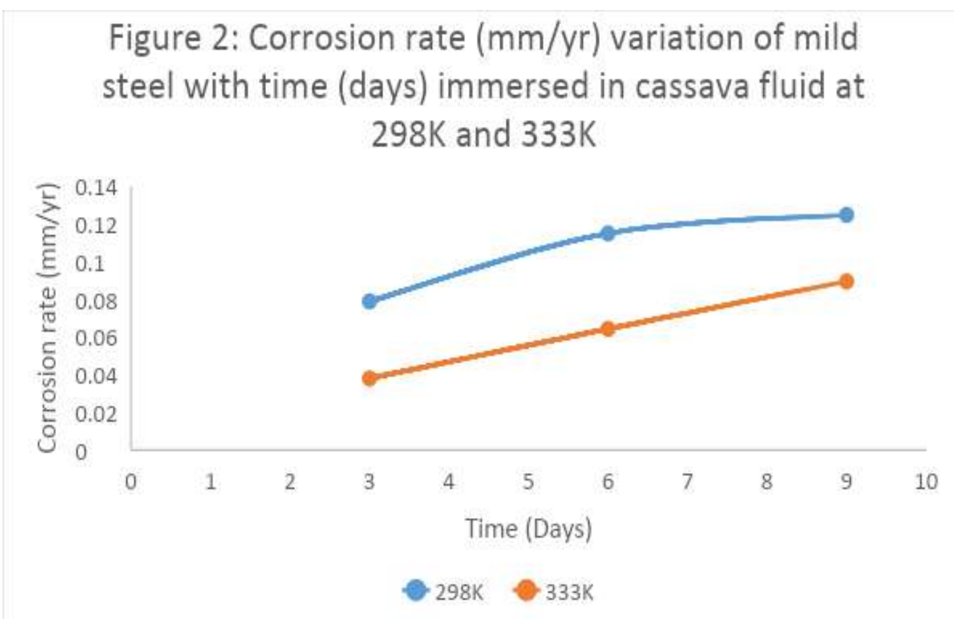
III. RESULTS AND DISCUSSION

Mild Steel Corrosion in Cassava Fluid Without Inhibitor

Mild steel coupon immersed in cassava fluid without inhibitor at 298K and 333K showed a remarkable loss in weight as the experiment progressed from day 3 to day 9. In figure 1, loss of metal progressed from 0.0503, 0.1632 t0 0.2198mm at 298K and 0.0243, 0.0814 to 0.1663mm at 333K. there was also an increase in the corrosion rate from 0.0789, 0.1150 to 0.1248 mm/yr at 298K and 0.0380, 0.0643 to 0.0895 mm/yr at 333K. The results revealed that cassava fluid corroded mild steel at 298K and 333K. The result agreed with Amuda et al., (2006), Igwe and Edori, (2020), that cassava fluid corroded mild steel coupons when immersed in it.

The loss of metal and the consequent increase in the corrosion rate may be due to the hydrogen cyanide, a fluid that corrodes which is present in cassava roots. There is iron dissolution due the dissociation reaction of hydrogen cyanide to form a brown scale (iron cyanide) which brings about reduction in the concentration of iron in the environment. There is also the consumption of in the process (Amuda et al., 2008, Igwe and Edori, 2020). An enzyme called linamarase is also present contained in cassava root. This enzyme helps the breaking down of cyanogenic glucosides releasing cyanohydrin. The cyanohydrin produces hydrogen cyanide when it dissociates and gives rise to the corrosion of the steel coupon in the cassava fluid. The dissociation reaction of the cyanohydrin is increased when it comes in contact with heat and alkali (CAC/RTP, 2013). As the temperature increased from 298K to 333K, the rate of corrosion decreased. This observation agreed with Ajide, et al., (2012) and Igwe and Edori, (2020) and disagreed with Okafor et al., (2004) and James et al., (2007), which observed increase in loss of weight due to temperature increase. At the increased temperature, hydrogen cyanide which is very volatile and easily lost to the environment due to heat has greatly reduced, and there is the possibility that starch present in cassava roots has overlayed the surfaces of the metal coupon, due to the increased solubility of the cassava fluid, hence giving protection to the coupon specimen (Bello et al., 2011, CAC/RTP, 2013, Igwe and Edori, 2020).





