ISSN: 0975 -8542

Journal of Global Pharma Technology

Available Online at: www.jgpt.co.in

RESEARCH ARTICLE

Corrosion Protection Enhancement using Electropolymerized Aniline Coating on Carbon Steel Pipelines in Industrial Water

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Abstract

Corrosion of carbon steel in different water system utilities exhibited serious source of financial loses. In this study, electrochemical polymerization of aniline on carbon steel were studied in three types of industrial water (cooling water, waste water and treatment water) as corrosive media. The corrosion parameters; corrosion potential, corrosion current, polarization resistance, corrosion rates, and thermodynamic functions were estimated from Tafel and potentiodynamic procedures at four temperatures; 293,303,313and 323K. Protection enhancements were recorded at all industrial water used in this study and efficiencies of 78-91% were achieved. The results are supported by surface morphology examination before and after coating of carbon steel using atomic force microscope (AFM) and optical light microscopy (OM).

Keywords: *Electrochemical polymerization, Polyaniline, Nanofibers, carbon steel, Industrial water.*

Introduction

The petroleum refinery industry transform crude oil into more than 2500 refined products, involving liquefied petroleum gas, gasoline, kerosene, aviation fuel, diesel fuel, fuel oils, and lubricating oils [1, 2]. Large volume of water is used in refinery operations, especially for distillation, hydro-treating, desalting and cooling systems [3-5].

The main problem associated with carbon steel pipelines used in the transportation of oil, gas and water is corrosion [6, 7, 8].Corrosion causes degradation of a metal by electrochemical reaction with oxygen or aggressive ions which exist in oil or industrial water that lead to major economic lose [9-11]. The most important method for corrosion protection used in wild world is coating with conductive polymers such as polyaniline, polypyrole, polythiophene and others [12-14]. The conductive polymers have a wild field in many applications, they commonly used in chemical transistor, rechargeable batteries, production of indictors and ion selective electrodes and biochemical analysis [15, 16].

Experimental

The chemical composition of the carbon steel alloy which are used in this study is presented in Table 1, have been determined by the manufacturers [17].

Table 1: Chemical composition of carbon steel (CS) used in this study

Element	C	S	Si	N	Cu	Mn	Ni	Cr
%	0.26	0.031	0.28	0.010	0.28	0.73	0.13	0.12

The electrochemical polymerization of aniline monomer (0.3M) with H_2SO_4 (0.1M) as a doping on carbon steel (CS) surface (working electrode) carried out by using potantiost at technique. The voltages apply for coating is range between (100-1500 mV). For corrosion studies, carbon steel used as working electrode (WE), it's grading by (1200 mesh) of carbide silicon and washed by distill water and acetone. Ag/AgCl saturated with KCl used as reference electrode (RE). Platinum used as auxiliary electrode (AE). In these study three types of industrial water were uses as corrosive media (cooling water, waste water and treatment water) at different temperature (293, 303, 313 and 323). The change in the microstructure and morphology of the surface followed by optical microscope (Nikon Eclipse ME 600, Japan) and atomic force microscope (SPM AA3000, Angstrom Advanced Inc., USA) [18] respectively.

Results and Discussions

Fig. 1 shows the recorded Tafel plots for uncoated carbon steel immersed in different industrial water(cooling water, waste water and treatment water) at different temperature (293, 303, 313 and 323).

