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A Study of Using *Allium Cepa* (Onion) as Natural Corrosion Inhibitor in Industrial Chill Wastewater System

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Abstract

One major problem that is constantly associated with the industrial chill wastewater system is corrosion. As water is an integral part of this system, corrosion among the piping is inevitable. Corrosion tends to disintegrate the piping substance making it fragile and easy to rupture. The disintegrated parts of the piping could block the system and cause a decline in pressure and contributes to water pollution. Essentially, industries use inhibitor to retard corrosion and generally there are toxic and exhibit carcinogenic properties. However, these vital inhibitors are still being used in a small quantity due to lack of safe, natural based corrosion inhibitor. Accordingly, the current study describes the potential of using Allium cepa (Onion) as a natural corrosion inhibitor. The effectiveness of using Allium cepa was characterized in terms of metal weight loss, inhibitory efficiency, corrosion rate, area affected, turbidity and pH. Results showed that the optimum inhibition efficiency (IE) for iron, nickel and copper were 92%, 88% and 46%, respectively when Allium cepa was present at 0.6 g/L. In addition, the reduction in weight loss for iron, nickel and copper were 92%, 88% and 46%, respectively, demonstrating Allium cepa as an effective corrosion inhibitor, primarily for iron.

Key words: Industrial chill wastewater, corrosion, *Allium cepa*, natural inhibitor.

Introduction

In general, chilled water is generally used in commercial and industrial facilities to cool process machinery and the surrounding air inside the factory or industrial plant[1]. In the chilled water system, water acts as a medium to transfer heat from liquid and the continuous circulating water absorbs heat and replaces it to create a cooler and fresher environment.

One major problem that is constantly associated with the industrial chill system is corrosion. As water is an integral part of this system, corrosion is inevitable and measures have been taken to inhibit, control and prevent this predicament[2]. The corrosion of steel piping and its related components is a continuous and unstoppable process. The end product, which is commonly referred to as rust, is simply the result of an electrochemical reaction through which the higher energy processed metal is slowly reverted back to its naturally occurring form which is basically, metal ore[3]. Corrosion can produce problems ranging from lost of heat transfer efficiency and constricted pipes to annoyance pinhole leaks and temporary shutdowns. More serious failures are often in the form of major floods, property damage, operating failures, lost production, and personal injury. The failure to recognize a serious corrosion problem will result in the need to replace some or all of the piping system at extraordinary cost, and possibly with the loss of critical services[4].

Corrosion inhibitors retard the corrosion rate by effecting two elements of the corrosion process; the anodic and cathodic reaction. The anodic reaction refers to the process where the metal ions pass into solution from anode, where else the cathodic reaction is pertaining the negatively charged electron flowing from metal to an acceptor[5]. They are added to reduce the aggressiveness of the corrosion process. Inhibitors function by adsorption of ions or molecules onto the metal surface. They reduce the corrosion rate by increasing or decreasing the anodic and cathodic reaction. They decrease the diffusion rate for reactants to the surface of the metal and decrease the electrical resistance of the metal surface. There are several types of inhibitor that are available to control corrosion in the industries such as chemical inhibitors, electroplating and galvanising[6].

Two significant factors that need to be considered before choosing the right corrosion inhibitor for a particular material including for the industrial chill water system is whether the compound is feasible in the sense of cost[7]. Most effective corrosion inhibitors are synthetic chemicals which are costly, therefore, not economical to be used. The second factor is whether the compound is safe and environmentally friendly. Synthetic compound is proven to be harmful to human and the environment, thus it is not a compatible choice. Other elements that contribute to the selection of corrosion inhibitors are like their accessibility. The question is whether the inhibitor could be found or produced easily. The significance of finding and identifying inhibitors which are safe, cheap, and easily accessible and does not emit dangerous substances and gaseous are acknowledged [7]. That is why more and more research on plants, seeds and flower based inhibitors are being developed as naturally occurring substances contain the chemicals proven in being able to inhibit corrosion, they are cheap, easy to find, renewable and are safe to be used. Some examples of such natural inhibitors are henna, olive, shirsh zallouh, vanillin, natural honey, khella, onion, ficus and opuntia[4].

