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FRACTAL QUANTIFICATION OF CORROSION OF PIPE USED FOR DRINKING WATER TREATMENT AND SUPPLY

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ABSTRACT: This work looked at fractal dimension as a tool for measuring corrosion. The data obtained from corrosion of steel pipes used for drinking water supply was used, this research provides alternative method of measuring 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 time of period, 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. this also provide means of avoiding errors which might be committed when weighing the corrosion coupon, an image j image processing and analysis is used to generate the fractal dimension of corrosion of steel pipe.

KEYWORDS: fractal, corrosion, box counting.

1 INTRODUCTION

1.1 FRACTALS

They are mathematical sets with a high degree of geometrical complexity that can model many natural phenomena. Almost all natural objects can be observed as fractals (coastlines, trees, mountains, and clouds). Fractals are of rough or fragmented geometric shape that can be subdivided in parts, each of which is (at least approximately) a reduced copy of the whole

1.2 FRACTAL DIMENSION

The number, very often non-integer, often the only one measure of fractals. ,It measures the degree of fractal boundary fragmentation or irregularity over multiple scales

1.3 BOX-COUNTING METHOD

One of the methods used to establish fractal dimension, It determines the fractal dimension of black & white digitised images of fractals, It 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 dimension [8][4][5].

Fractal dimension D can reflect the intensity of the changes in the amplitude of the surface morphology, i.e. the large D value showed a large variation of the surface amplitude, and vice versa. During the study of corrosion behavior, in addition to the measurement methods such as weight loss, electrochemical parameters and etc, fractal dimension, as a means of characterizing materials surface complexity and uneven morphology in corrosion, is more and more widely applied to the

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corrosion behavior. The morphology as one of the important characteristics in material corrosion, has been used to evaluate the extent and level of corrosion, Therefore, the study on the corrosion morphology is of significance to analyze the extent of corrosion and to explore the corrosion law. [2][3]

2 METHODOLOGY

Data used for this work was that of [6]carried out a test on coupons made from a steel plate of class 11, thickness 1 mm with a surface without corrosion with size of 42 x 42 mm. these coupon were exposed to three different corrosion environment, that is raw , filterered and treated water, for a period of 35 and 70 days , these coupons were transformed into electronic form through 3D electronic scanner as shown in figure 1.

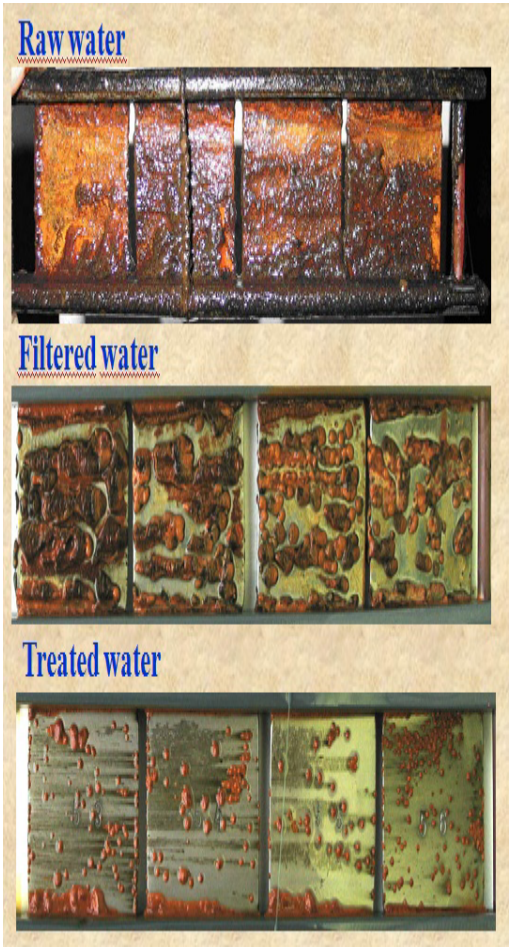

Figure 1: coupons after exposure

2.1 IMAGE J IMAGE PROCESSING AND ANALYSING SOFTWARE

Image J is a public domain Java image processing program inspired by the NIH Image for the Macintosh. It runs, either as an online applet or as a downloadable application, on any computer with a Java 1.4 It can display, edit, analyze, process, save and print 8-bit, 16-bit and 32-bit images. It can read many image formats including TIFF, It can calculate area and pixel value statistics of user-defined selections. It can measure distances and angles. It can create density histograms andline profile plots. It supports standard image processing functions such as contrast manipulation, sharpening, smoothing, edge detection and median filtering. It does geometric atransformations such as scaling, rotation and flips. Image can be zoomed up to 32:1 and down to 1:32. All analysis and processing functions are available at any magnification factor. The program supports any number of windows (images) simultaneously, limited only by available memory. [1][7], image j analysis and processing software was used to perform the following task.