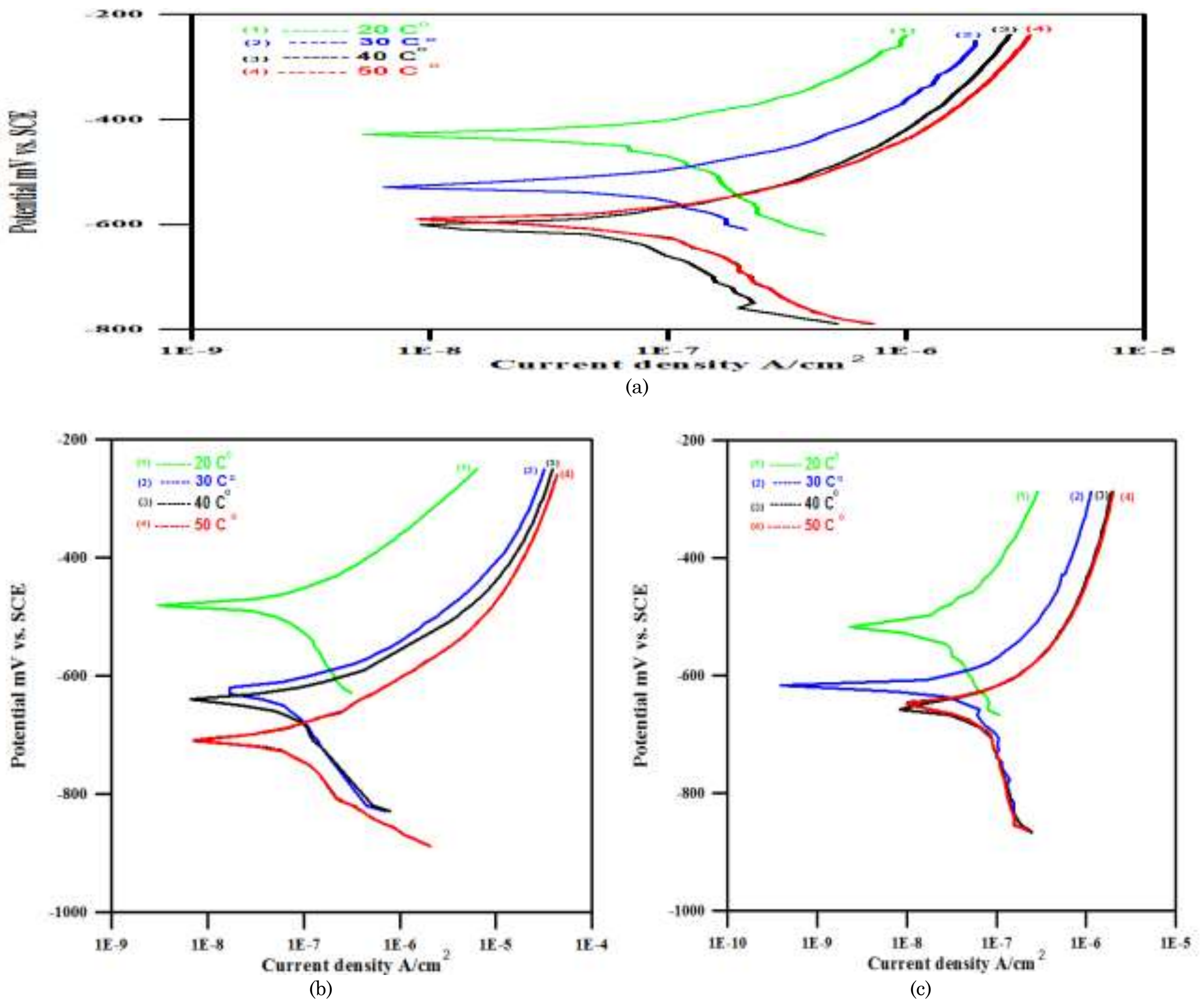


Figure 1: Tafel plots of carbon steel polarized in (a) cooling water (b) waste water (c) treatment water at different temperatures

Table (2) summarizes all calculated corrosion parameters for uncoated carbon steel in three types of industrial water.

