Application Of Fractal Dimension On Atmospheric Corrosion Of Galvanized Iron Roofing Material

Issa A.K, Abba. M. Aji

Abstract: Corrosion rates of galvanized iron roofing sheet In yola north eastern part of Nigeria were assessed and determined by weight loss method and scanner (fractal analysis) method,. Scanning electronic machine (SEM) was used to transform corrosion coupons to electronic form for image j processing and analysing software, The result of corrosion rates for these two methods after six months of the samples exposure in industrial. Coastal, market and urban areas in the region are 1.51, 1.079, 1.051, 0.779 and 1.9941, 1.9585, 1.9565, 1.9059 for weight loss and scanner (fractal dimension) methods respectively. and the results from the two methods were in agreement This establish the reliability of fractal dimension in measuring atmospheric corrosion, this research also provides alternative method of measuring atmospheric corrosion and overcome the limitation of conventional weight loss technique in its inability to measure corrosion rate which is not significantly change over a long period of time, moreover weight loss cannot demonstrate the area of concentration of corrosion on the surface of the coupon it rather gives the weight loss value, and this will aid in determining the real level or extent of corrosion damage in the material and this can be obtained when measuring the material through fractal analysis these results clearly indicate that corrosion is heavier on locations close to the industrial areas. This also shows the negative impact of industrial activities on the corrodible materials and consequently on the plants and environment.

Keywords: galvanized, fractal, box counting, weight loss.

1.0 Introduction

Fractal dimensions are numbers, very often non-integer, often the only one measure of fractals, it measures the degree of fractal boundary fragmentation or irregularity over multiple scales, it determines how fractal differs from Euclidean objects (point, line, plane, circle etc.) [13] One of the methods used to establish fractal dimensionis Box-Counting,this method determines the fractal dimension of black & white digitised images of fractals and works by covering fractal (its image) with boxes (squares) and then evaluating how many boxes are needed to cover fractal completely. Repeating this measurement with different sizes of boxes will result into logarithmical function of box size (x-axis) and number of boxes needed to cover fractal (y-axis). The slope of this function is referred as box dimension. Box dimension is taken as an appropriate approximation of fractal. Mandelbrot's fractal geometry theory [5] provided a new way to study irregular surfaces; the fractal dimension has been favoured by more and more experts and scholars [7]. Sarmiento [11] researched the corrosion inhibition of carbon steel in a bromide solution by fractal analysis. Masashi Kurose [6] studied the problem of metal corrosion in salt solution by fractal geometry, and observed that corrosion defects in the surface morphology have fractal characteristics. Jin [3] indicated that the fractal geometry was a non-destructive testing method, and calculated the fractal dimension of the aluminium alloy corrosion surface in two ways. Sarmiento [10] studied the corrosion characteristics of carbon steel in bromide solution with fractal method, Park [4] have found that the formation and development of the 600 alloy pitting had fractal characteristics, and pitting fractal dimension increased with the increase in corrosive liquid temperature. DONG Yuan et al [12]analyzed and compared the amount of calculation and sphere of application of the commonly used image fractal dimension algorithm, and found BB Chaudhuri law and Peleg law were better. Wang et al [9] introduced the application of fractal theory in describing the corrosion behaviour and researching corrosion model.

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2.0 Materials and methods

The materials for the experiment included cut pieces of corrugated galvanized iron, wooden rack and nail to suspend the specimens. Others are WA210 model analytical electronic weighing balance manufactured by Adam Equipment Company Limited, United Kingdom, scanning electronic microscope (SEM), engineer square Scissors, Abrasive paper, compass. Four sites were selected, (Bajabure) is selected as marine environments, (Jimeta) as market area, (kofare) as industrial environment and (jimets Government Residential way) as urban area. The cut pieces of the corrugated galvanized iron specimens (100mm x 150mm) were first washed in ethanol solution degreased and scrubbed and cleaned with 120 number abrasive papers in accordance with ASTM GI standards. Each specimen was then weighing on the electronic balance and its initial mass was recorded. Four replicates of the specimens were suspended on a wooden rack using nail, the entire assembly was then inclined at 2200 to the horizontal an elevated 1.3m from the ground, the 2200 inclination represents the advantage roof slope in the region while the 1.3m elevation was to avoid water splashes due to rain drops; each assembly was stationed in an open field away from trees and buildings. The experiment was lasted for a period of six months at the end of which the specimens were removed, and cleaned finally, as described earlier and re-weighed to know the new mass. The difference between the initial mass and the final mass is the specimen's mass loss. The mean of the mass losses of the four replicates were became the representative mass loss the station, then the corrosion rates are calculated. The period of exposure was six months, from July, August, September and October representing the rainy season and November, and December representing the dry season.