- Icon image where this tool automatically or interactively set lower and upper threshold values, segmenting the image into features of interest and background. The image was re-size into 1024x1024 pixels, type 8bits, use Image>lookuptable>colour>gray>black and white.
- Icon process also there some icons find edge was used to make a perfect edge of the picture, Icons sharpen was used to increases contrast and accentuates detail in the image or selection, icon binary was used to make binary to prepare the picture for fractal dimension generation.
- Icon analyzes use Counts the number of boxes of an increasing size needed to cover a one pixel binary object boundary. The box size and the number of boxes necessary to cover the boundary are plotted on a log-log plot and the fractal dimension determined from the slope, i.e. D=-slope in this icon used get to plot and result as fractal and box counter fractal. this figure shows program image,

2.2 CORROSION RATES COMPUTATION USING FRACTAL DIMENSION METHOD

The fractal dimension D of the pores were estimated by equation

$$D = \frac{\log(count)}{\log(box\ size)} \qquad (3.3)$$

$\log(\ count)$ is logarithms of number of boxes

$\log(box\ size)$ is the total area of the box [1]

3 RESULT AND DISCUSSION

The true-color image shown in figure 2, 3, 4 were converted to grayscale image,using image j umage processing and analysis software then the gray-scale image was stored in a 1024 ×1024 matrix, where each value represented a gray scale value , and the so called gray value was the integer between 0 (black) and (white). The size and distribution of the gray value in a certain extent reflected the unevenness of morphology of wire corrosion surface. as shown in figure 2,3,4.