Table 2: corrosion measurements parameters for uncoated carbon steel specimens in cooling water, waste water and treatment water at different temperatures

Sys.	T(K)	E_{corr} (mV)	i_{corr} (μA/cm²)	βa (mV/ Dec)	βc (mV/ Dec	R_p Ω.cm²	CR (gm/m².d)	CP (mm/y)
Uncoated CS in cooling water	293	-426.6	59.46	-190.2	97.5	470.7	14.9	0.69
	303	-528.3	71.99	-170.3	119.5	423.5	18.0	0.836
	313	-601.4	76.68	-315.1	135.1	535.4	19.2	0.890
	323	-590.6	106.76	-345.9	143.9	413.3	26.7	1.24
Uncoated CS in waste water	293	-478.9	72.56	-265.7	99.1	431.93	18.1	0.842
	303	-627.8	79.06	-376.7	76.8	350.37	19.8	0.918
	313	-643.3	86.10	-380.4	79.8	332.65	21.5	0.999
	323	-707.9	90.09	-364.2	100.1	378.44	22.5	1.05
Uncoated CS in treatment water	293	-517.9	24.81	-269.8	174.9	1857.1	6.20	0.200
	303	-616.4	52.93	-344.5	145.6	839.6	13.2	0.614
	313	-656.9	73.67	-539.2	149.4	689.5	18.4	0.855
	323	-650.5	80.59	-707.7	144.0	644.6	20.1	0.935

Fig. 2 shows the recorded Tafel plots for coated carbon steel with polyaniline immersed in cooling water, waste water and treatment water at different temperatures (293, 303, 313 and 323).