Allium cepa (Onion) is a plant that can be found in everyday household kitchen. It is cheap, fairly abundant to be accessed, can be consumed, so it is safe and environmentally friendly. Research has been conducted on *Allium cepa* and its properties to distinguish whether it is compatible to be used as corrosion inhibitor, and the findings has proven that the compounds in the red onion skin can inhibit corrosion[8]. Onion skin has the highest concentration of substance which has the potential to inhibit corrosion. Using weight loss technique, the efficiency of onion as corrosion inhibitor was found to be dependent on its concentration[8].

In essence, the compound responsible for the inhibitory action of the *Allium cepa* is Quercetin, a conjugated and electron rich compound. The oxygen atom in Quercetin is electron rich and serves as a good adsorption site on the surface of the metal, thus preventing any further contact between the metal and ions present in water which can cause corrosion. Quercetin found in *Allium cepa* is a plant derived flavanoid. Flavanoid or also known as secondary metabolites are organic compound found in plants that are not directly involved in the normal growth, development, or reproduction of organisms. In *Allium cepa*, the highest concentration of Quercetin can be found in the outermost ring. It has anti inflammatory and antioxidant properties thus make it suitable to be used in various fields, such as medical, engineering related research and food industries[8].

The aim of this study was to determine the inhibitory efficiency of *Allium cepa* and the impact towards corrosion rate of three metals; iron, nickel and copper. These three metals is the main constituent that makes up the industrial chill wastewater system. In addition, the maximum concentration needed for the *Allium cepa* to portray its optimum inhibitory potential, was also investigated. It should be pointed out here is that there are not many reported work that has been carried out using *Allium cepa* as a natural corrosion inhibitor[8, 9].

Material and Methods

The wastewater was collected from three plastic factories utilizing industrial chill system in Gebeng Industrial area, Kuantan, Pahang, Malaysia. Onion was pealed and the outermost ring containing Quercetin was removed and crashed, later mixed with 1 L of water before heating to produce concentrated liquid extract. This step was repeated using different quantity of onion (0.2 to 1.4 g/L) to produce varied level of concentrated extract. The experimental flow chart is illustrated in figure 1.

Three containers with lid were filled with these concentrated liquid extract and the initially weighed metal sample was immersed in the liquid. After 24 hours, the metal sample was removed from the container and its weight was recorded. The water in the container was also tested for the presence of copper, iron and nickel. The analysis was carried out using DR2500 spectrometer at room temperature (29.4^{o}C).

The inhibition efficiency (IE) was evaluated by weight loss techniques[10]. The percentage inhibition efficiency (IE %) was calculated by subtracting the final weight of metal (after submersion in the inhibitor extract solution) with the initial weight (before submersion) and then divide by the final weight. The submersion period was 24 hours and the results were obtained from mean of three runs, each conducted with fresh wastewater solution. A control sample was also prepared with and without the inhibitor of different concentration.

Nitric acid (an oxidizing agent) was used to preserve the chemical properties of water samples. The wastewater sample was then placed in a chiller to prevent biochemical activity. In order to evaluate the process performance, the following parameters were analyzed: turbidity, corrosion rate, area affected, pH, inhibitory efficiency, metal weight loss, iron, nickel and copper concentration. All analysis was performed according to the Standard Examination of Water and Wastewater by American Public Health[11]. Iron, nickel and copper were placed in solutions varying in concentration to test the results of corrosion rate and inhibition efficiency of *Allium cepa* in the presence and absence of the inhibitor. The data were analyzed by SPSS software through paired sample T.

