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Application of Plants Extracts as Green Corrosion Inhibitors for Steel in Concrete - A review

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ABSTRACT

High requirements in protection of steel reinforcing bar (steel rebar) from corrosion are necessary since there are multi interaction of corrosive chemicals which cause early damage of concrete buildings. Corrosion of steel in concrete can destroy the concretes and reduce concrete strength. To protect rebar from corrosion, application of corrosion inhibitor is believed to have higher performance compared to other protection systems. To date, organic inhibitors have promising methods in steel rebar protection as they are environment-friendly, compatible with concrete, cost effective and applicable in any various concrete conditions. Thus, demands in using these inhibitors tend to increase significantly. This paper reviews the applications of green corrosion inhibitor specifically highlighted in protecting mechanisms, typical plants extracted, performance in corrosion protection, and classification of green corrosion inhibitors. The corrosion resistances of carbon steels in concrete protected by green inhibitors are in focus. As summary, it can be confidently notified that green corrosion inhibitors for steel in concrete will have a prospect to be used as corrosion prevention in the future with further improvements.

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1. INTRODUCTION

Corrosion in steel rebar is one of the most factors which causes damages on concrete structures. Rebar has serious corrosion problems when they are contacted with water, salt (NaCl) and carbon dioxide (CO_2). In industrial areas where CO_2,H_2S, S and C are present, corrosive species are more complex which complicate corrosion mechanism (Asmara *et al.,* 2016; Alia *et al.,* 2017; Asmara *et al.,* 2013; Asmara *et al.,* 2011). Corrosion of rebar does not only damage concretes but also reduces concrete strength. Typical corrosion forms on rebar are uniform corrosion, galvanic and pitting corrosion. Vermany (Vermany *et al.,* 1985; Jenifer *et al.,* 2000) reported that at the year of 1997, it was estimated that among 580,000 concrete bridges in the United States, there was structurally deficient of 100.000. The cost to repair these bridge deficiencies was estimated to be ranging from $78 billion to $112 billion. Thus, the need to manage corrosion protection on rebar has been an important element in designing concrete structures

To provide long-term life service, integrated approaches in selecting an appropriate material to protect rebar from corrosion are required. Among the various protection methods, applying inhibitors mixed in concrete is believed to have more advantages. To avoid environmental issue, green corrosion inhibitors have become one main promising key. These types of inhibitors are not hazardous to environments, compatible with any type concretes and economically affordable. Accordingly, research studies on green corrosion inhibitors are growing fast. The beneficial properties of green inhibitors or so-called organic inhibitors are environment-friendly and biodegradable (Asmara *et al.,* 2016; Sangeetha *et al.,* 2011). Green corrosion inhibitors are commonly made of extracts of natural plants which are abundantly available in many countries. Most of green inhibitors commonly contain P, N, S, O. These atoms coordinate with metals ions to form protective films formed on the metal surface to inhibit further corrosion process (Sangeetha *et al.,* 2011). The other mechanism proposed by Amitha et al (Amitha *et al.,* 2012) is that cation of onium is adsorbed on the cathodic sites of the metal surface to block the corrosion reaction. In further explanations, they suggested some inhibition mechanism which are adsorption on metal surface, change anodic and/or cathodic reaction, interfere diffusion rate, and decreasing the electrical resistance (Amitha *et al.,* 2012).

2. CORROSION ON REBAR

Corrosion on rebar occurs when concretes expose to severe environments such as high acidity, high CO_2 contents, and high humidity environments (Asmara *et al.,* 2016). Concretes which have high pH (about 12- 13) tend form passive film to the reinforcing steel surface. In this condition, steel is in corrosion resistant condition (Bentur *et al.,* 1997). However, pH may decrease when corrosive species penetrate to the concrete pores. Corrosive species such as CO_2, H_2S and chlorides which ingress through concrete pores will react with reinforcing steels bar resulting in corrosion to the steel. Corrosion products in the form of ferric oxides/hydroxides will expand volume of steels to 3-6 times than the volume of original steel which can induce crack to the concretes (Kumar & Quraishi, 2013; Asmara *et al.,* 2017). Durability of the rebar depends on several factors such as temperature, ratio of cement/water, pH, humidity, quality of cement or concrete composition, and environmental effects. In marine conditions which represent corrosive environments, chloride ions are the most aggressive corrosion agents as these ions are able to decrease concrete pH. Chlorides ions have the ability to bond with cement to form Friedel's salt ($Ca_2Al(OH)_6Cl \cdot 2H_2O$, or $C_3A \cdot CaCl_2 \cdot 10H$) which reduce concrete strength (James, 2004). Thus, the concentration of chlorides