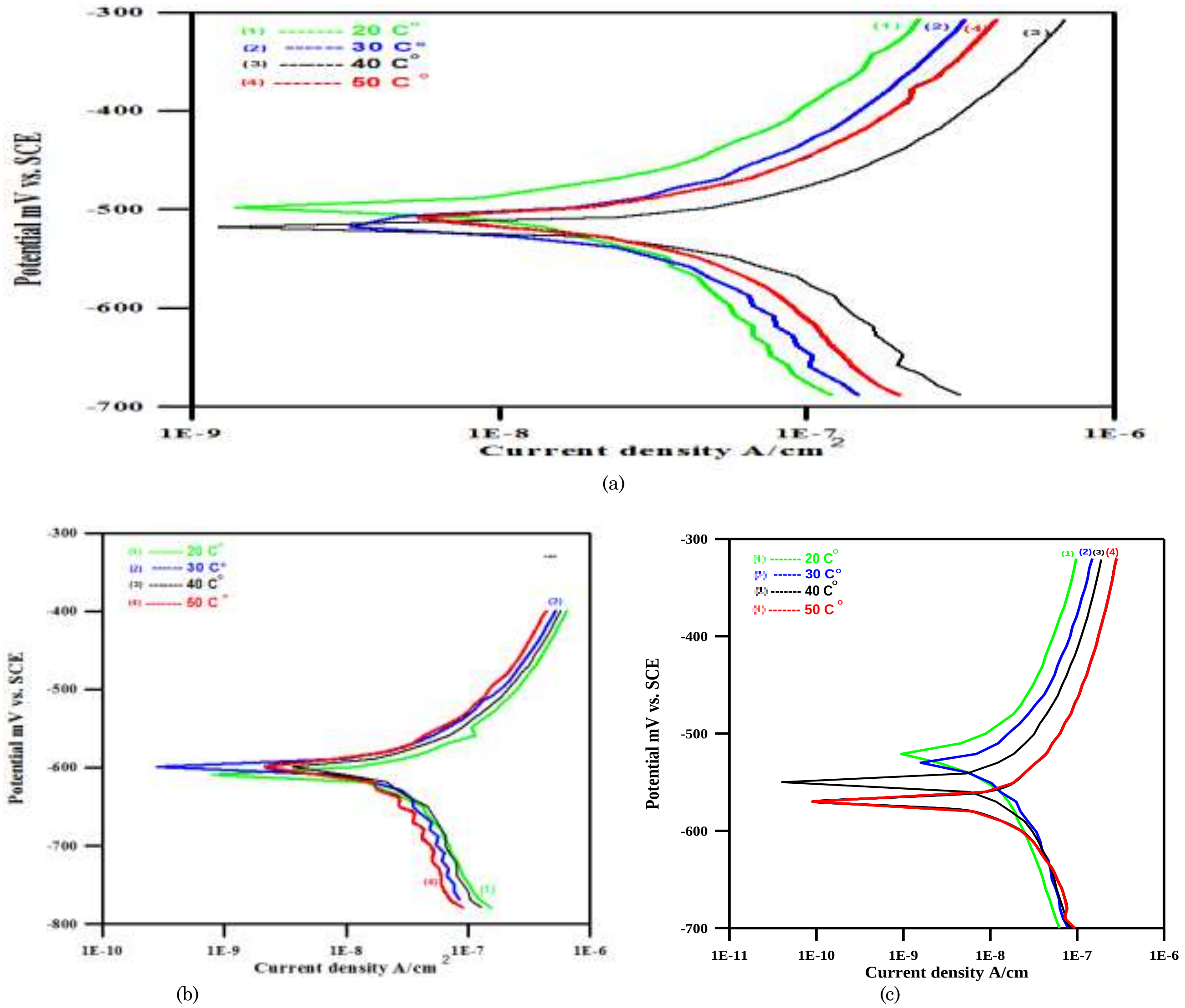


Figure 2: Tafel plots of polyaniline coated carbon steel in (a) cooling water (b) waste water (c) treatment water at different temperatures

Table (3) summarizes all calculated corrosion parameters for coated carbon steel with polyaniline in three types of industrial water.

Table 3: Corrosion parameters of polyaniline coated carbon steel in cooling water, waste water and treatment water at different temperatures

Sys.	T(K)	E_{corr} (mV)	i_{corr} (μA/cm²)	βa (mV/Dec)	βc (mV/Dec	R_p Ω.cm²	CR (gm/m².d)	CP (mm/y)	PE%
coated CS in cooling water	293	-498.0	7.35	-73.7	61.3	1977.0	1.84	0.085	87.6
	303	-515.1	14.55	-99.4	88.9	1400.4	3.64	0.169	79.8
	313	-518.9	16.92	-63.0	51.9	730.28	4.23	0.196	78.0
	323	-508.6	17.45	-104.5	73.3	1072.0	4.36	0.203	83.7
Coated CS in waste water	293	-606.8	9.31	-63.6	41.7	1174.6	2.33	0.108	87.1
	303	-598.3	10.73	-88.0	59.5	1436.5	2.68	0.125	86.4
	313	-598.5	12.50	-91.6	55.3	1197.8	3.13	0.145	85.5
	323	-598.4	13.32	-163.6	75.9	1690.1	3.33	0.155	85.2
Coated CS treatment water	293	-520.5	3.06	-65.7	57.3	4343.1	0.765	0.0355	87.6
	303	-529.8	5.82	-82.4	70.8	2841.1	1.45	0.0675	89.0
	313	-550.9	6.57	-71.6	71.1	2357.7	1.64	0.0763	91.1
	323	-568.3	7.13	-69.1	53.5	1836.3	1.78	0.0828	91.2

The polarization resistance was determined by Stern-Gery equation [19, 20]:

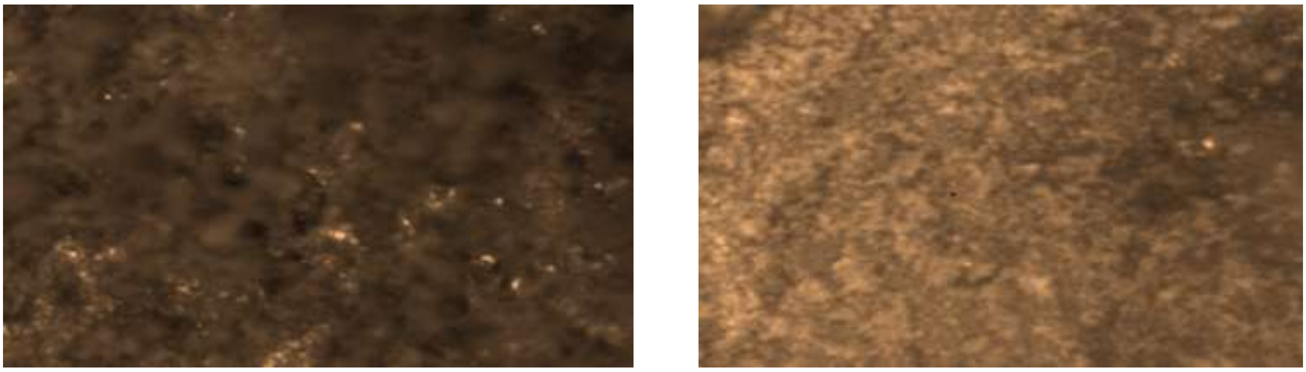
$$Rp = \frac{\beta a \beta c}{2.303\ (icorr)(\beta a + \beta c)} \qquad (1)$$