Results and discussion

In this section, the overall effect on the wastewater with the absence and presence of *Allium cepa* treatment was described. In general, metal weight loss is the easiest technique to evaluate corrosion rate and inhibition efficiency[12, 13]. In most cases, when corrosion occurs, metal surface tends to disintegrate, thus reducing its weight. On the other hand, if an effective inhibitor is used, corrosion process is retarded and metal disintegration is prevented. The outer layer of *Allium cepa* contains Quercetin, an electron rich site which allows the reaction of water molecules to take place. Consequently, instead of reacting with the metal ions found on the metal surface, the water molecules react with the electron found on Quercetin, thus inhibiting the corrosion. This is essentially the most important property of an inhibitor should have. Figure 2 illustrates the metal weight loss in the presence of *Allium cepa* and it can be seen that the weight loss has been reduced when *Allium cepa* concentration was increased gradually from 0.2 to 1.4 g/L. The reduction in metal weight loss for iron, nickel and copper were 92%, 88% and 46%, respectively, demonstrating *Allium cepa* as an effective corrosion inhibitor, particularly for iron.

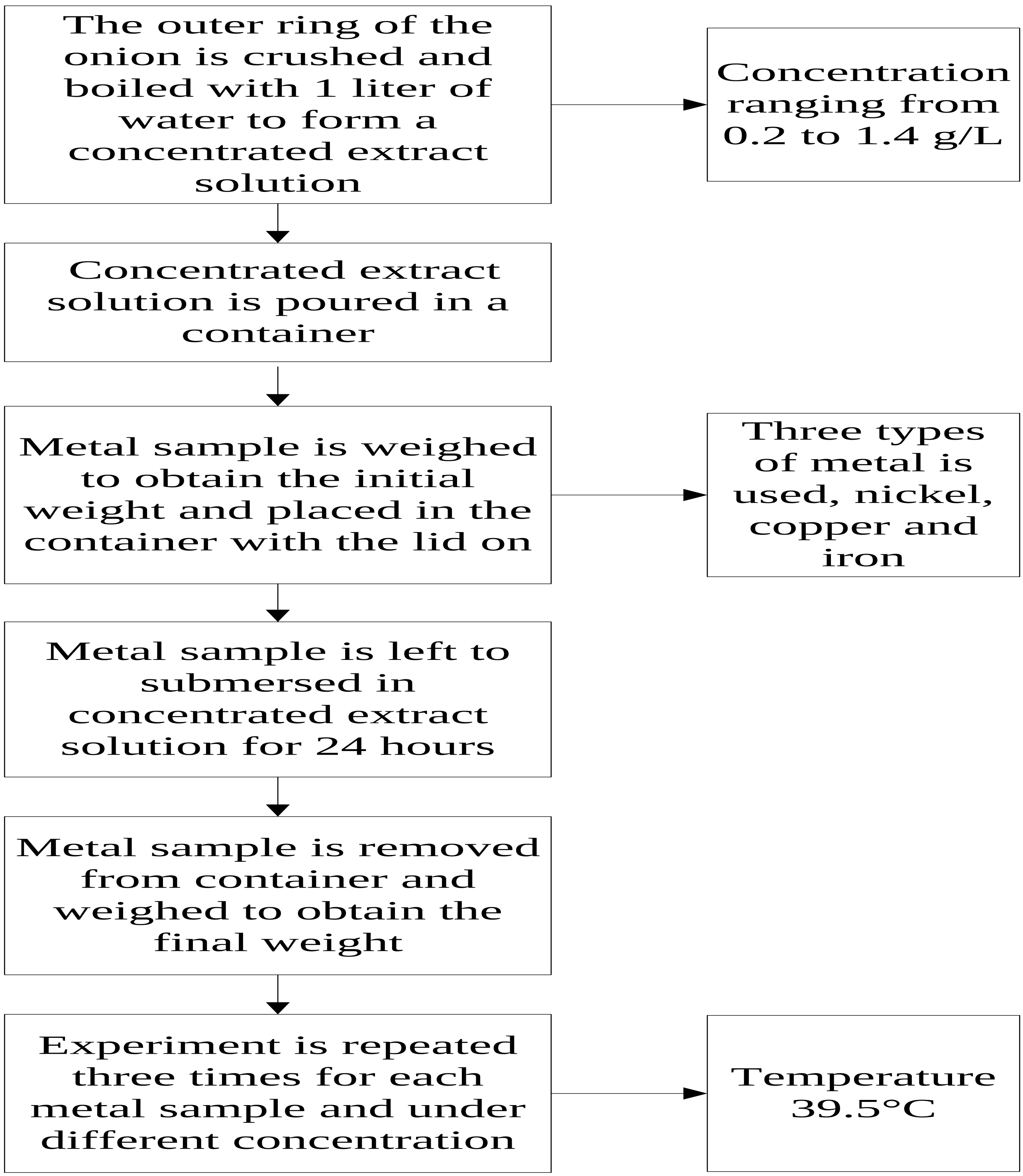


Figure-1
Experimental flow chart

Allium cepa inhibition efficiency reflects the effectiveness of the inhibitor in retarding the corrosion process. Usually, if there is a reduction in corrosion rate, then the inhibitor is effective and there should be a significant reduction in inhibition efficiency. The inhibition efficiency increased with increase in *Allium cepa* concentration (from 0.2 to 0.6 g/L), but stabilized thereafter when its concentration was increased from 0.8 to 1.4 g/L. The maximum inhibition efficiency of *Allium cepa* (at 0.6 g/L) for iron, nickel and copper were 92%, 88% and 46%, respectively (figure 3), confirming there was a reduction in corrosion rate and inhibition efficiency, particularly for iron.