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ions allowed in the concrete mixture are important parameters which should be considered in order to obtain durable concrete structures. Critical chloride threshold (CCTL) in concrete is defined as the minimum concentration of chloride in the concrete which causes concrete is in active (pitting) corrosion for the reinforcing steel. The other definition of CCTL is the chloride content at which causes current density exceeded 10 $\mu A \cdot cm^{-2}$ for 5 hours (Hurley, 2006).

3. CORROSION MECHANISM OF STEEL REBAR

Several researchers proposed mechanism of steel corrosion in concrete (Shahid, 2011; Jae et al., 2016; Cabrini et al., 2015; Elsener, 2001; Söylev, 2008; Ormellese et al., 2006; Page, 1975; Hausmann, 1967; Gouda, 1970; Valcarce, 2008; Freire, *et al.,* 2009; Cabrini, 2002; Asma *et al.,* 2011). All agree that corrosion on rebar is influenced by properties of concretes. Structure of concrete which is porous can be easily penetrated by water and acidic ions. Ions, typically chlorides cause depassivation of the protective films lead to corrosion process. Process corrosion on rebar can be simplified by the following reactions (Asmara *et al.*, 2011; Magdalena, 2016):

In anodic site, there is reaction oxidation process on steel (Asmara *et al.,* 2013; Asmara, 2011).

$Fe^{o} \rightarrow Fe^{2+} + 2e$

when steel reacts with water, pits will grow starting from anodic oxidation of steel to produce hexaaquo iron (II) (Sastri *et al.*, 2011).

$Fe^{2+} + 6H_2O \rightarrow Fe(H_2O)_6{}^{2+}$

$[Fe(H2O)_6]^{2+} \rightarrow [Fe(OH)(H_2O)_5]^{+} + H^{+}$

$[Fe(OH)(H2O)_5]^{+} \rightarrow Fe(OH)_2 + 4H_2O + H^{+}$

.

In the presence of oxygen/chloride ions Fe^{2+} will hydrate to form ferric oxide $FeO \cdot OH$ which follows this reaction.

$2Fe(OH)_2 + 1/2O_2 \rightarrow 2\gamma\text{-}FeOOH + H_2O$

Another expression for chemical reaction of steel in concrete is presented by A. Rosenberg as (Rosenberg & Andrade, 1989):

$xFe^{2+} + yO_2 + H_2O \rightarrow Fe_3O_4, Fe(OH_3), Fe(OH_3).3H_2O$

Combinations of corrosive ions or species cause corrosion processes involving both physico-chemical and electrochemical reactions. The reactions locate on cathodic site. It consumes electrons and increase corrosion rate.

$O_2 + 2H_2O + 4e \rightarrow 4OH^-$

$2H^+ + 2e \rightarrow H_2$

Product of reaction such as ions OH^- will form ferro-hydroxide which is soluble in aqueous media. Concrete, typically, has high pH and tend to form passive layer of Fe_2O_3 on the steel surface. Increasing number of ions OH^- in concrete, create very high pH causes reducing integrity of rebar strength.

