Experimental study to determine atmospheric corrosion rate of mild carbon steel at Beida city - Libya.

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ABSTRACT

The aim of this study is to determine the atmospheric corrosion rate of carbon steel (0.114% C), in specific area Beida city, Libya. No study has been conducted to find the corrosion rate of any kind of steel in this area. The study was carried out using steel sheets produced by Musrata factory located in Libya. This steel is the common material in the local market used for different metal structures. The weight loss method was used to find the corrosion rate of the steel samples over a period of 8 months, The corrosion rate was found as 0.6 mpy (0.015 mmy) , which is considered as very low according to standards.

KEYWORDS *–Atmospheric corrosion, carbon steel, corrosion rate, weight loss, Beida city,* Libya

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1. Introduction

Corrosion can cause damage to everything such as pipelines, bridges, and public buildings, vehicles, water and wastewater systems and even home appliances. Losses due to corrosion sustained by industry and governments amount to many billions of dollars annually, approximately $ 276 billion in the United States, which 3.1% of its Gross Domestic Product (GDP) [1] , some of the direct and indirect effects of corrosion contribute to the following costs:

Replacement of corroded equipment.

Unscheduled plant shutdowns for replacement.

Process upsets resulting from corrosion.

Product contamination.

Product loss from a vessels and tanks.

Otherwise unnecessary preventive maintenance.

Over design to allow for corrosion.

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 devastating effects upon modern industrial businesses. It is essential, therefore, for operators of industrial process plants to have a program for controlling corrosion.

Mild steel is still being used in many engineering applications such as Tanks, Pipelines, Towers and Bridges. One of the major problems in those applications is the corrosion of steel when it is exposed to different corrosive environments, corrosion usually expressed by corrosion rate .

The corrosion rate is a critical factor to specify the corrosion level and to suggest the corrosion protection method, which could be painting, wrapping or other method. It is also main factor in determining the corrosion allowance.

The atmospheric corrosion rate (C.R) is classified as follows [2]

C.R < 1.3	Very low
1.3< C.R < 2.5 mmy	.Low

2.5< C.R < 5.0 mmy	Mild
5.0< C.R < 8.0 mmy	High
8.0< C.R < 20.0mmy	Very high

mmy = millimeter per year

Also the relative scale for corrosion of metal is given as [3,4]

Safe: Less than 5 mpy or 0.125 mmy

Moderate: 5 mpy to 50 mpy or 0.125 mmy to 1.25 mmy.

Severe: Greater than 50 mpy or 1.25 mmy.

mpy = mil per year.

The general corrosion rate (GCR) is expressed in the weight loss for specific area over a specific period, This will be more practical and useful when it is converted to the Penetration corrosion rate (PCR) which expressed by the loss of metal thickness over specific period, and that can be calculated by using the following equation:

$$PCR = \frac{K*\Delta W}{A.t.\rho} \quad \text{---------- (1)}$$

Where:

PCR –Penetration corrosion rate measured on (mpy) or (mmy)

Δw – Weight loss

A – Total coupon area

t. – Exposed time

ϱ – Material density

K– Factor depend on the used units

2. Methodology

In this study, which was carried out from October 2017 to May 2018, nine samples of carbon steel coupons were used; coupons were exposed to outside open air at one location only because the air conditions (humidity, temperature and rainwater) in the Green Mountain area (Beida) region are almost the same. The area is Agricultural land free from industrial contamination (Rural Urban).

2.1 Atmospheric conditions

During the experimental period the atmospheric conditions (Temperature, Humidity, rain and wind) were observed, the minimum temperature was 2° C and the maximum was 38° C the humidity was varied from 40 to 75%. A sample of rain water was collected and analyzed. The result of the rain water analysis is shown in table1, and the monthly average rate of the temperature and rain for year 2017 are shown in table 2, wind monthly average speed shown in table 3 [5].

Table 1: Rain water analysis.

Metal	Ca	Mg	Na	Cl	So_4
Mg/L (ppml)	1.6	52.75	27.69	1.33	0.29

Table 2: Temperature and Rain monthly average rate.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Temp.℃	7	9	11	13	16	20	22	25	20	17	15	9
Rain water. mm	123	105	58	25	10	2	0	0	8	38	57	120

Table 3: Wind monthly average rate.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Wind speed **(km/hr)**	9.2	9.0	8.0	8.3	7.0	7.0	7.6	8.0	8.2	6	5.8	7.2

2.2 Coupons Composition and preparation:

Coupons were made of mild steel (0.114% C), with overall dimensions of 15 cm length, 10 cm width, and 2mm thickness. The coupons density is 7407 kg/m^3 and Their chemical composition is given in table 4 .