The Effect of Inhibitor Concentration on the Rate of Mild Steel Corrosion in Cassava Fluid

The variation in weight loss of metal coupons with time in cassava fluid under different concentrations of inhibitor at 298k and 333K are shown in Figures 3, 4, 5 and 6. There were noticeable decrease in corrosion rate due to increase in the diethanolamine (inhibitor) concentration when compared to results obtained without the presence of the inhibitor as illustrated in Figures 1 and 2. The decrease in corrosion rate is due to the presence of the inhibitor is borne out of passivation, which is the formation of protective film on the surface of the steel coupons, thereby preventing the steel from in-depth attack. The increase in the concentration of the inhibitor led to effective shielding of the metal surface from corrosion attack. The diethanolamine produced a film (layer) on the metal surface which made it difficult for the cassava fluid to penetrate and break the barrier created by the inhibitor on the surface of the metal. This observation agreed with Lotto et al., (2011). The results observed from Figures 3, 4, 5 and 6 indicated that diethanolamine as inhibitor is more effective at 333K as compared to 298K under the different concentrations. The observation here is contrary to what was observed by Igwe and Edori, (2020), where potassium chromate as inhibitor in cassava fluid extract produced better inhibition at lower temperature of 25^{o}C to that of 60^{o}C. the increase in concentration of diethanolamine at both temperatures indicated that it inhibited the corrosion of mild steel in cassava fluid and its effectiveness increased due to increase in its concentration and temperature. The observed result is in agreement with James and Akaranta, (2009), where aloe vera reduced the corrosion of zinc in HCl solution as the temperature was progressively increased from 30^{o}C, 40^{o}C to 50 ^{o}C.

Figure 3: Weight loss variation of mild steel with time (days) immersed in cassava fluid at 298 K under different concentrations of diethanolamine