2.1 Corrosion Rates Computation using weight loss method

Corrosion rate C_R is computed as follows (1):

$$C_R = \frac{22300(\text{wt loss})}{\rho A t} \qquad (2.1)$$

Where $wt\ loss$ is weight loss in g shorter time,
ρ is galvanized iron density in g/cm^3,
A Is exposed area of coupon, in in^2
t is time of exposure in days .

$$\text{wt (loss)} = w_f - w_i \qquad (2.2)$$

Where w_i is weight of coupon before exposure (g)
w_f is weight of coupon after exposure (g). [8]

2.2 Corrosion Rates Computation using fractal dimension method

The fractal dimension D of the pores were estimated by equation

$$D = \frac{\log(count)}{\log(box\ size)} \qquad (2.3)$$

$\log(count)$ is logarithms of number of boxes counted
$\log(box\ size)$ is the total area of the box [1]

3.0 Result and discussion

3.1 Weightlessness rate calculation and analysis

The results of calculated corrosion rate parameters for the galvanized iron roofing sheet exposed in different locations from weight loss method are presented in table 3.1. Observation from this table shows that corrosion rate is greatest at sample exposed at coastal area within the first three months, this is due to the fact there was heavy rainfall during rainy season which makes more salt to be deposited on the sheet by marine fog and wind -blown as shown in fig 3.1. After six month it can be seen that the sample exposed at industrial area became the highest this may be due the fact that these atmospheres are associated with heavy industrial manufacturing facilities and can contain concentrations of sulfur dioxide, chlorides, phosphates, and nitrates which were some-how washing away during the rainy season that is the first three months, because dry season usually starts from September and October in the region as shown in figure 3.2

Table 3.1: *Estimated corrosion rate parameters on samples of galvanized iron roofing sheet from study areas*

Sample location	Sample	surface	Surface	Initial	final	Weight lost	Corrosion
	identification	Area(cm^2)	Area(inches)	weight	weight	duration	rates
Industrial	A1	264	42.24	40	38.2	1.8	1.335
	A2	264	44.38	40	35.7	4.3	1.518
Coastal	B1	265.2	42.43	47.2	44.6	2.4	1.772
	B2	265.2	45.01	47.2	43.9	3.1	1.079
Market	C1	270.3	43.81	49.5	47.4	2.1	1.502
	C2	270.3	43.24	49.5	45.6	2.9	1.051
Urban	D1	265.53	42.48	48.3	46.9	1.4	1.032
	D2	265.53	42.48	48.3	46.2	2.1	0.774