Table 4: Coupon chemical composition.

Element	Mn	S	C	Si	Ni	Pr
% w	0.517	0.06	0.114	0.014	0.058	0.018

Coupons were cleaned with distilled water and coarse paper. Electronic balance with 0.2% sensitivity was used to measure samples weight that is defined as original weight, the total area of each coupon was measured and the results were as shown in table 5 .

Table 5: Coupons original weight and total area.

Coupon No.	1	2	3	4	5	6	7	8	9
Original Weight (gram)	302.04	284.19	322.94	307.44	318.56	318.39	306.49	309.04	325.64
Total Area(cm^2)	308.49	291.63	337.23	305.55	331.15	331.15	305.55	324.13	340.27

2.3 Experimental Plan

The nine coupons where divided into three groups , three coupons per each group, each group was inspected cleaned and weighted at different periods as mentioned below:

Group I**,** every two months. **The readings were taken at 2months, 4monthes, 6months and 8monthes period.**

Group J**,** every four months. **The readings were taken at 4monthes and 8monthes period.**

Group K**,** every six months. **The readings were taken at 6monthes.**
The purpose of this arrangement and schedule is to study the effect of the corrosion layer on the corrosion rate

3. Results and Discussion

At the end of the observation periods mentioned above, the following results were obtained:
The Coupons weight loss and average corrosion rate were shown in table 6 and the bar graph explaining the relation between C.R and respective coupon is given in figure-1.
The difference in the results for the same group could be due to the human errors while measuring the areas and also in the coupons cleaning.

Table 6: Coupons data and weight loss

Group	Coupon No.	Initial weight (gram)	Area cm	Weight loss at Inspection Interval – month (gram)				Average C.R (mpy)	Group Average C.R (mpy)
				2	4	6	8		
I	I1	302.04	308.49	1.00	0.640	0.40	0.250	0.422	0.526
	I2	284.19	291.63	0.870	0.580	0.310	0.300	0.571	
	I3	322.94	337.23	1.000	0.600	0.350	0.490	0.585	
J	J1	307.44	305.55	-	1.070	-	1.340	0.705	0.79
	J2	318.56	331.15	-	1.720	-	1.740	0.85	
	J3	319.39	331.4	-	1.820	-	1.670	0.815	
K	K1	306.49	305.55	-	-	1.480	-	0.522	0.645
	K2	302.28	334.19	-	-	1.860	-	0.626	
	K3	290.48	300.27	-	-	2.190	-	0.786	

Atmospheric average CR = 0.602 mpy

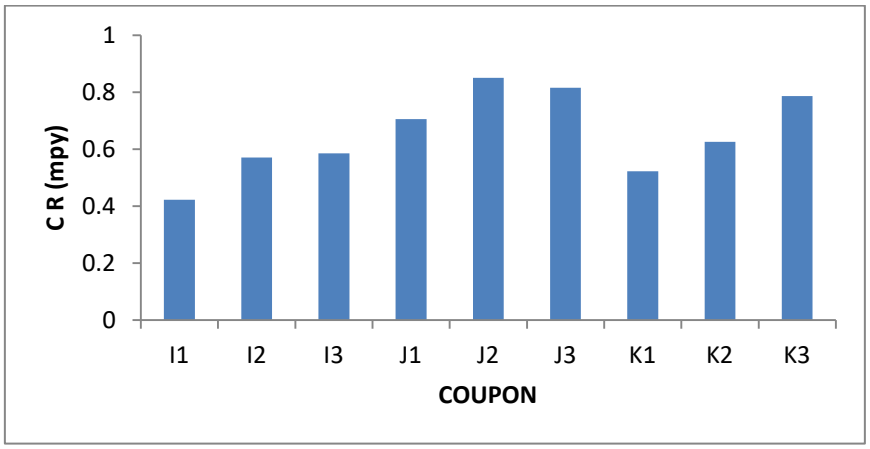

Figure 1: Coupons Corrosion Rate.