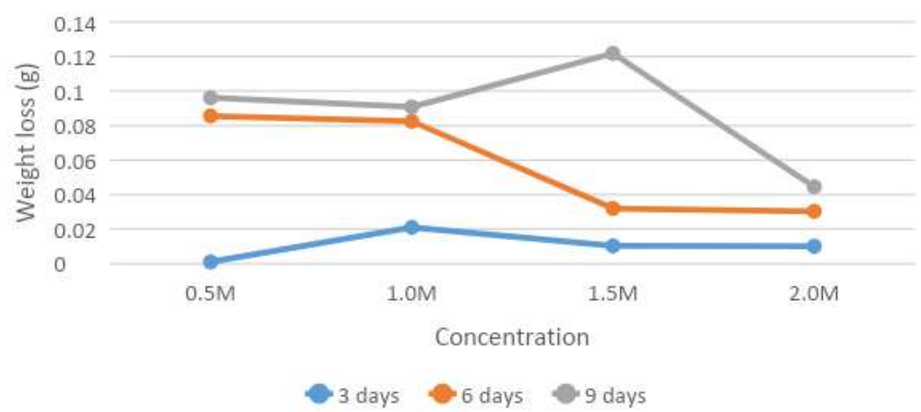
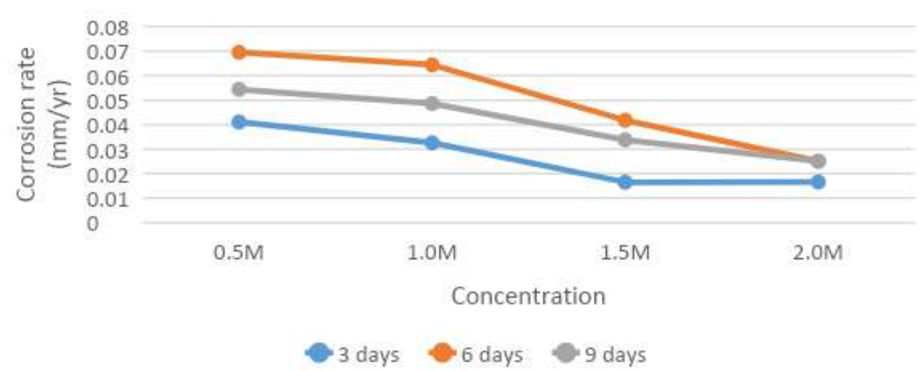
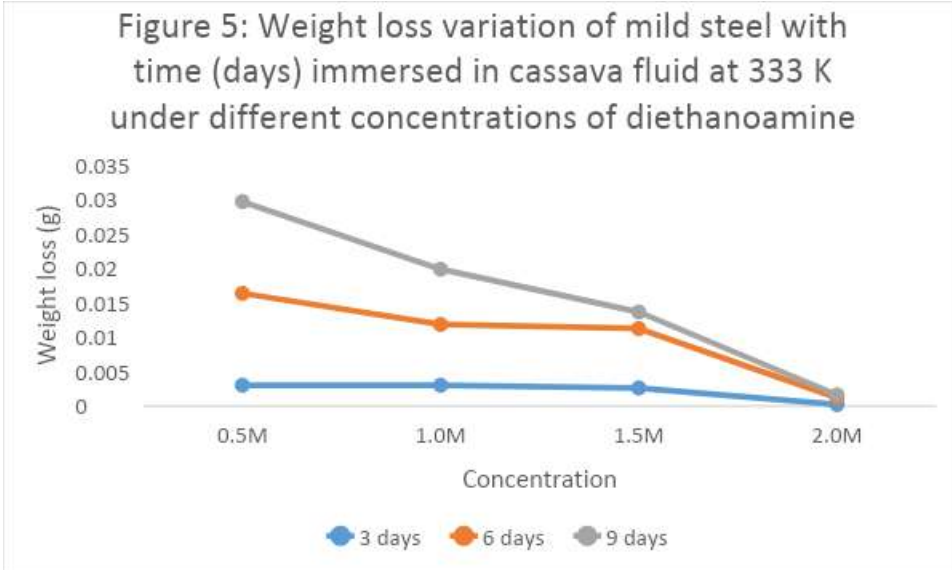
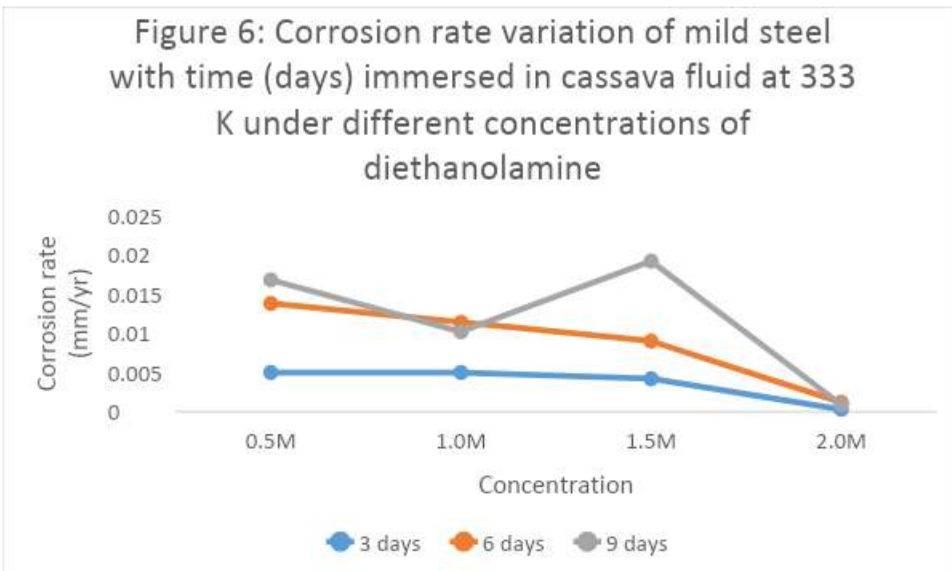


Figure 4: Corrosion rate (mm/yr) variation of mild steel with time (days) immesred in cassava fluid at 298 K under different concentrations of diethanolamine