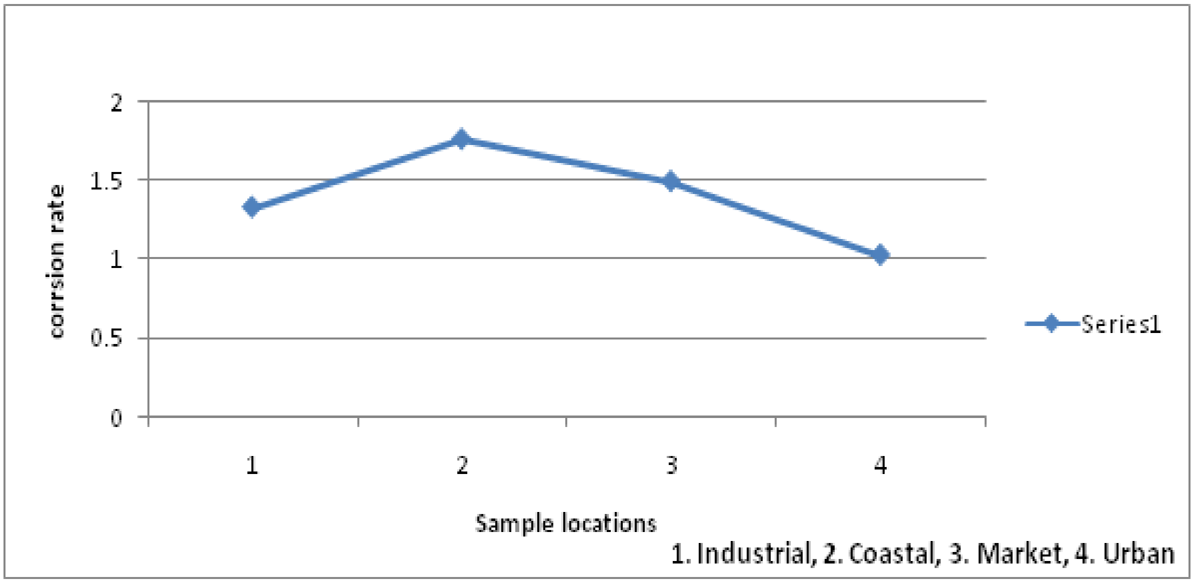


Figure 3.1 *Corrosion rate comparison-90 days exposure*

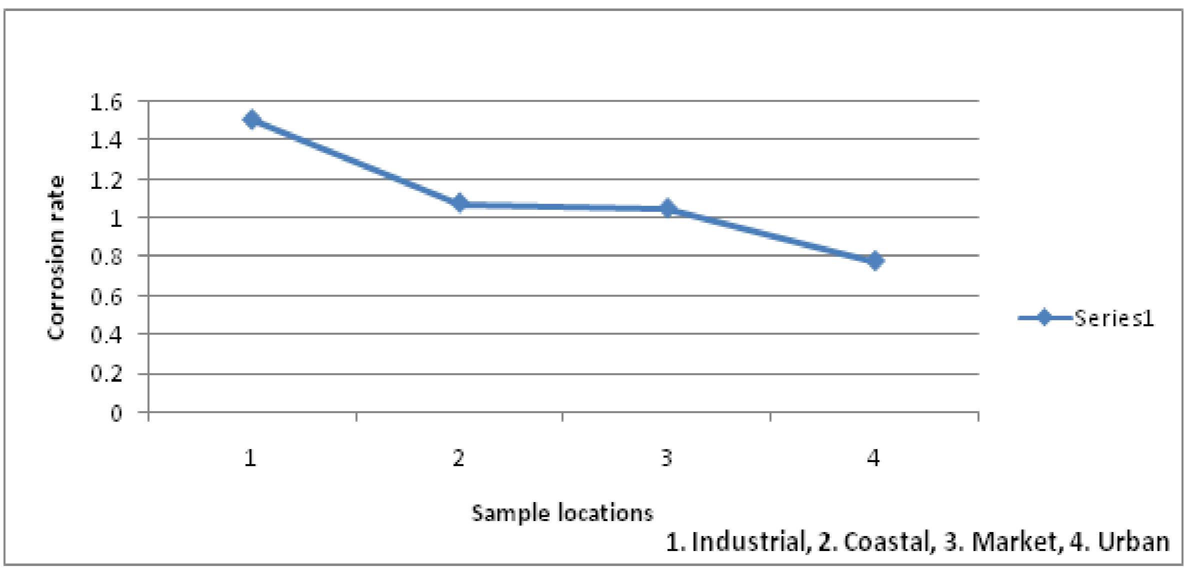
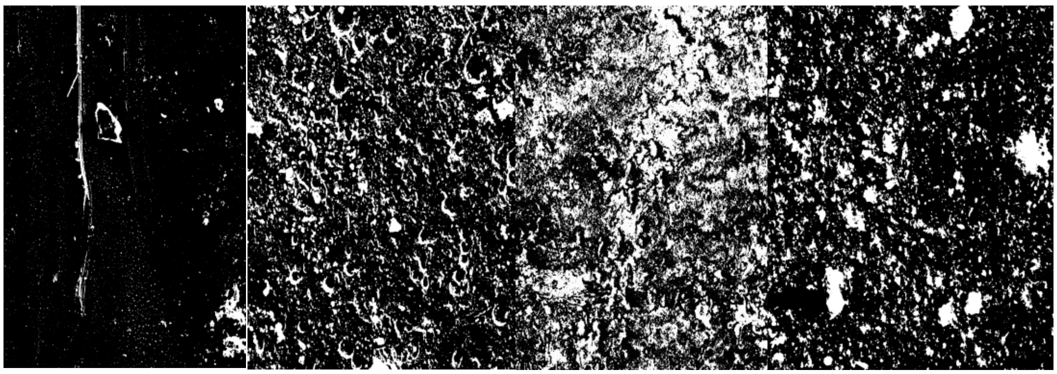