Steps of corrosion process in concretes can be summarized as follows: firstly, corrosive ions penetration of oxide film by chloride ion, competition between adsorption and passivating of ions, and finally oxidising the steel rebar. The other reactions are catalysis of corrosion reaction by creating bridging structure and forming complex compound between ions and steels (Gaidis, 2004)

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Tabel 1. Critical Chloride Threshold Level values of the different reinforcing metals in concrete

Types of Metals	Concrete conditions	Threshold concentration	Corrosive specimen method investigation	Ref.
Carbon steel	Mortar suspensions OPC	2.4%	Anodic polarisation	(Ggouda, 1970)
SS	OPC solution	4%	Corrosion rate	(Garcia *et al.*, 2007)
Alloy 254 SMO	OPC solution	10%	Corrosion rate	(Bertolini, 2007)
Galvanised Zinc	OPC solution	1.5 Kg/m^3	Corrosion rate	(Darwin *et al.*, 1974)
304 L SS	OPC solution	4 % (W)	Anodic polarisation	(Hurley, 2006)
316 L SS	OPC solution	5.5 % (W)	Anodic polarisation	(Hurley, 2006)
LDX 2101 Duplex SS	OPC solution	6.5 % – 7 % (W)	Anodic polarisation	(Hurley, 2006)
Carbon steel	Concrete slabs with added Clto various exposure conditions OPC	0.1 - 0.19	Corrosion rate, visual inspection, mass loss	(Hope, 1987)
Carbon steel	Cements with high or low alkali content; Mortars 80% RH 100% RH	0.6 -1.8 0.5 - 1.7	Corrosion rate	(Petterson, 1994)

4. GREEN CORROSION INHIBITOR FOR STEEL REBAR

4.1. Inhibitor

A corrosion inhibitor is a chemical compound which is added in small quantity in solutions or gas can reduce corrosion rate of metals or alloys. Performances of inhibitors are indicated by effectiveness which is percentage of corrosion rate reduction. Corrosion inhibitor reduces corrosion rate by formation of a film which inhibit corrosion process in the metal surface. The other mechanism is by increasing solution resistivity of the solutions to reduce corrosion rate. Based on protection mechanisms, there are three types of corrosion inhibitors. The first, inhibitors which work by polarise corrosion potential on anodic region called anodic inhibitor. Anodic inhibitors passivate by forming film on the metals surface to reduce corrosion rate. Examples of anodic inhibitors are chromates, nitrates, molybdates, and tungstate. Secondly cathodic inhibitors which are inhibitors acting by polarising corrosion potential to cathodic regions. They limit corrosive species through diffusion process. The last are corrosion inhibitors which act by combining both anodic and cathodic mechanism. Corrosion inhibitors are also can be classified as chemicals or natural and organic or inorganic. Generally, the inorganic inhibitors have mechanism of cathodic and anodic polarisation. While organics inhibitors work by absorption mechanism to form film on the metal surface.

4.2. Green Inhibitor

Green corrosion inhibitors are inhibitors made by extracting plants for corrosion prevention. These inhibitors have become priority for researchers as it is proposed to replace application of chemicals inhibitors which are environmentally hazardous substances. Researches on green corrosion inhibitors have shown increasingly as green inhibitors are safe, biodegradable and environmentally friendly. Green inhibitors also could be found or produced easily. There are many researchers have been conducted to investigate these

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natural resources over the years. Delonix regia used rosemary leaves as green inhibitor to protect aluminium in hydrochloric acid solutions (Abiola *et al.*, 2007). Hazwan investigated natural oil palm as a corrosion inhibitor for mild steel. Hazwan *et al.*, (2016) showed the inhibition of corrosion with ethanolic extract of African bush pepper (Piper guinensis) on mild steel.

Inhibitors from black pepper extracted and nicotine have been studied by Quraishi *et al.*, (2009) and showed best performances. They studied corrosion inhibition of mild steel in hydrochloric solution by black pepper extract (Piper nigrum family: piperaceae) by mass loss measurements, potentiodynamic polarisation, and electrochemical impedance spectroscopy (EIS). Black pepper extract gave maximum inhibition efficiency (98%) at 120 ppm at 35°C for mild steel in hydrochloric acid medium. Electrochemical evaluation revealed it to be a mixed-type inhibitor and that charge transfer controls the corrosion process (Ebenso *et al.*, 2004).