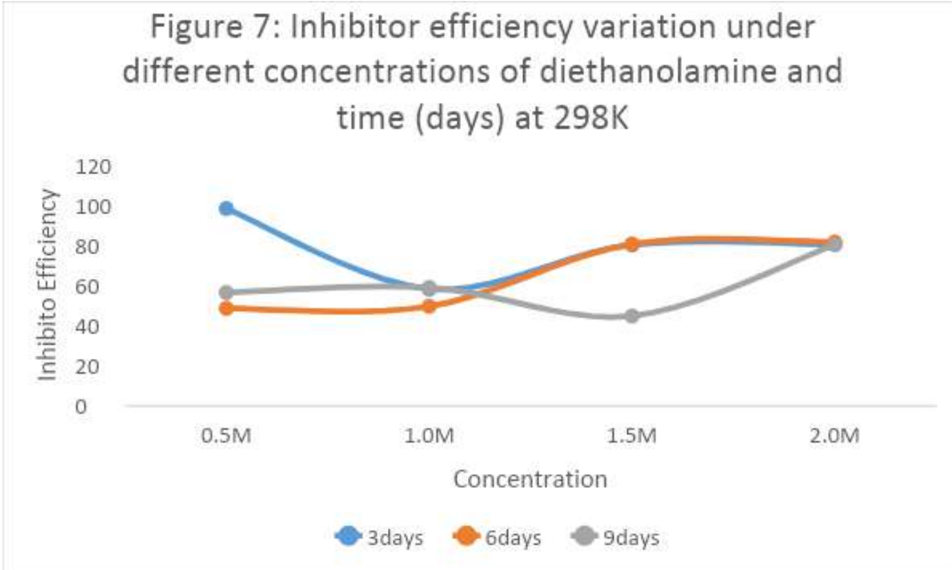


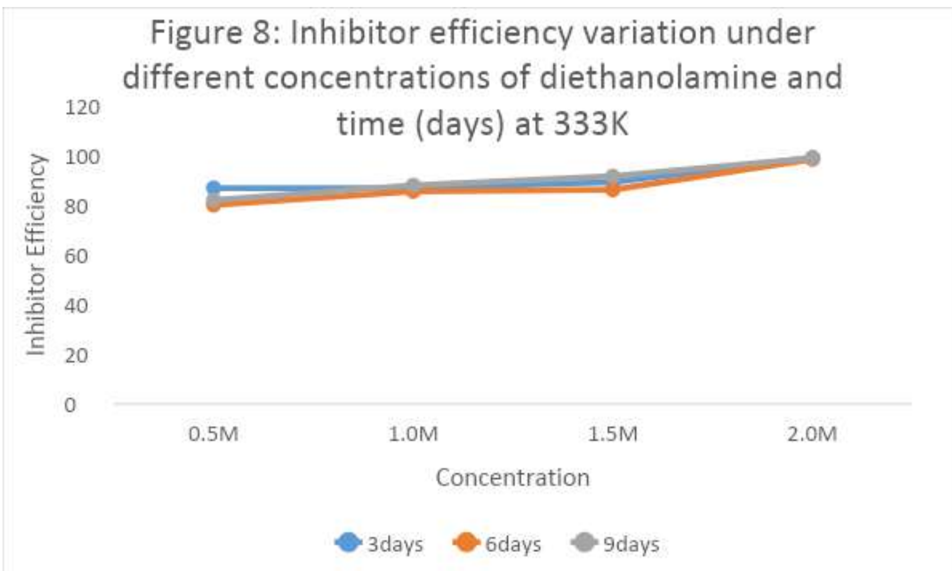




Efficiency of Diethanolamine Additive in Cassava Fluid

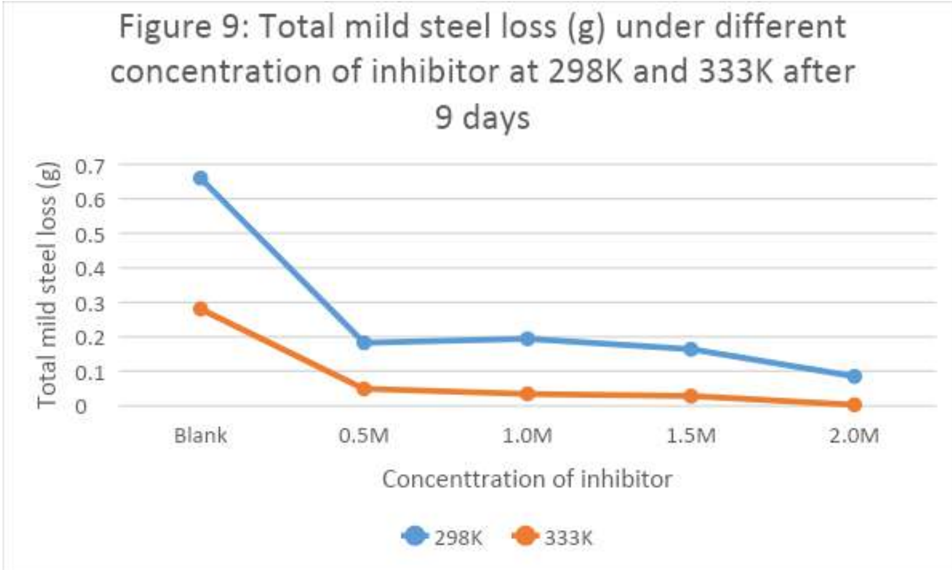
Figures 7 and 8 presented a graphical representation of the efficiency of diethanolamine as inhibitor in the presence of cassava fluid corrosion of mild steel at varying concentrations and temperatures of 298K and 333K. The inhibitor performance at 298K did not follow any pattern as illustrated in Figure 7, since the efficiency did not increase as the inhibitor concentration is increased, neither did it increase with the increase in time. A decrease was observed as the day progresses. At 0.5M concentration, efficiency of 98.01% was recorded at the end of the first 3 days, this decreased to 47.55% on the 6th day and slightly increased to 56.28% on the 9th day. At 1.0M and 1.5M concentrations, similar observations were recorded, but for the 2.0M concentration there was an appreciable decrease in the corrosion rate, since the efficiency fluctuated between 79.92, 81.37 and 79.66% on the 3rd, 6th and 9th day respectively. In Figure 8, the graphical representation of the efficiencies revealed that at 333K, there were remarkable increases due to the increase in the concentration of diethanolamine (inhibitor). Within the 9 days, highest efficiencies were recorded with 2.0M inhibitor. Inhibitor performance was noted to be more effective on the 3rd day followed by the 9th day and then the 6th day. The efficiencies ranged between79.98% to 99.18% within the period of investigation. The result further revealed that diethanolamine inhibits the corrosion of mild steel in cassava fluid at higher temperatures. Findings from the investigation showed that the results agreed with Ajide et al., (2012), Osarolube and James (2012) and Igwe and Edori (2020), that increase in temperature produces higher efficiencies of inhibitors. The results also proved that increased concentrations lead to increased efficiencies of inhibitor (Soroya et al 2018).