Figure 3.2 *Corrosion rate comparison-180 days exposure*

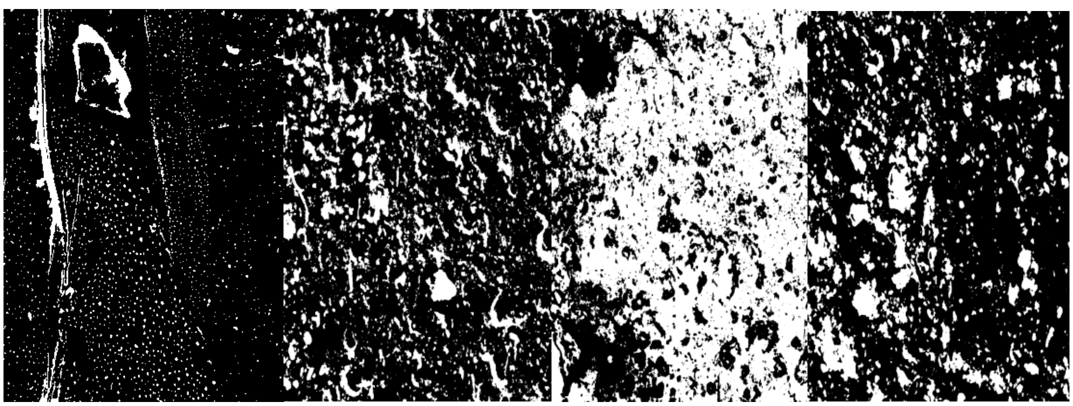
3.2 Surface morphology of corrosion of galvanized iron roofing sheet

To show that surface roughness and surface height variation change with different locations and time difference of corroded galvanized iron roofing sheet surfaces particles, the surface morphology of corrosion of galvanized sheet was carried out, it can be seen that surface morphology of corrosion of surface of galvanized sheet can be influenced by its internal change in microstructure. These microstructure images were gotten from scanning electronic microscope (SEM), the colour images are converted to gray-level images and are then converted to black and white binary images for fractal box counting analysis through image j image processing and analysing software as shown in plate 1 and 2. At each observation (image capture) time, a set of eight images were obtained, and the procedures were repeated for all eight observation times. These images are presented in plates below



(a) Industrial (b) Coastal (c) Market (d)Urban

Plate1:*Black and White binary image of Surface corrosion of galvanized sheet after 90 days*



(a) Industrial (b) Coastal (c) Market (d)Urban

Plate2: *Black and White binary image of Surface corrosion of galvanized sheet after 180 days*

The fractal dimensions of corrosion were estimated by equation 2.3. Using Image J image processing and analysis software. The relationship are linear with their slope giving the fractal dimension (D) of corrosion the values of (D) varied from 1.7085 to 1.9929 for these set eight coupon. this is achieved by using box Counting Method which Count number of boxes of different size length L to cover the object , Plot log (count)versus log (box size)since fractal curve follows $N \sim L - D$, Slope gives the fractal dimension D Thus, increasing the corrosion particles size enhanced the fractal dimension of the surface corroded galvanized iron surface membrane. Fractal dimension graphs of samples of galvanized iron roofing sheet exposed at different location in the period of three and six months arepresented in Figures 3.3and 3.4.