Where βa and βc are Tafel slopes and icorr is the corrosion current density.

The protection efficiencies were measured using the following equation [21]:

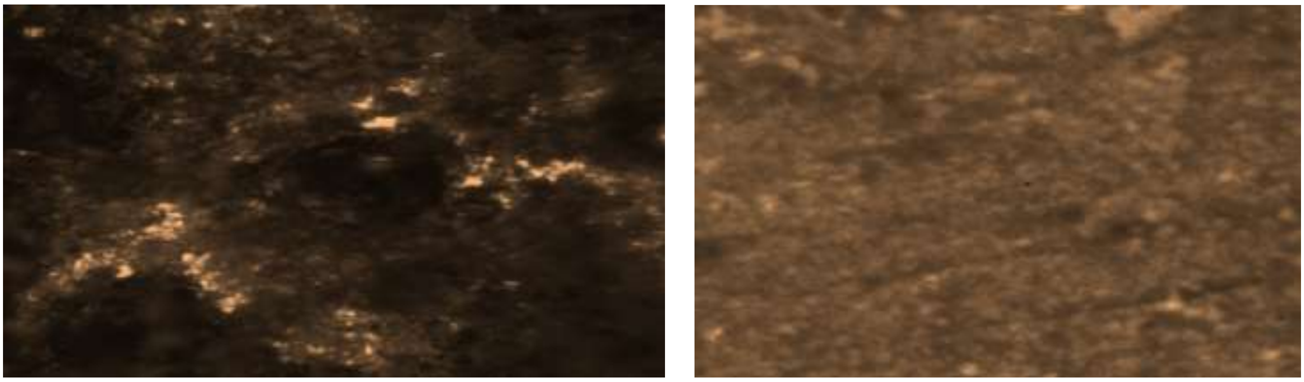
$$PE\% = [(CR_0 - CR_x) / CR_0] * 100 \qquad (2)$$

Where CR_0 and CR_x are the corrosion rate without and with coating CS by polyaniline respectively. From Tables (2) and (3), the value of corrosion potential (E_{corr}) shifted into more positive values (noble direction) which indicates the corrosion resistant feature of the coating, also it is seen that the values of corrosion current density (icorr) for polyaniline coated CS are lower than the corresponding values for bare CS[22] . The most important evaluated parameter is the PE% of polyaniline coated samples, which reflects the effect of coating process on sample, the best protection ability was observed for CS metal in cooling water and waste water about(87%) at 293 K while PE% in treatment water is about (91%) at 313 and 323 K. It is seen that the values of Rp for polyaniline-CS are increasing with compared corresponding values of blank CS for all types of industrial water which used in this study. The morphology and topography of uncoated and coated CS were examined by optical and AFM microcopies, Figure (3-5) show the microscopic effects on the surface of uncoated and coated CS, the corrosion sites became much less in the case of coating CS with polyaniline than in uncoated.