Total Weight Loss Due to Different Concentrations of Diethanolamine at 298K and 333k After 9 Days

The total weight loss of metal at different concentrations of the inhibitor under varying temperatures of 298K and 333K are shown in Figure 9. At 298k, total weight loss was observed to decrease from 0.6599mm without inhibitor to 0,0852mm at 2.0M concentration of inhibitor. Also, at 333K, it was observed that when there was no inhibitor, total weight loss of metal 0.2720mm, this decreased to 0.003mm at 2.0m concentration of the inhibitor. The result revealed that there was a remarkable decline in the corrosion rate or weight loss due to the addition of inhibitor to the cassava fluid. The result indicated that total weight loss at 298K was more than that recorded at 333K. At the higher temperature, the cassava fluid protected the metal more by forming a covering on the surface, thus passivating the metal from in-depth corrosion attack. Possibly, the starch in cassava has become more soluble thereby depositing on the metal surface giving it a shield from the effect of the corroding agent in the fluid (Rosliza and Wan Nik, 2009, Ajide et al., 2012, Igwe and Edori, 2020). The total weight lost to the environment at both temperatures under different concentrations also attested to the fact that increased concentration of additives brings about decreased corrosion rates (James et al., 2007).



IV. CONCLUSION

The study proved that diethanolamine is an effective inhibitor of corrosion rate of mild steel in cassava fluid. Higher inhibitor efficiencies were obtained at temperature of 333K as compared to 298K under different concentrations of diethanolamine. Increased concentration of inhibitor also reduced the rate at which the metal (steel coupon) were lost to the environment.

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