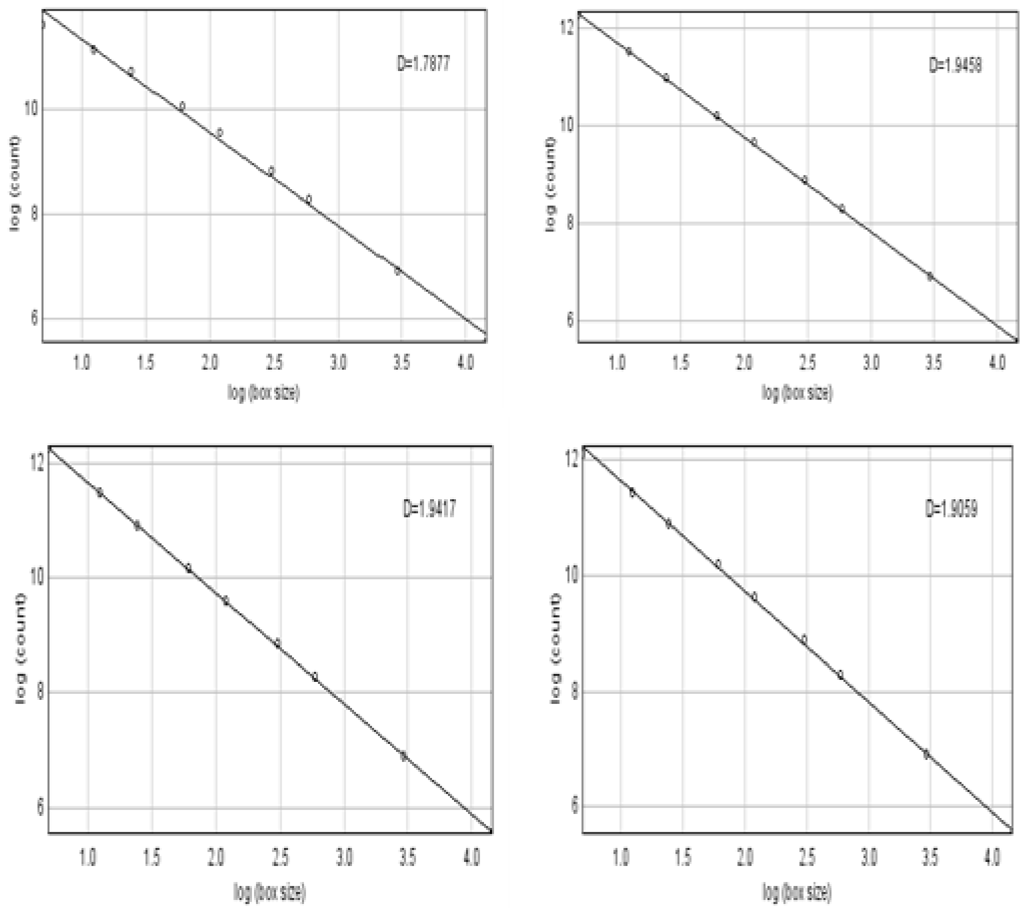


Figure 3.3 *Varriation curves of fractal dimension of (a) industrial (b) Coastal (c) Market (d) Urban after 90 days*