The corrosion inhibition property was attributed to an alkaloid "piperine". Nicotine is an organic compound belonging to the alkaloids: a liquid, oily, and colorless derivative of the ortinina. This organic compound is a candidate for the protection of petroleum pipeline systems, since it is of natural origin, readily found in tobacco plants (nicotiana tabacum), in which it is the major active chemical component. Furthermore, the nicotiana tabacum extract has been reported (Njokua *et al.*, 2013). They demonstrated that the best concentration was 1200 mg/L with 89% efficiency and Bhawsar *et al.*, (2009) found to have inhibitory corrosion properties for mild steel in acidic medium, attaining 94.13% IE at an optimum concentration of 10 g/L under static conditions for 6 hours at 303°K. As summary, **Table 2.** reviews of discussion the development of green inhibitor for various metals.

4.3. Current researches on green inhibitor for steel rebar

Green corrosion inhibitor is an inhibitor made of organic substance or plant extracted. The inhibitor is able to form a protective layer to prevent ingress of aggressive species like oxygen, carbon-di-oxide, sulfate, chloride, and moisture. In reinforcement corrosion, many researchers have conducted various experimental works to improve inhibitor's efficiency. Their effectiveness of inhibitor depends on the property of their chemical constituents. Role of inhibitor to extent service life of steel on concrete have shown improvements. The following are presented literature surveys of various organic constituents used to produce green inhibitor. The following researchers presented comprehensive reviews of extract plants to inhibit corrosion process of rebar.

Quraishi *et al.*, (2012) in the present investigation, studied effects of calcium palmitate alone and in combination with calcium nitrite on corrosion of steel in concrete. The results of the investigation demonstrated that calcium palmitate showed an effective inhibitor. Inhibitor provided 91 % to 92% efficiency after 90 days of exposure time in 3.5% NaCl solution. It was shown that the inhibitor did not have effects on the mechanical strength of cement and concrete. Petrographic examination revealed that calcium palmitate blocs the pores and reduced the corrosion rate of steel. Further investigation, they found that calcium palmitate inhibited corrosion though adsorption mechanism. Inhibitor created film to the steel surface through polar carboxylate group blocking the pores forming insoluble hydrophobic ferric stearate salt.

Tabel 2. Green corrosion inhibitors for any metals and mechanism

Plants Extract	Elements	Protection mechanism	Metal	Solutions	Ref.
Argemone mexicana	alkaloid	The free electrons on the O and N atoms form bonds with the electrons on the metal surface. O atom helps to free an electron on the N atom and forms a stronger bond with the metallic electrons.			(Amitha *et al.,* 2012)
Garlic	allyl propyl disulphide	Affects the potential cathodic process of steel.			(Amitha *et al.,* 2012)
Carrot	pyrrolidine ionizes	N atom acquires a negative charge, and the free electrons on N possess still higher charge, resulting in stronger bond formation at N		Alkaline	(Amitha *et al.,* 2012)
Black Pepper	alkaloid "Piperine".	Mixed-type inhibitor and that charge transfer controls the corrosion process.	mild steel	HCl	(Amitha *et al.,* 2012)
Fennel Seeds	limonene (20.8%) and pinene (17.8%).	Adsorption on the metallic surface.	carbon steel	1 M HCl	(Amitha *et al.,* 2012)
Soya Bean	hydroxy aromatic compound	Form complexes with metals.			(Amitha *et al.,* 2012)
Allium Cepa (Onion)	Quercetin	Adsorption site on the surface of the metal	Aluminium	Waste water	(Sulaiman *et al.*2012)
Orange peel	Butyric acid, 2-bromo-, 1-methylethyl ester	Adsorption site on the surface of the metal	Mild steel	HCl	(Nazanin *et al.,* 2016)

Again, Quraishi *et al.,* (2011) demonstrated performance of calcium stearate as inhibitor. They embedded carbon steel on ordinary portland cement standard IS: 456-2000. The results showed that inhibitor efficiencies were achieved at 90 % and 93% at the concentration of 3% and 5% respectively in 60 days experiments using 3.5% NaCl. In line with previous study, this inhibitor reduced corrosion rate of steel by blocking concretes porous to limit ingression of chloride ions.