The CR for all groups is almost the same regardless of the cleaning interval. This means the corrosion layers formed on the coupons do not act as insulation or reduce corrosion of the metal. Figure 2 show the average corrosion rate for each group

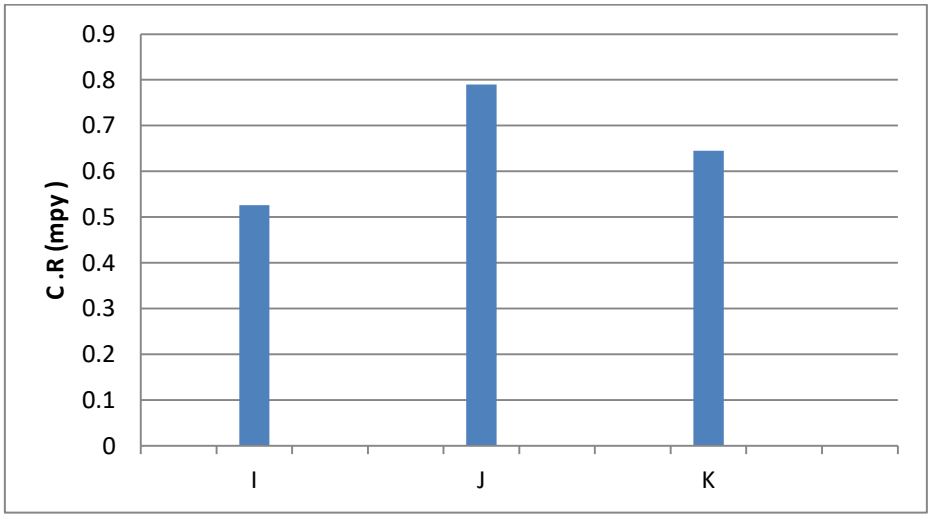

Figure 2: Group Average Corrosion Rate.

From the results, it can be stated that the atmospheric CR at Beida city is very low and safe, that will have great effect on the selection of the corrosion protection method, and will have great impact on reducing the cost, Figure 3 show the corrosion rate safe level and corrosion rate of coupons

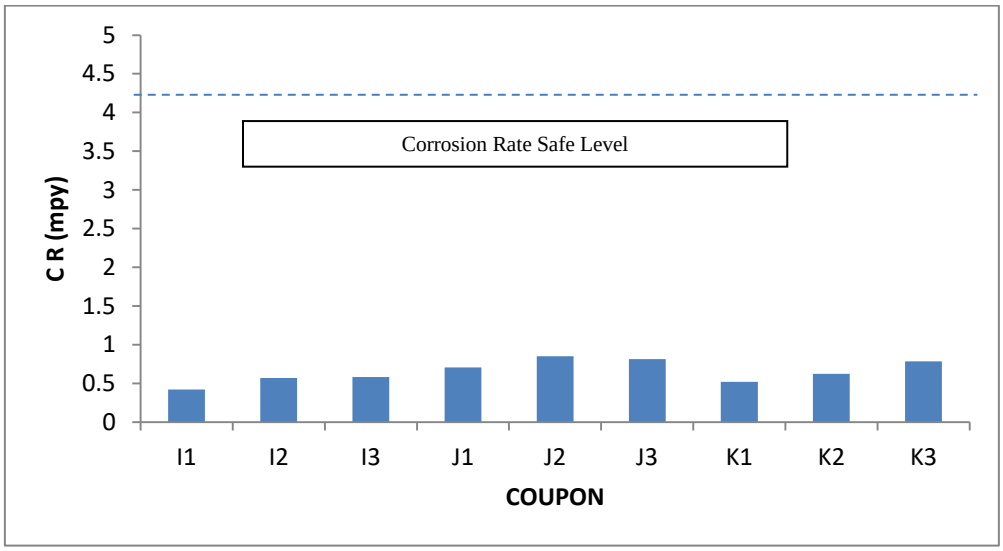

Figure 3: The corrosion Rate Safe Level.

4. Conclusion and Recommendations

Form the above experiments and associated results, it is concluded that the study is a success as it helped in making the first record for corrosion level in the Beida area and gave indication on the level of the CR of steel. It is suggested that weight change as the measure of corrosion rate requires careful preparation of specimen before exposing them to corrosion media and proper cleaning procedure to remove the corrosion product forms so that the base metal is not removed during the cleaning process. For accurate results, the test should be carried for longer time; more than a year. In additional future work should be carried using other types of steel and other materials to build a complete data base for the CR in Beida area.

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Reference

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