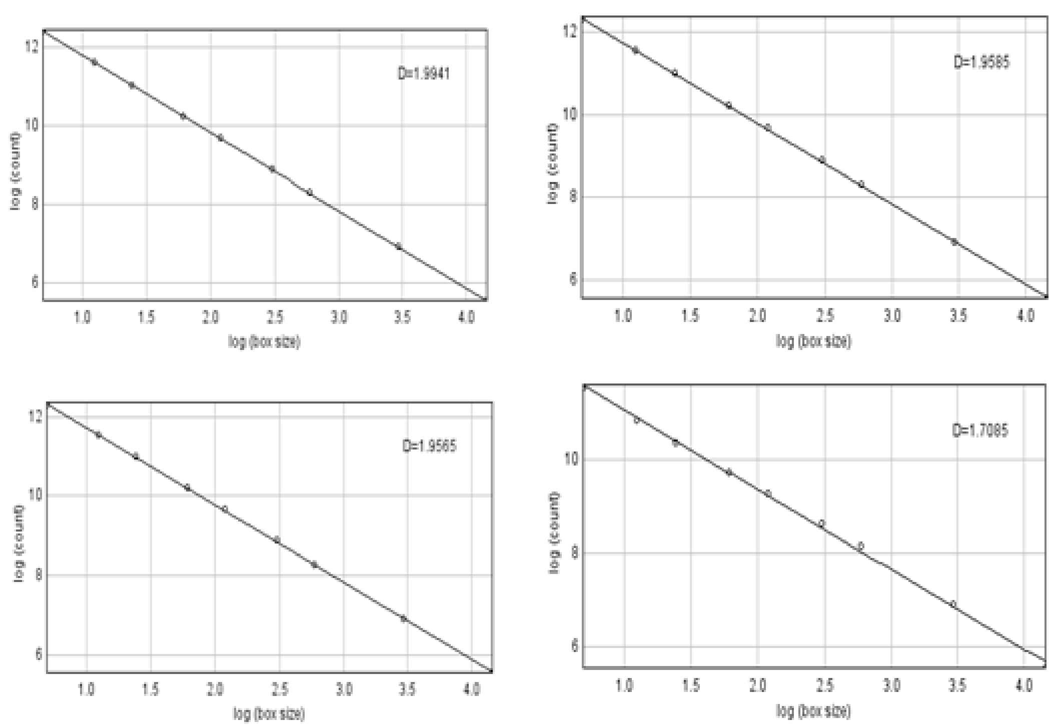


Figure 3.4 *Varriation curves of fractal dimension of (a) industrial (b) Coastal (c) Market (d) Urban after 180 days*

Table 3.2 *Summary of F.D exposure period, Variation of fractal dimension, D with different sample locations*

Sample location	Fractal dimensions	
	3-months	6-months
Industrial	1.7877	1.9941
Coastal	1.9458	1.9585
Market	1.9417	1.9565
Urban	1.7085	1.9059

The result of fractal analysis method showed that the maximum fractal dimension of the samples in coastal area in the first three months was 1.9458 which means that the loss of weight was much more pronounced within the first three months whose period fall within rainy season which is higher than that experienced in industrial. . The industrial area was having a minimum fractal dimension of 1.7877 relatively small to that of coastal area. While Urban area was having the least fractal dimension of 1.7085 as shown in fig 3.5 The result of fractal analysis after six months showed a gradual increment in weight loss in coastal and Market but was more significant in the industrial areas which are mainly dry season period. Furthermore, the sample exposed at industrial area has maximum fractal dimension of 1.9941. This value was higher compared to other three sites including coastal area which was having maximum fractal dimension in the first three months. Generally, the weight loss values increased at a higher rate within the early first four months which were rainy and declined or increase gradually in the last three dry months as shown in Figure 3.6