Joshua *et al.,* (2015) characterized phyllanthus muellerianus as inhibitor for reducing concrete steel-reinforcement corrosion in industrial environment. They used 0.5M of H_2SO_4 medium to simulate industrial/microbial environment. At the concentration of 6.67 g/l, this inhibitor reduced corrosion rate of rebar to 90 %. While at the concentration of 1.67 %, the reducing corrosion rate was 78 %. From investigation, leaves of phyllanthus muellerianus and euphorbiaceae contained constituents which were tannins, phlobatanins, saponins, flavooids, terpenoids and alkanoids. P. muellerianus.

Abbas *et al.,* (2018) investigated effectiveness of green inhibitor extracted from waste of orange peel. They extracted dry orange peel using methanol extract at 6-hour immersion time in methanol at the pressure (60 mbar) and 40°C. From the experimental data using electrochemical polarisation measurements and weight-loss testing for 7 days immersion time of rebar, it was showed that this inhibition showed a good performance in aqueous 3.5 wt% NaCl solutions. The steel rebar showed that corrosion rates of rebar decreased to 0.02 mm/year at the 3% concentration of inhibitor.

Shaymaa *et al.,* (2017), studied powdered rice husk for corrosion of steel in concrete. They added extract of rice husk to the concrete with American mix design method (ACI 211) at

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the strength of 30 MPa at age of 28 days. The samples of rebar were cured in tap water for a period 30 days with immersed in 3.5% NaCl solution. Corrosion test were conducted at the solution in different concentration (1%, 2% and 3%) of inhibitor. The data recorded that the corrosion current was 41.3 μA/cm^2 for the solution without inhibitor and it become 28.5 μA/cm^2 and 7.8 μA/cm2 for the solution with inhibitor 1% and 3% rice husk powder, respectively. It means the reduction of corrosion rate was 30% and 81% respectively.

Loto *et al.,* (2013) developed vernonia amygdalina (bitter leaf) as corrosion inhibitor for rebar. The rebar with chemical composition of: 0.3%C, 0.25 %Si, 1.5%Mn, 0.04%P, 0.64%S, 0.25% Cu, 0.1% Cr, 0.11% Ni, and the rest of Fe, was used for the reinforcement. Four different concentrations of 25%, 50%, 75% and 100% of the extract were used. They used electrochemical potential measurement, pH and gravimetric (weight loss) methods. The experiments were performed using bitter leaf extract as a green inhibitor in 3.5% sodium chloride solution. Inhibitor extracts concentrations of 25, 50 75, and 100% were prepared from the fresh leaves of vernonia amygdalina with distilled water. Vernonia amygdalina extract gave good corrosion inhibition performance of the embedded steel rebar in concrete at 25%, 50% and 75% concentrations in NaCl test medium. The highest inhibition efficiency of 90.08 % was achieved at 25% concentration, the lowest inhibitor concentration used. The also recorded pH of concrete which showed effects of vernonia Amygdalina at 25% concentration addition at the concrete, The pH reduced from 10.63 – 9.04. At 50% concentration, pH reduced from 10.52 – 9.10.

Inhibitor extracted form leaves of bambusa arundinacea (Indian Bamboo) for rebar protection was under investigated (Gouda, 1970). Ordinary Portland Cement (OPC) was used in this research. The concretes were mixed with chloride concentrations of 0.94%. The water content was kept constant to 230 kg/m^3. The water–cement ratio (w/c) used was 0.45. The fresh density of concrete was then obtained as per guidelines specified by British method of mix selection (DOE) to be 2380Kg/m^3. Corrosion tests were carried out after 180 days of exposure of wet and dry cycles. From the data, bambusa arundinacea extract reduced corrosion rate of rebar to 1.53 x 10^{-3} as calculated using EIS and LPR methods. Compared without inhibitor, corrosion rate of rebar was 2.169 x 10^{-3} (EIS) and 1.8 x 10^{-3} (LPR) which means that there was an efficiency of 72%. The results of LPR and EIS also showed that the concrete resistivity (Rc) and polarization resistance (Rp) values increased as bambusa arundinacea was added.