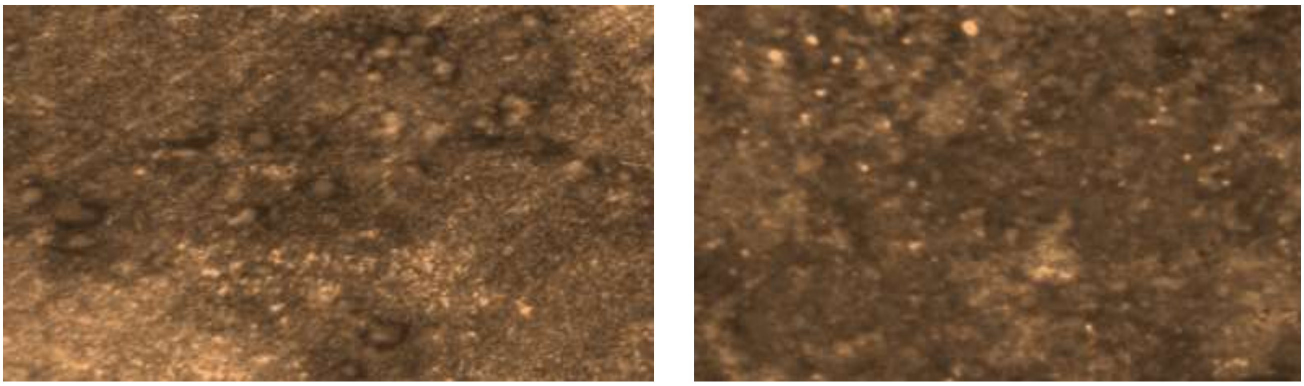
(a) (b)

Figure 3: Optical microscope images of (a) uncoated (b) polyaniline coated CS in cooling water



(a) (b)

Figure 4: Optical microscope images of (a) uncoated (b) polyaniline coated CS in waste water



(a) (b)

Figure 5: Optical microscope images of (a) uncoated (b) polyaniline coated CS in treatment water

AFM images reflected the surface morphology of the carbon steel samples, Fig.(6) show a clear unaffected surface of cleaned polished carbon steel used in the corrosion study, while Fig.(7) reflected the formation of polyaniline nanofiber with average diameter of 48nm on the carbon steel surface sample due to the electropolymerization of aniline monomer, the surface of the carbon steel samples after polarization in different industrial water and the roughness's are highly affected by the degree of corrosion in each type, as shown in Fig. (8).