Metal concentration is the amount of metal ions in the solution after the metal is removed from the oven after 24 hours. As corrosion rate decreases, less disintegration of metal ions occur, therefore only a small amount of ions would have been present in the solution. The difference in metal concentration of iron, nickel and copper in the absence and presence of *Allium cepa* was 93%, 91% and 22%, respectively (figure 4). Once again, iron exhibit less disintegrations, leaving small quantity (average 3 mg/L) when *Allium cepa* concentration was gradually increased to 1.4 g/L.

Corrosion rate is the opposite of inhibition efficiency. It shows the measure of corrosion process that occurs to the tested metals. When corrosion rate declines, the inhibitor applied are considered efficient as it can prevent corrosion of metals from occurring. The difference of corrosion rate measured in the absence and presence of *Allium cepa* for all the three metals (iron, nickel and copper) were 92%, 86% and 43%, respectively (figure 5).

Area affected by the corrosion reflects the surface area of the metals tested which are affected. As corrosion rate decreases, the area affected by corrosion reduces as less mechanism of corrosion occurs. The average difference of area affected by corrosion on the surface of all three metals (iron, nickel and copper) was 66% due to the presence of *Allium cepa* (figure 6).

Turbidity is the degree of cloudiness of the water. As corrosion take place, the disintegrated particles of the metal diffuse causing the water to be murky and cloudy. As corrosion rate decreases, the turbidity level also decreases due to the decline in disintegration of the metal particles. The difference of turbidity affected in the investigated wastewater of all three metals; iron, nickel and copper without and with the presence of *Allium cepa* were 53%, 67% and 52%, respectively (figure 7). Iron showed tremendous reduction, from 6.5 to 3 NTU when A*llium cepa* concentration was increased from 0.2 to 1.4 g/L.

The pH is the direct reflection of the amount of hydrogen ions present in the solution. As corrosion rate decrease, the amount of hydrogen ions also decreases causing pH increment. The ideal pH of water with respect to inhibition of corrosion should be in the range 6.8 to 7.3[14]. The difference in pH in the tested wastewater of all three metals; iron, nickel and copper when *Allium cepa* was gradually increased was 0.41, 0.2 and 0.15, respectively (figure 8). Once more, iron showed highest pH increment from 6.35 to 6.76, confirming corrosion rate was decreased.