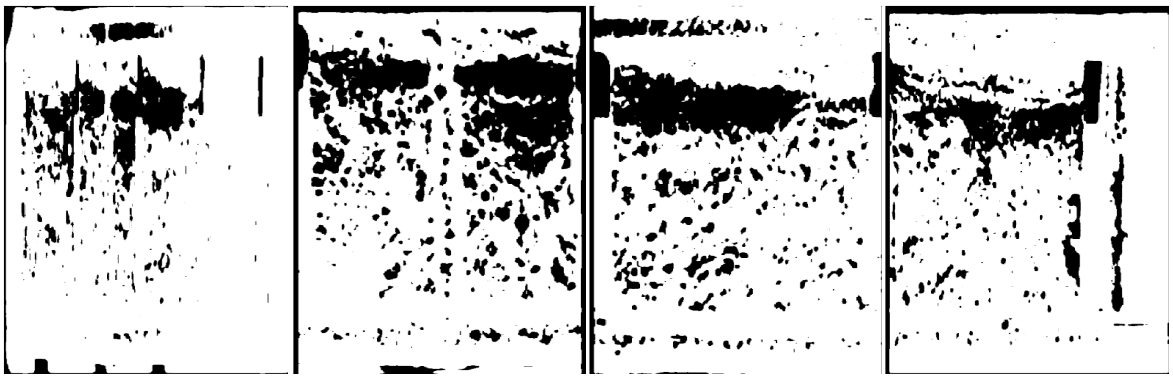

Figure 2: image j black and white image of sample exposed in raw water

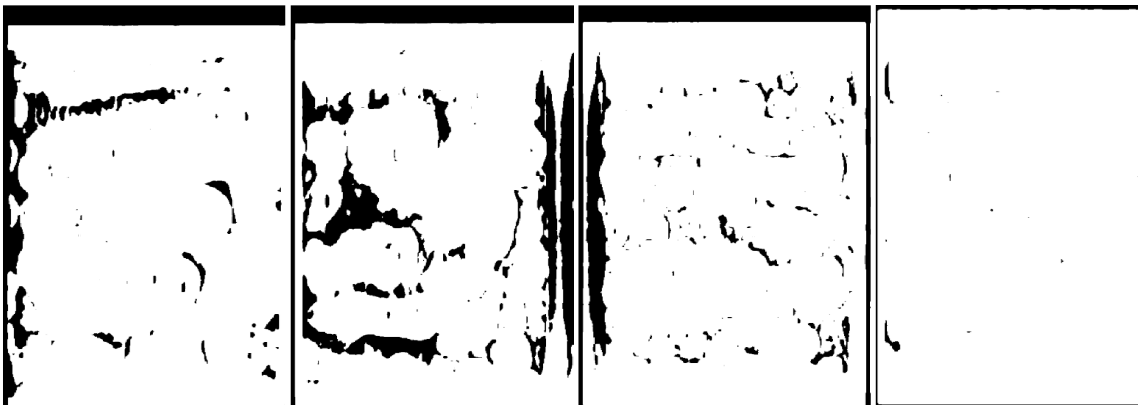

Figure 3: image j black and white image of sample exposed in filtered water

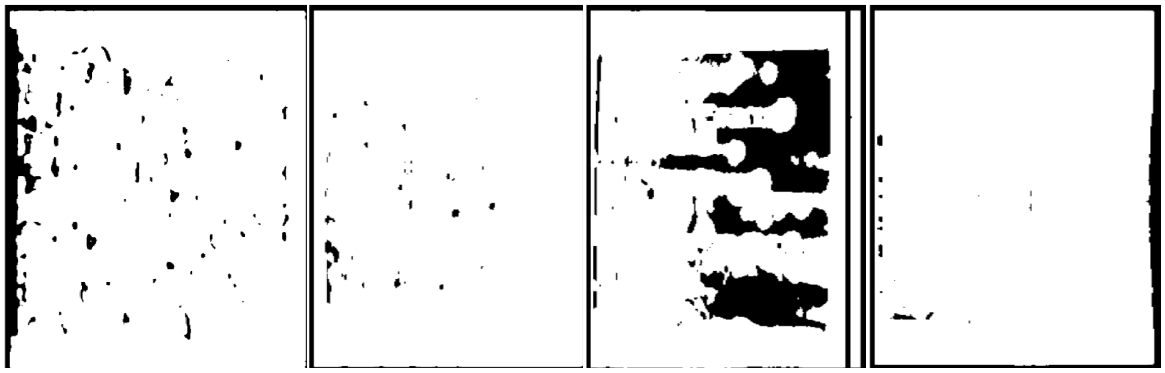

Figure 4: image j black and white image of sample exposed in treated water

Tables 1, 2, 3, show the calculation of fractal dimensions of that explains different calculation results at different times using ImageJ image analysis software. The number of self- similar corrosion particles log (Box size) versus the logarithm of the magnification factor log (count)

Table 1: calculation of fractal dimension for coupon exposed in raw water

Box size	Box count	X	Y_1	Y_2	Y_3	Y_4
2	193477	0.6931	12.1729	12.2942	12.2446	12.1542
3	86987	1.0986	11.3735	11.4990	11.4458	11.3592
4	49309	1.3863	10.8059	10.9283	10.8776	10 7885
6	22363	1.7918	10.0152	10.1453	10.0935	10.0051
8	12798	2.0794	9.4567	9.5805	9.5316	9.4471
12	5939	2.4849	8.6893	8.8225	8.7759	8.6842
16	3383	2.7726	8.1256	8.2540	8.2112	8.1304
32	926	3.4657	6.8309	6.9117	6.8959	6.8480
64	246	4.1589	4.1589	5.542	5.5413	5.5290

Table 2: calculation of fractal dimension for coupon exposed in Filtered water

Box size	Box count	X	Y_1	Y_2	Y_3	Y_4
2	197192	0.6931	12.1919	12.2046	12.1713	12.1954
3	88572	1.0986	11.3916	11.4069	11.3741	11.3916
4	49636	1.3863	10. 8125	10.8315	10.7960	10.8130
6	22383	1.7918	10.0161	1.0401	10.0056	10.0096
8	12565	2.0794	9.4387	9.4697	9.4355	9.4342
12	5835	2.4849	8.6716	8.7043	8.6727	8.6510
16	3250	2.7726	8.0864	8.1304	8.1068	8.0697
32	861	3.4659	6.7581	6.8178	6.8167	6.7154
64	236	4.1589	5.4638	5.5175	5.5175	5.4116