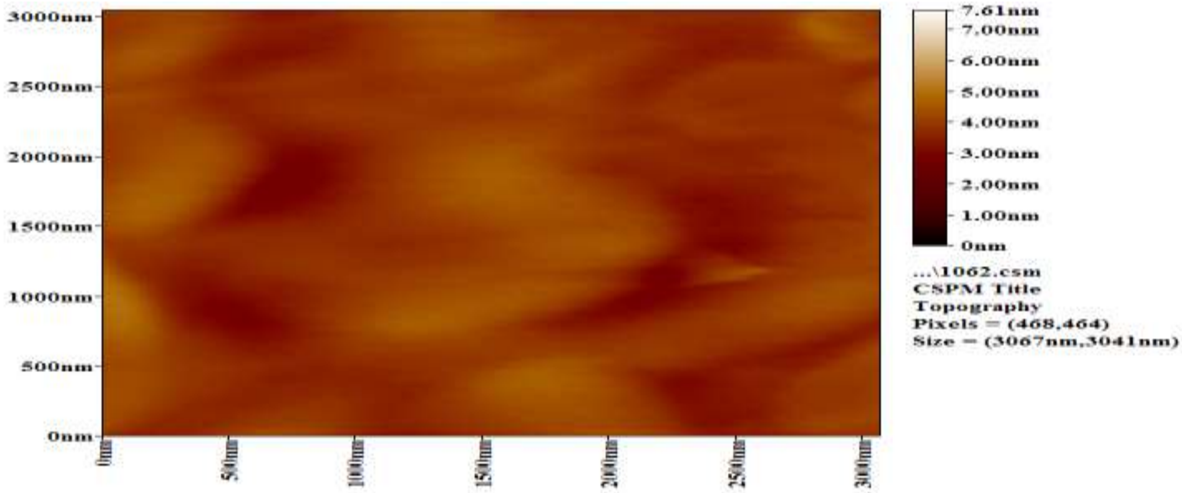


Figure 6: AFM image of cleaned carbon steel sample before polarization

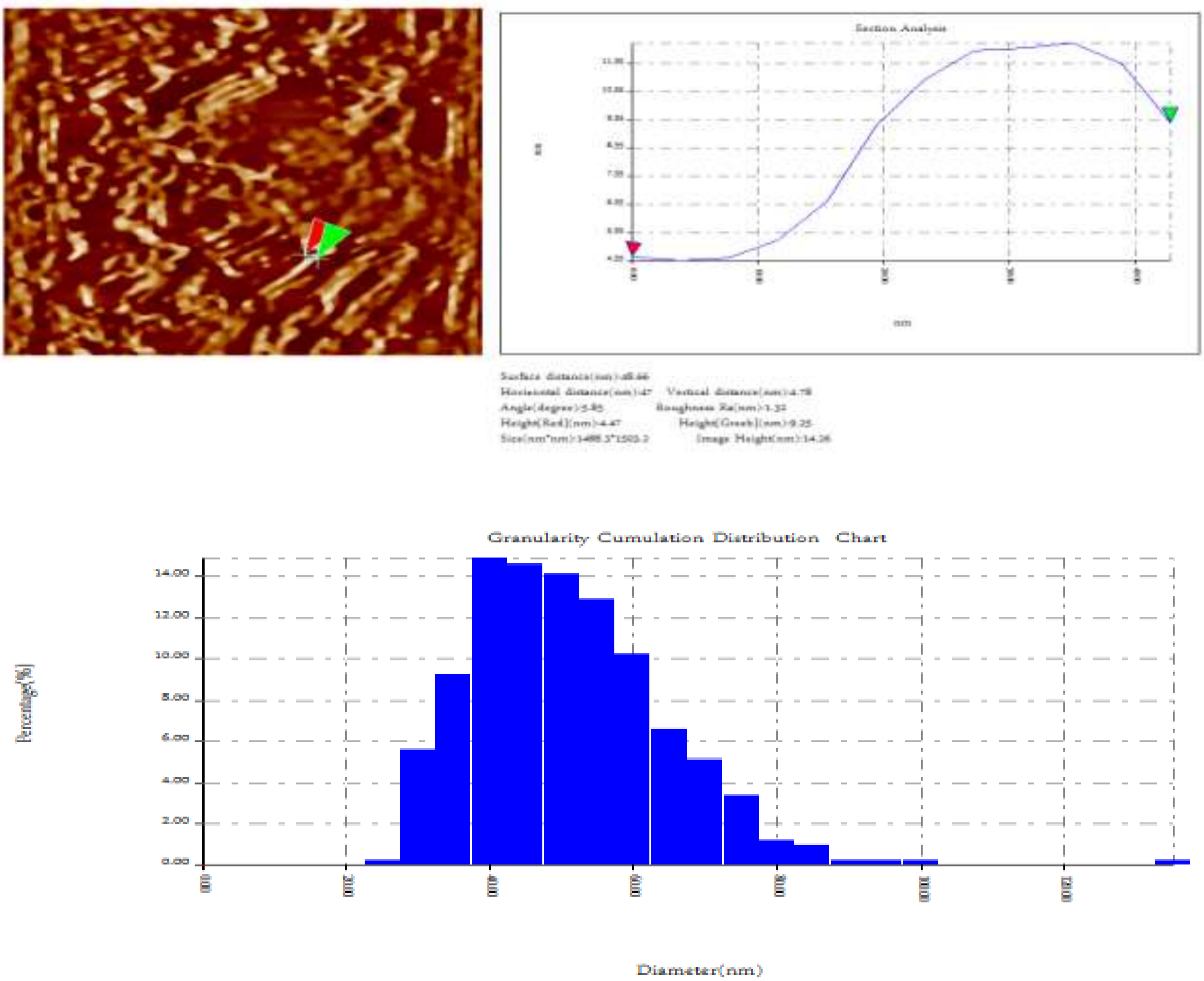
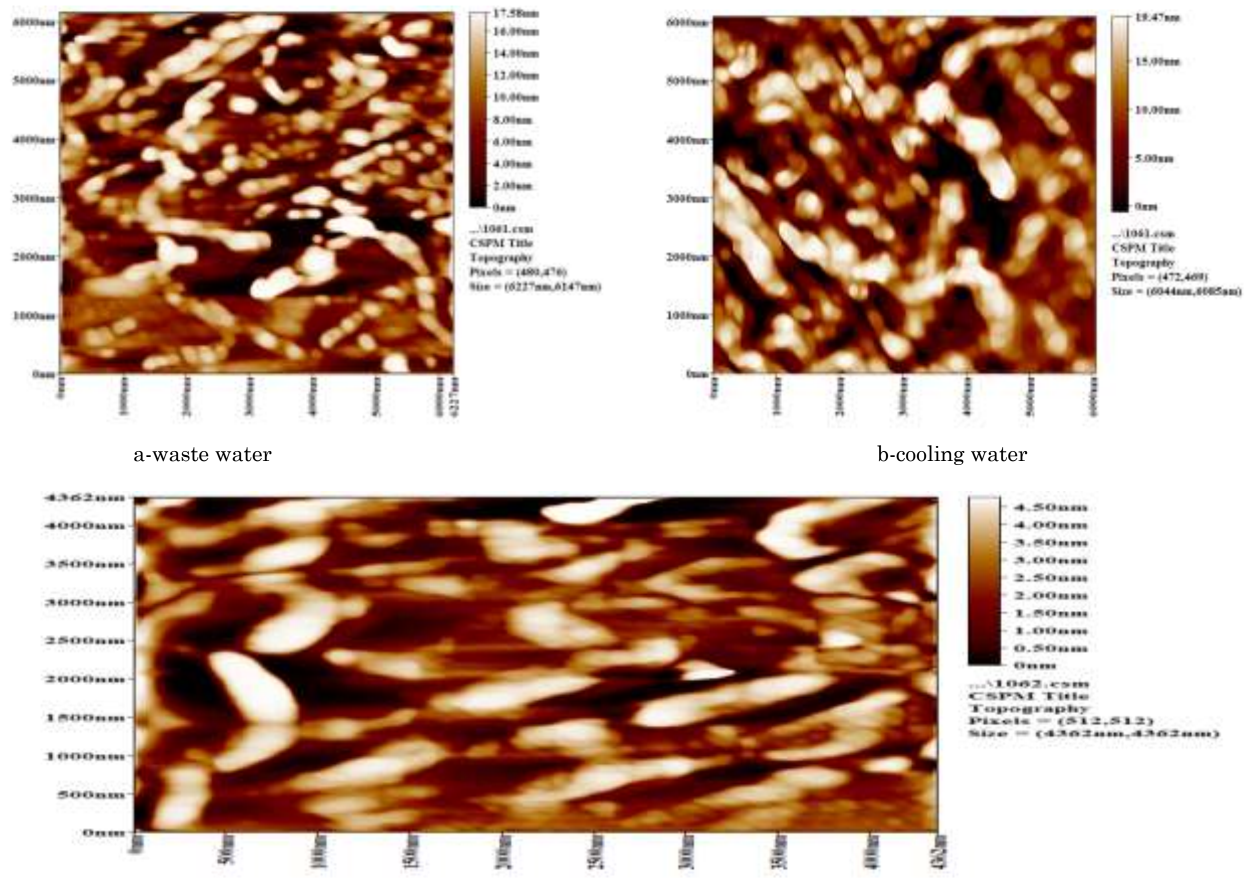


Figure: 7 AFM image and granularity distribution plot of polyaniline coated carbon steel before polarization

The surfaces of the carbon steel coated with polyaniline after polarization in different industrial water are shown in Fig. 8.



a-waste water b-cooling water

C-treatment water

Figure 8: AFM images of uncoated carbon steel sample polarized in different industrial water

Conclusions

Electropolymerized polyaniline coating on carbon steel acts as good anti-corrosion coating in the three types of the industrial water in petroleum refinery such as cooling water, waste water and treatment water. The optical and Atomic force microscopes highly supported the results deduced from potentiodynamic measurements. From Tafel plots.

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