Lisha *et al.,* (2017) used azadirachta indica (neem) powder and dehydrated aloe vera as corrosion inhibitor for steel in concrete. M 25 grade concrete was used with coarse aggregates of 20 mm size. The concrete was immersed in solution with salinity of about 3.5% (35 g/L). The concrete with green corrosion of neem inhibitors have reduced corrosion rate of steel on concrete from 0.3 mm/y to 0.22 mm/y. Inhibitor of aloe vera extract showed that the corrosion rate reduced to 0.27 mm/y. The results of inhibitors showed that azadirachta indica (neem) has better corrosion inhibition efficiency compared to the aloe vera inhibitor.

Akshatha *et al.,* (2015) did studies on inhibitor with leaves of ruta graveolens and azadirachta. The extracted leaf of azadirachta indica (neem) and ruta graveolens plants were used as organic inhibitors. They compared with inorganic inhibitor which was sodium nitrate and ethylene diaminetetra acetic (EDTA) disodium dihydrate. The inhibitors were added during mixing of concrete and the reinforcing steel bar. The concrete was made of cement of OPC 43 grade with specific gravity 3.279. The

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rebar were immersed in the hydrochloric acid (HCl), sodium chloride (NaCl) and magnesium sulphate ($MgSO_4$) solution for corrosion test. From half cell potential measurement, experimental in 5% HCl for 56 days, it can be seen that extracts of azadirachta Indica have shown the most positive potential which followed by ruta graveolens, sodium nitrate and EDTA disodium dihydrate. The same trend also occurred when the experiments were conducted in 5% NaCl solutions which showed that azadirachta Indica gave the most positive corrosion potential. On contrary happened when rebar were immersed in 5% $MgSO_4$ solutions, inorganic inhibitors (EDTA disodium dehydrate and sodium nitrate) showed the most positive corrosion potential.

Eyu *et al.* (2013) studied application of vernonia amygdalina (bitter leaf) as corrosion inhibitor for carbon steel (grade 40) reinforcing bar immersed in 3.5% NaCl solution for 8 weeks immersing time. They extracted the leaf using methanol to obtain liquid inhibitor. By using cylindrical concrete block mixed with vernonia extracts, they studied corrosion rate of the rebar. The other experiments, they used sodium nitrite as inorganic corrosion inhibitor for comparison. From observation vernonia extracts contains alkaloids, saponin and tannin. Data recorded showed that sodium nitrite at 2% v/v in 3.5% NaCl solution had corrosion rate of 0.007 mm/y for 8 weeks immersing time. Corrosion rate of rebar without inhibitor was 0.09 mm/y. From the data, they recorded that sodium nitrite inhibitor had highest inhibition efficiency which was 96%. The vernonia amygdalina inhibitor shows increased E_{corr} to +95 mV and calcium nitrite +85mV for concentration of 12 l/m^3 within the 70 days of immersion. Further investigation, they noted that the presence of tannins, alkaloids and saponnins in vernonia amygdalina which acted as barrier for chloride ingression. Weight loss test revealed that sodium nitrite inhibitor shows higher inhibition efficiency of 96% followed by calcium nitrite with 91% for 2%v/v inhibitor. However, vernonia amygdalina has inhibition efficiency of 75% with 6%v/v.

Palanisamy *et al.* (2016) investigated effect of prosopis juliflora extract on corrosion of steel in concrete in 3.5 % NaCl. Corrosion test were conducted after 30 days immersion time of rebar without and with the inhibitor. From corrosion test, it was revealed that corrosion inhibitor will reach efficiency 91% at concentration of inhibitor 120 ppm. At low concentration of inhibitor (100 ppm), the efficiency was 51%. From EIS studies, it was stated that there was diffusion process and precipitation effect of the solid calcium hydroxide layer for formation of a protective layer at the steel/concrete interface. Further, the increasing concentration of inhibitor will reduce surface inhomogeneity due to the adsorption of the extract molecules over the surface of the embedded steel. From AFM images, it can be seen there was absorption of inhibitors molecules to the rebar surface to form protective layer which reduced corrosion rate of the rebar.