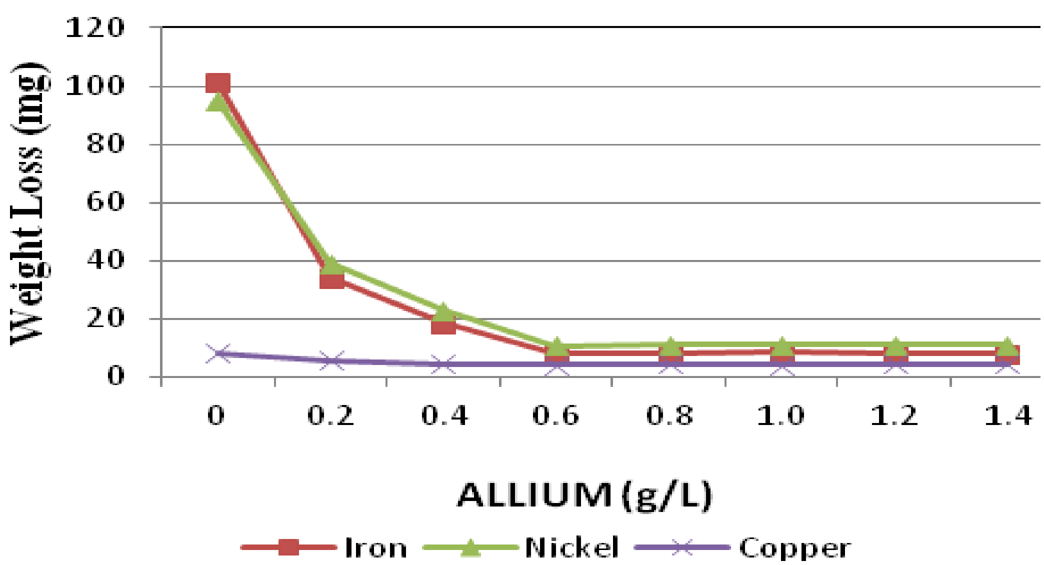


Figure-2
Metal weight loss at various concentration of *Allium cepa*

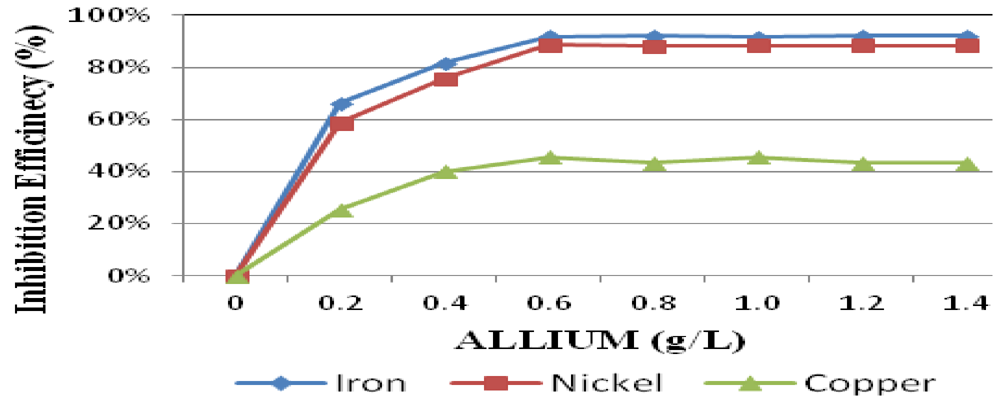
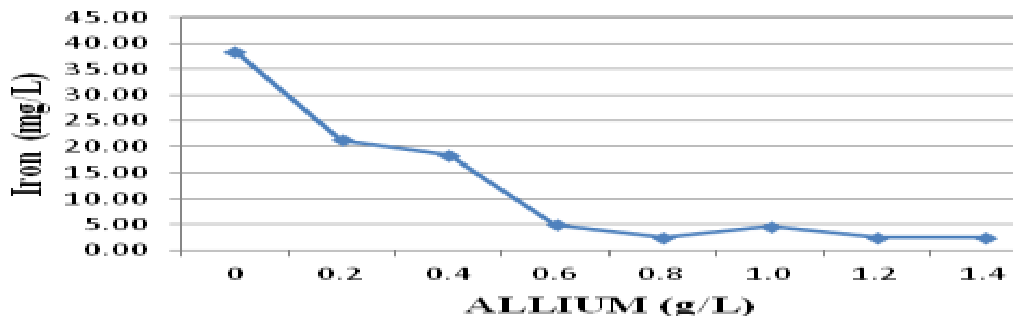
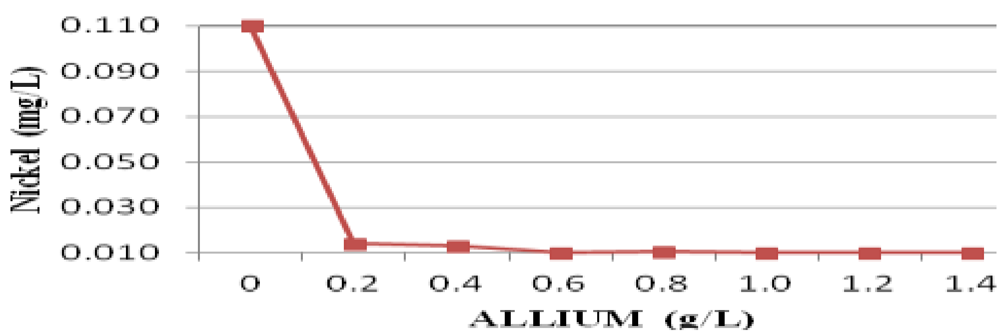