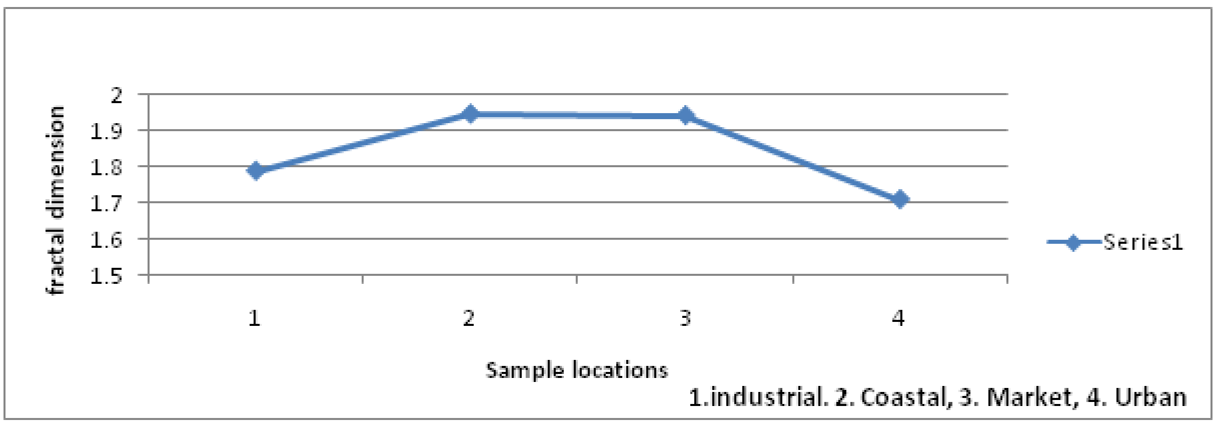


Figure 3.5 *Corrosion rate comparison-90 days exposure*

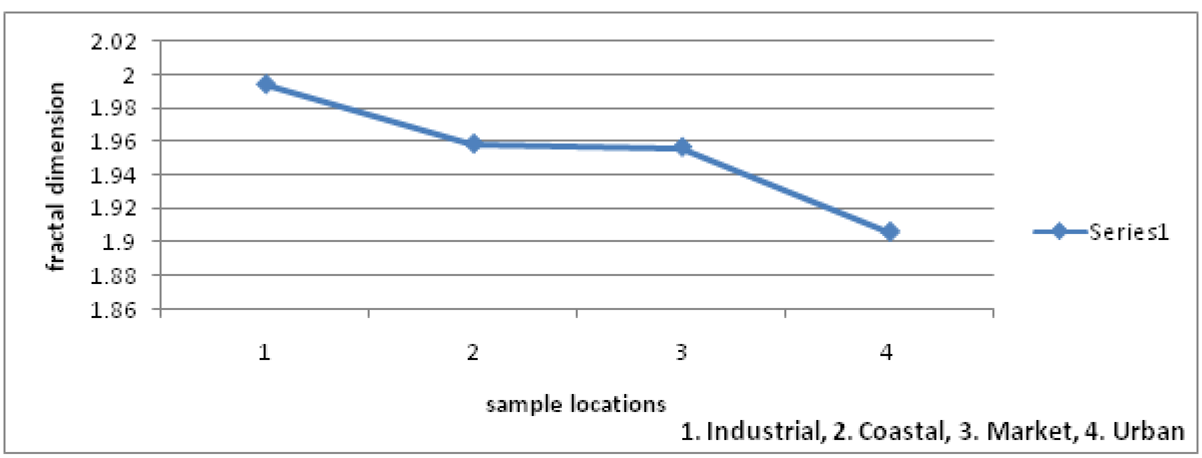


Figure 3.6 *Corrosion rate comparison-180 days exposure*

3.3.0 Comparative analysis of weightlessness rate, and fractal dimension

In order to analyze the reliability of the fractal analysis in the corrosion behaviour of galvanized iron roofing sheet, comparisons of the weight loss rate curve, and fractal dimension curve, were made as shown in Figure 3.7 and 3.8 Finally, the fractal dimension curve was compared with the weight loss rate curve found in the same environments, It was observed that, fractal dimension curve had a consistent variation trend with the weight loss curve, which showed that the fractal dimension of galvanized iron corrosion morphology could well reflect the variation of the corrosion rate of galvanized iron roofing sheet. The literature [2] pointed out that the larger the fractal dimension, the more irregular and the rougher the surface of the image and vice versa that is, the lower the fractal dimension, the more regular and smoother the surface of image.

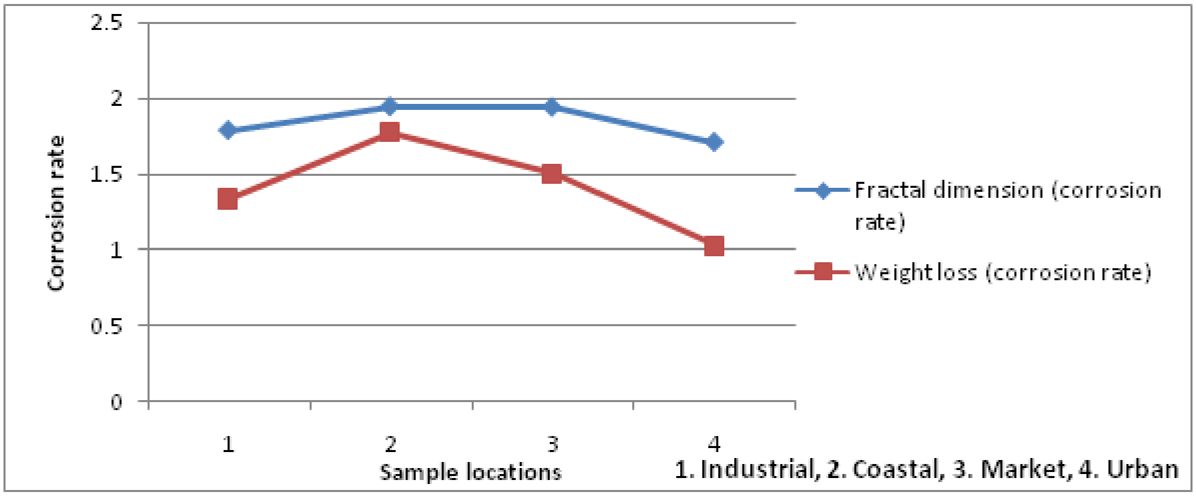


Fig 3.7 *Comparative graph of weight loss method and fractal analysis method after three months*