Figure 1 shows the two-dimensional AFM images of the surface of the reinforced steel in concrete without and with the p. juliflora extract. **Figure 1a** shows that there was coroded surface of the steel embedded in concrete caused by chloride ions. **Figure 1b** shows the corroded steel was protected by p. julifora extract used as inhibitor. The inhibitor forms zonal film adsorbed on embedded steel surface when the concentration of inhibitor was 100 ppm. This inhibitor also affected on surface roughness (Sa). Surface of steel without inhibitor has Sa 119 nm compared to 19 nm for steel with 100 ppm inhibitor of p. juliflora extract.

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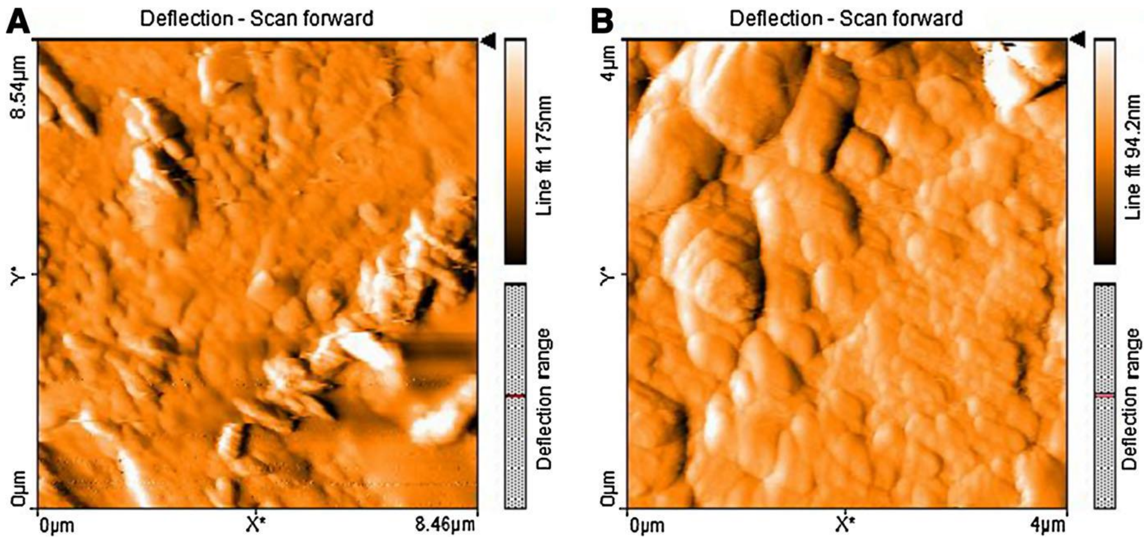

Figure 1. Ilustration of Cu-ETA complex compound (Cho *et al*, 2014)

5. CONCLUSION

Normally, inorganic/chemical inhibitors have satisfied in corrosion prevention of steels in concretes. But because of hazardous for environments, applications of these inhibitors are going to be restricted. As alternative, green corrosion inhibitors, have become a main concern in selecting inhibitor for steels in concretes. These green inhibitors meet the requirement properties of inhibitors used for steel in concretes which are low cost, compatible with concretes, non-toxic, degradable and applicable for industrial constructions. Mechanism theories of inhibitors in inhibiting corrosion process in steel rebar are by forming barrier film on the metal surface through physical and chemical reactions between steel and concretes. Thus, they prevent the diffusion of corrosive ions to the metal surface and blocking concretes porous. In addition, inhibitors can interference anodic or cathodic reactions to reduce corrosion rates. Typically, the more concentration inhibitor the thicker oxide films formed on the metal surface which increase films resistivity and improves inhibitors efficiency. Demand on eco-friendly inhibitor for steel rebar has increased significantly. From the reviews, there are evidences that the extract plants are the most possible to use as excellent corrosion inhibitors for steel rebar. However, the promising researches in the use of plants as corrosion inhibitors for rebar are still far from the ideal inhibitors which are high efficiency as inorganic/chemical inhibitors. However, it can be confidently stated that green inhibitors will continue to be used for corrosion prevention in the future with further modifications. Future improvements should combine types of inhibitors with the excellent adsorption properties and anodic or cathodic mechanism to achieve green inhibitors with the most attractive performance.

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