Table : calculation of fractal dimension for coupon exposed in treated water

Box size	Box count	X	Y_1	Y_2	Y_3	Y_4
2	193666	0.6931	11.4646	12.3951	12.4159	12.3964
3	86955	1.0986	10.6993	11.5909	11.6137	11.5917
4	48896	1.3863	10.1637	11.0107	11.0362	11.0112
6	22061	1.7918	9.4211	10.2065	10.2338	10.2071
8	12475	2.0794	8.9092	9.6291	9.6612	9.6281
12	5767	2.4849	8.2399	8.8400	8.8732	8.8386
16	3230	2.7726	7.7592	8.2569	8.2890	8.2511
32	881	3.4659	6.6080	6.8947	6.9197	6.8814
64	245	4.1589	5.4596	5.5334	5.5452	5.5134

Figure 5, 6, 7 are the graph generated by image j software which spelt out values of fractal dimension, one graph is generated per each sample.The literature [23] pointed out that the larger the fractal dimension, the more irregular and the more rough the surface of the image, and vice versa to flatten and smooth. The more serious corrosion, the greater the fractal dimension.

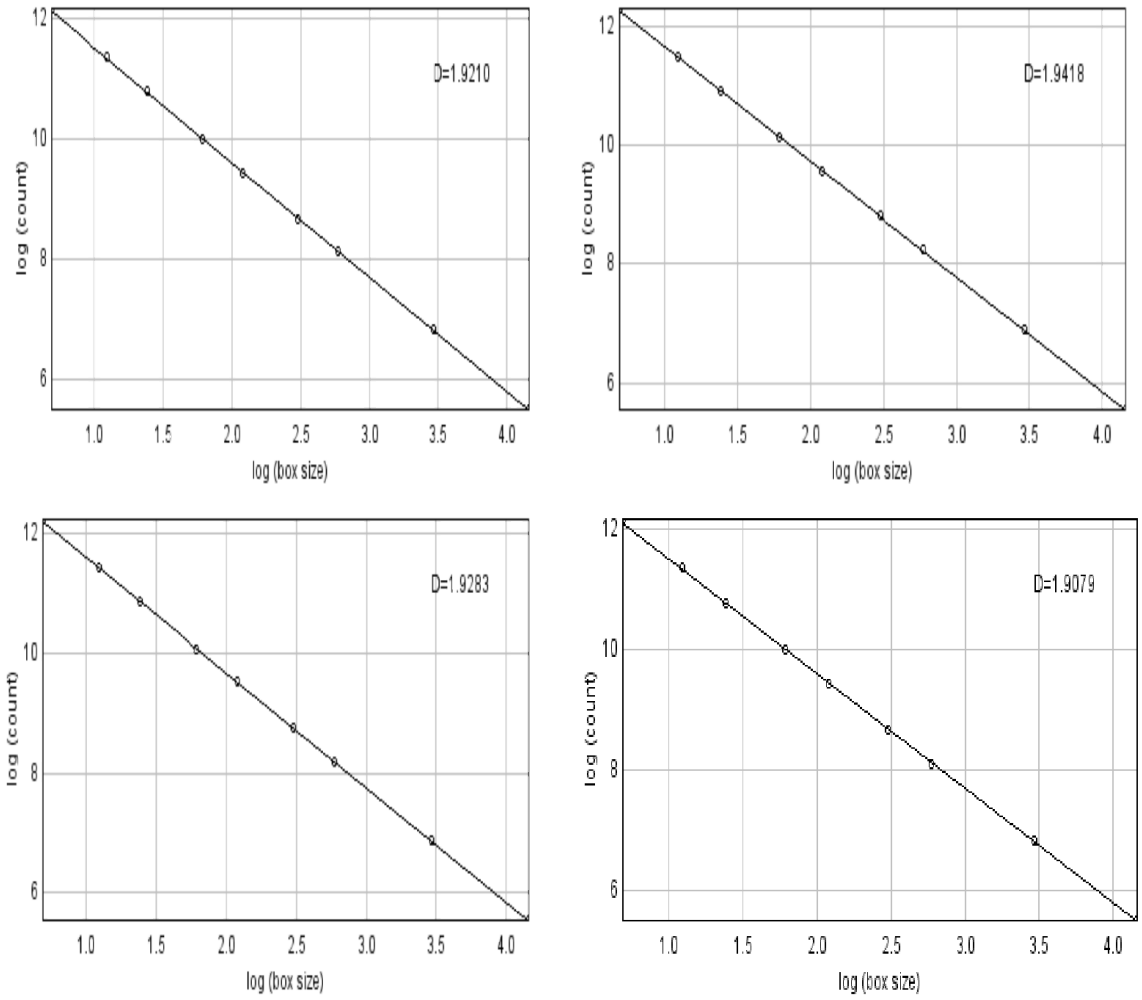

Figure 5: fractal dimension curve of samples exposed in Raw water

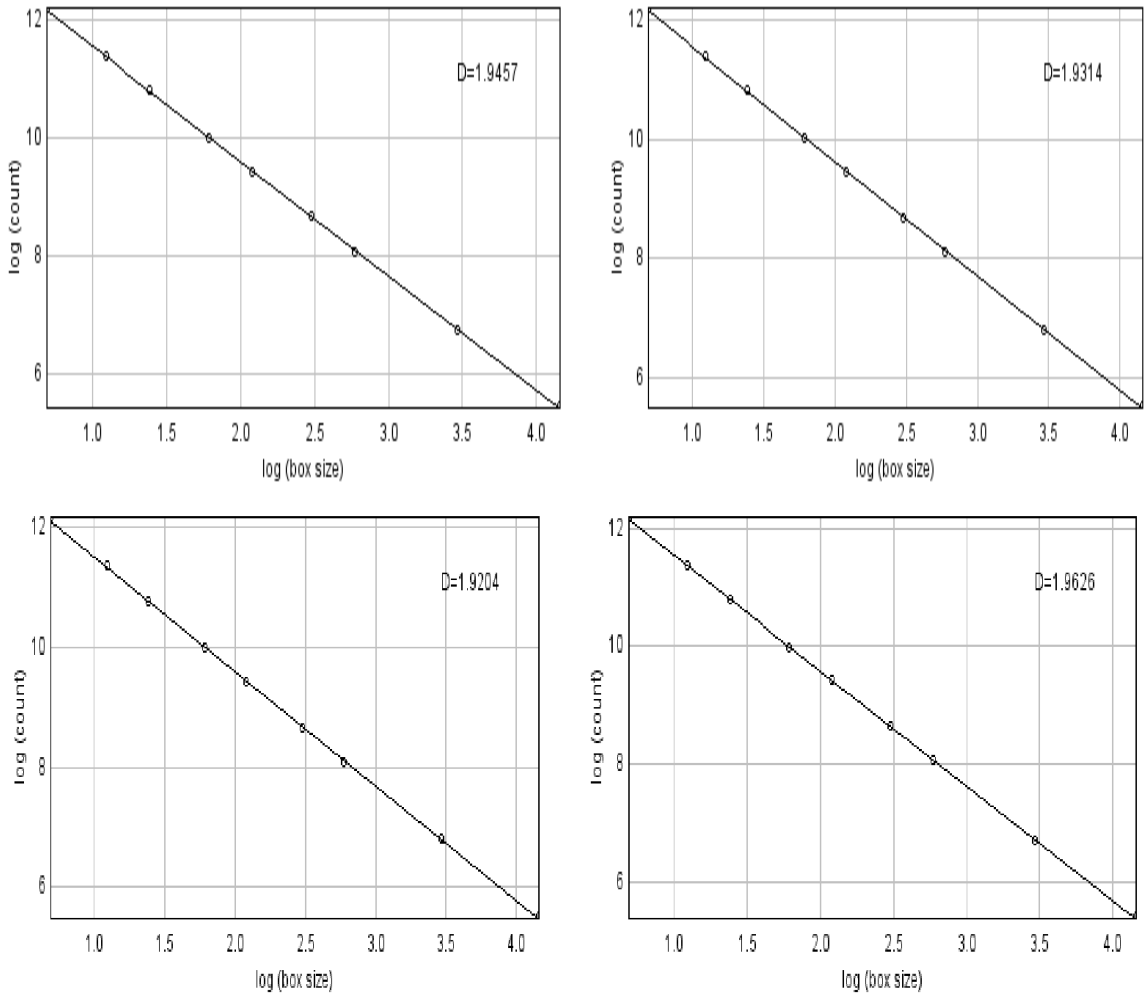

Figure 6: fractal dimension curve of samples exposed in Filtered water

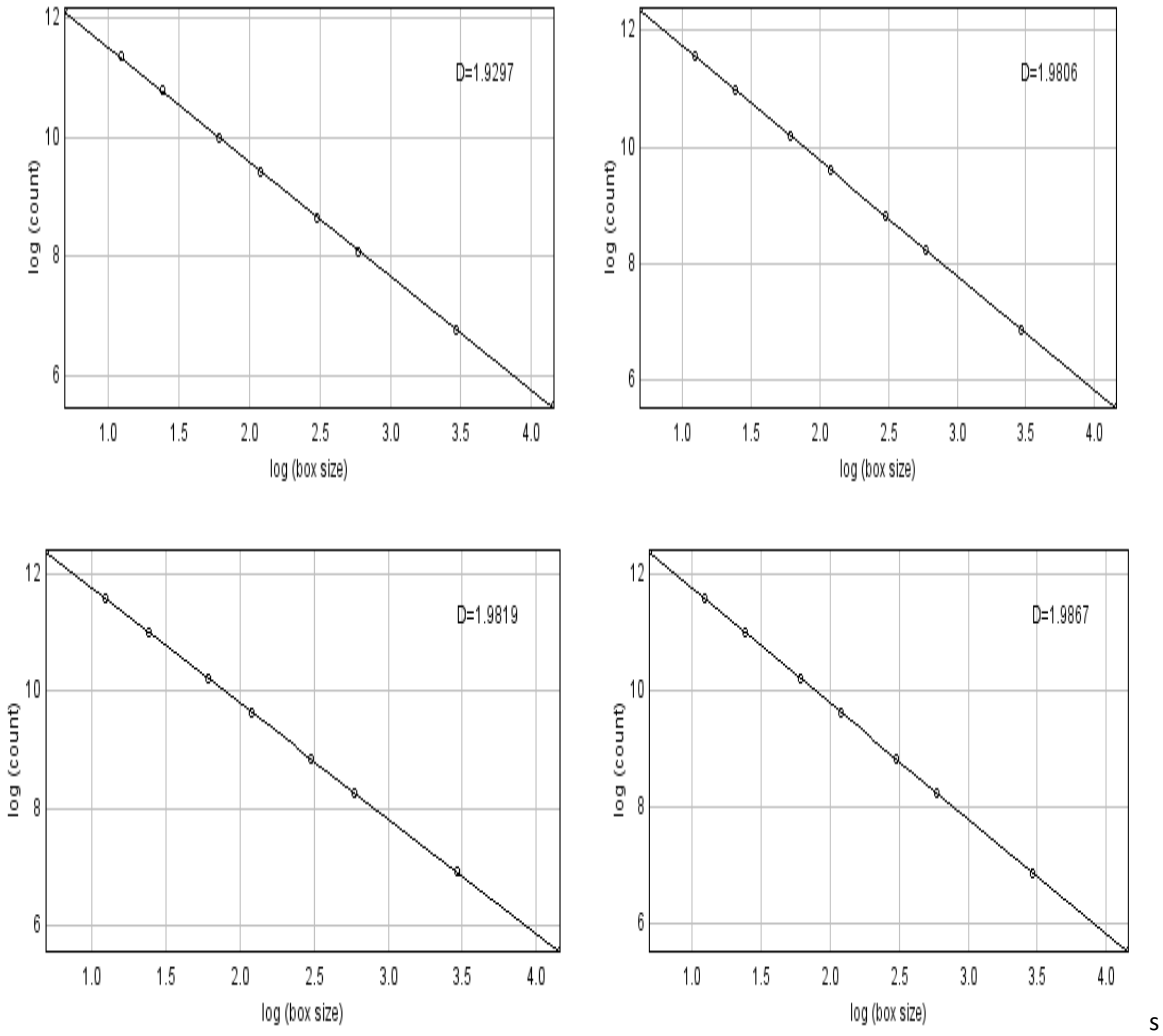

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Figure 7: fractal dimension curve of samples exposed in treated water

Table 1: fractal dimensions of the three medium of exposure

Raw water (fractal dimension)	1.9210	1.9418	1.9283	1.9079
Filtered water (fractal dimension)	1.9457	1.9314	1.9204	1.9626
Treated water (fractal dimension)	1.9297	1.9800	1.9819	1.9867

4 CONCLUSION

Due to inability of weight loss method to reflect area of concentration of corrosion on the coupon surface and also, to measure corrosion rate which is not significantly change over a long time of period fractal analysis is used as a new method which can compute the corrosion rate of corrosion coupon and as well show the area of concentration of corrosion on corrosion coupon,, this gives more accurate information about the stage of corroded materials

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