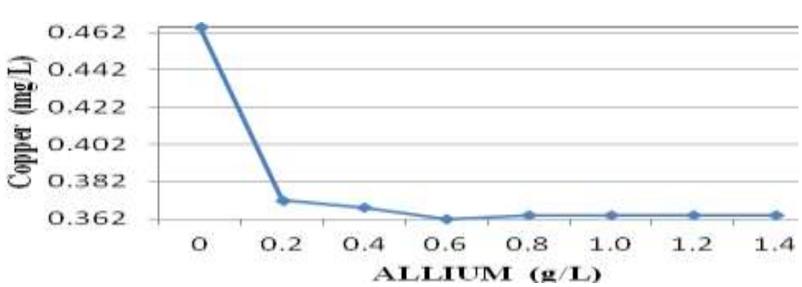
Figure-3
Inhibition efficiency profile of metals at various concentration of *Allium cepa*



(a)



(b)



(c)

Figure-4
Reduction profile for (a) iron, (b) nickel and (c) copper in the presence of Allium *cepa*

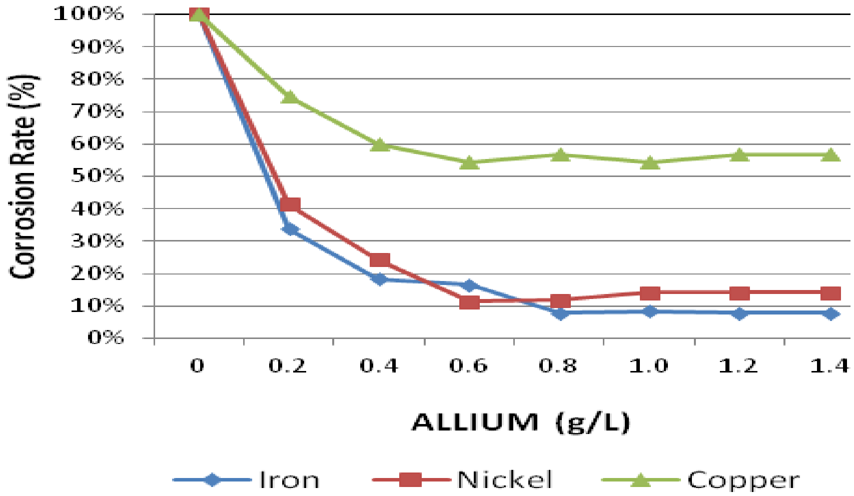


Figure-5
Corrosion rate of metals and various concentration of *Allium cepa*

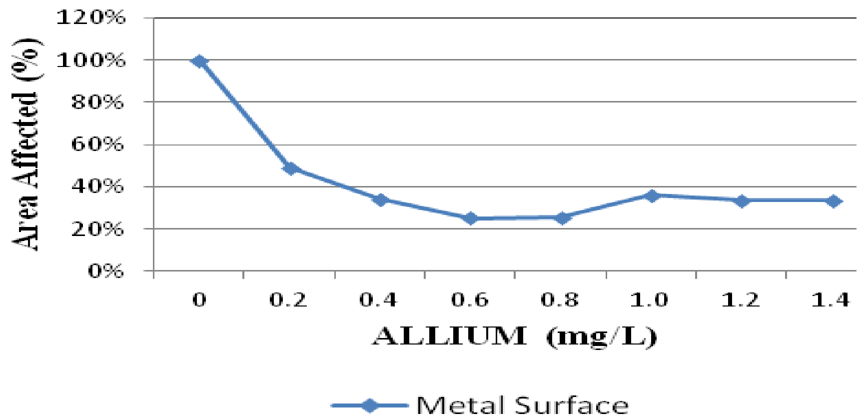


Figure-6
Area affected by corrosion for all three metals (iron, nickel and copper) at various concentration of *Allium cepa*

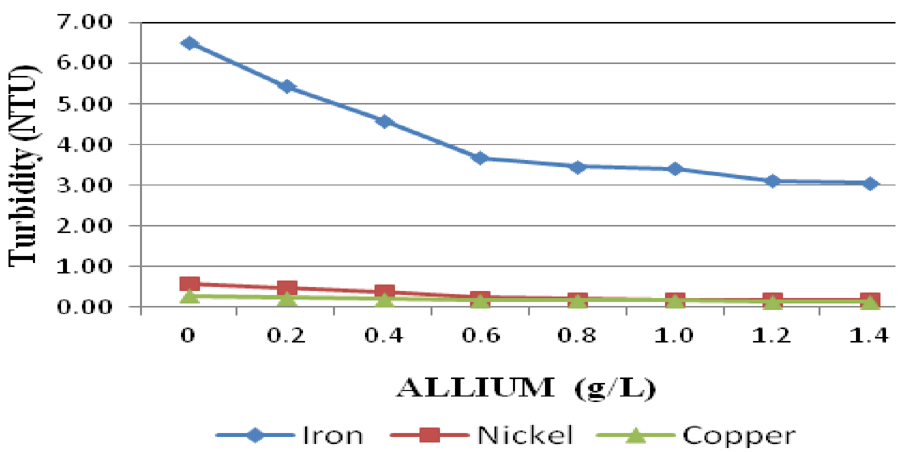


Figure-7
Turbidity profile of metal solutions at various concentration of *Allium cepa*

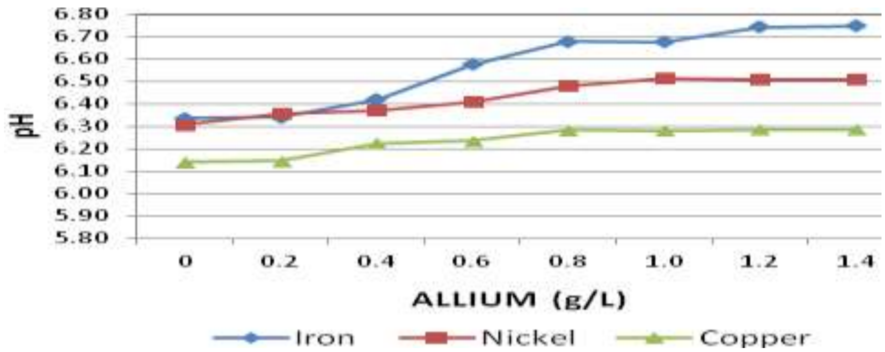


Figure-8
pH profile of metal solutions at various concentration of *Allium cepa*

Conclusion

Based on the experimental results, it has been proven that *Allium cepa* can be used as a natural corrosion inhibitor. The ideal concentration where *Allium cepa* exhibits the maximum inhibitory reaction was 0.6 g/L for all the three metals analyzed. The inhibition efficiency for iron, nickel and copper was 92%, 88% and 46%, respectively. Moreover, the corrosion rate was also successfully decreased to 92%, 86% and 43% for iron, nickel and copper, respectively. It can be concluded that the objective of finding a natural substance that is environmentally friendly, economical and effective has been achieved.

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