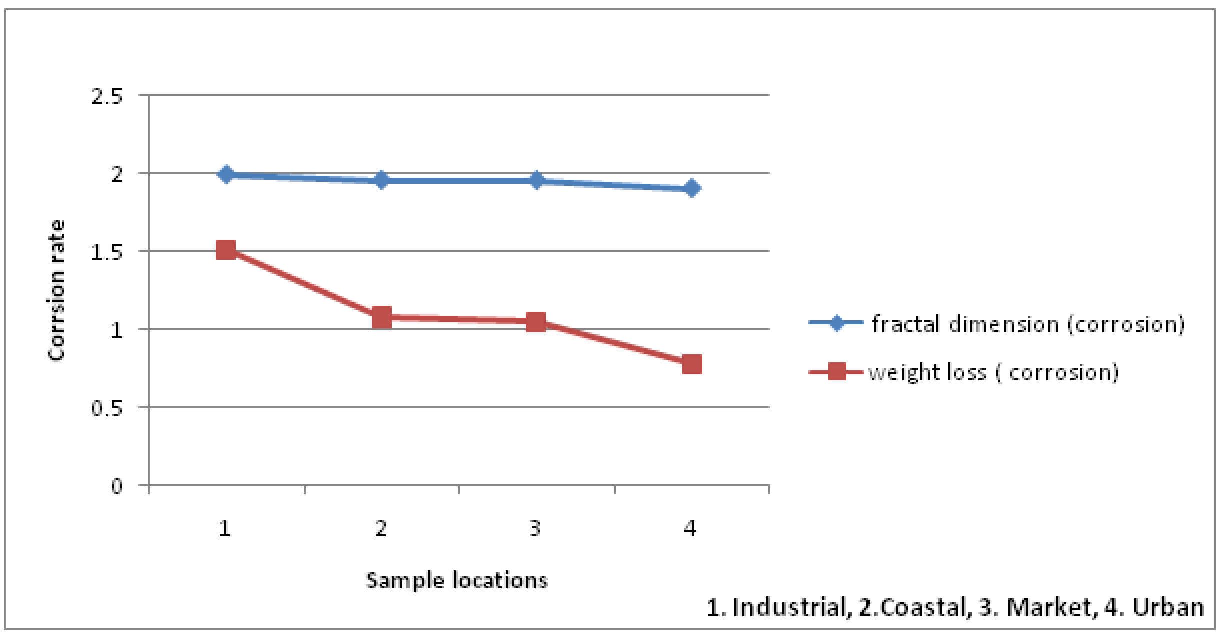


Fig 3.8 *Comparative graph of weight loss method and fractal analysis method after six months.*

Conclusion

Weight loss and scanner (fractal analysis) methods were used to monitor the corrosion rate of galvanized iron roofing sheet under varying atmospheric corrosion conditions. Image feature parameters were extracted from the experimental data obtained from SEM, and analyzed using image j image processing and analysing software. The results obtained from these two methods indicate that Kofare industrial layout usually experiences the highest corrosion rate followed by Bajabure marine environment, most of the factors causing corrosion in this region may be purely due to the salt laden atmosphere, followed by Jimeta market area, pollution from combustion of vehicle fuel, and generators, burning of fire wood can be the cause of corrosion in this region, and lastly by Jimets Government Residential way urban area. In the same atmosphere, the weight loss rate curve and fractal dimension curve had the similar trends, reflecting the test reliability and the variation of the corrosion of galvanized iron roofing sheet, indicating that the fractal dimension of corroded galvanized iron sheet surface can well reflect the variation of the galvanized iron sheet corrosion rate.

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