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Statistical analysis of the corrosion inhibition performance of three inorganic compounds on mild steel acid media

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Abstract. Sodium benzoate, zinc benzoate and zinc bromide were studied for their corrosion inhibition effect on mild steel in 0.5 M H2SO4 and HCl solution. Data obtained showed the performance of the inorganic compounds significantly varied with respect to exposure time. Zinc bromide (ZBM) exhibited the most effective inhibition performance on mild steel in H2SO4 solution with optimal inhibition value of 90.96% at 50% concentration, corresponding to corrosion rate of 1.330 mm/y. Sodium benzoate (SB) displayed the least effective inhibition performance with optimal value of 50.5% at 70% concentration corresponding to corrosion rate of 7.284 mm/y. Zinc benzoate (ZB) performed most effectively in HCl solution with inhibition value of 70.17% at 50% inhibitor concentration corresponding to corrosion rate of 1.251 mm/y while zinc bromide contrary to its performance in H2SO4 solution displayed weak inhibition performance in HCl solution with peak value 55.40% at 30% concentration corresponding to corrosion rate of 1.870 mm/y. Statistical data showed in H2SO4 solution, inhibitor concentration significantly influenced the inhibition performance of ZB and ZBM compounds with values of 98.37% and 94.57%. The effect of exposure time was negligible but statistically relevant. The statistical relevance value obtained for SB inhibitor concentration and exposure time are 65.96% and 25.20%. In HCl solution, the statistical relevance of ZBM and ZB exposure time at 58.4% and 41.51% is greater than the corresponding value for concentration at 32.46% and 38.14%. However, SB concentration overwhelmingly influenced the performance of SB compound at statistical relevance value of 95.75%.

1. Introduction

Corrosion problems are prevalent in most industries accounting for a significant proportion of the cost of maintenance [1-3]. Damage due to corrosion is responsible to a certain degree for toxic leakages leading to sustained environmental, industrial process interruptions and unplanned shutdown of production plants [4, 5]. Carbon steels have extensive application in nearly all industries due to its relatively low cost compared to corrosion-resistant stainless steels [6, 7]. Inability of carbon steels to passivate in corrosive environments is responsible for their weak corrosion resistance and significant decrease in their operational lifespan. Application of chemical compounds known as corrosion inhibitors is most economic method of sustaining the lifespan of metallic parts [8]. Most corrosion inhibitors are of organic origin whose inhibition mode is through adsorption on the steel surface [9-15]. The organic compounds in addition to known inorganic derivatives such as chromates, nitrates, phosphates etc. are toxic and their application limited by government regulations; hence the need for sustainable alternatives [16-18]. Compounds such as sodium and zinc benzoate have extensive applications in food industries. Their non-toxic nature in limited quantities is applicable in the pursuit of corrosion inhibitor compounds that combines environmental sustainability with effective corrosion control. The data reported in this manuscript focuses on the corrosion inhibition performance of sodium benzoate, zinc benzoate and zinc bromide on mild steel in dilute H2SO4 and HCl solution.

2. Experimental methods

Mild steel (MS) rod was machined into 6 major sets containing 5 MS samples per set. MS samples were washed with distilled H2O and acetone for coupon measurement. Sodium benzoate (SB), zinc benzoate (ZB) and zinc bromide (ZBM) compounds were each formulated in volumetric concentrations (0%, 10%, 30%, 50% and 70%) in 200 mL of H2SO4 and HCl solution. The acids were prepared from their analar grade reagents at 0.5 M concentration. Coupon measurement was performed every 48 h totalling 672 h of exposure. The weighing balance instrument was checked for possible causes of systematic errors. The uncertainty of single measurement is limited by the precision and accuracy of the measuring instrument. As a result, calibration of the instrument and hardware test was performed. Pre-experimental test confirmed the reproducibility of results. Corrosion rate, CR (mm/y) was calculated from the following formulae;

$$\text{CR}=\left[\frac{87.6W}{DAt}\right] \quad (1)$$

W represents weight loss (g), D represents density (g/cm^3), A represents total surface area of MS sample (cm2), 87.6 represents corrosion rate constant and t represents time (h). Inhibition efficiency (IE) of the compounds was calculated from the equation below;

$$\text{IE}=\left[\frac{W_1-W_2}{W_1}\right] \times 100 \quad (2)$$

W_1 and W_2 represent weight loss of MS at specific SB, ZB and ZBM concentrations. Two-factor single level experimental ANOVA test (F-test) was employed to evaluate the statistical importance of the SB, ZB and ZBM concentrations and exposure time on their inhibition performance in 0.5 M H2SO4 and HCl, solutions. The evaluation was done at confidence level of 95% i.e. a significance level of α=0.05 with respect to the following equations. The Sum of squares among columns (exposure time) was obtained from equation 3;

$$SS_c = \frac{\sum T_c{}^2}{nr} - \frac{T^2}{N} \quad (3)$$

The sum of squares among rows (inhibitor concentration) is as follows;

$$SS_r = \frac{\sum T_r{}^2}{nc} - \frac{T^2}{N} \quad (4)$$

The total sum of squares is shown below;

$$SS_{Total} = \sum x^2 - \frac{T^2}{N} \quad (5)$$

3. Results and discussion

3.1. Coupon measurement

Tables 1 to 3 shows the corrosion rate data of MS in H2SO4 and HCl solution at specific concentrations of SB, ZB and ZBM for 672 h of exposure time. Tables 4 to 6 shows the inhibition efficiency data of SB, ZB and ZBM on MS in H2SO4 and HCl solution for 672 h. Observation of Table 1 shows the corrosion rate values of MS in H2SO4 and HCl solution at specific SB concentration. The corrosion rate values MS at 0% SB concentration does not differ significantly from the values obtained at 10%, 30% and 50% until 480 h of exposure in H2SO4 solution. Beyond 480 h minimal variation was observed. The corrosion rate values of MS at 70% SB concentration are relatively lower from the onset to the end of the exposure period. In HCl solution, the corrosion rate of MS at 10% and 30% SB concentration differs significantly from the values obtained at 0% MS from

288 h of exposure till 672 h while the values obtained at 50% and 70% SB concentration varies slightly. The corrosion rate values of MS obtained in the presence ZB from both acids (Table 2) significantly contrast the values in Table 1. MS corrosion rate obtained at 0% ZB significantly differs from the values obtained at specific ZB concentrations in H2SO4 and HCl solution. At 672 h the corrosion rate of MS at 14.713 mm/y (0% ZB) progressively decreased with respect to concentration to 1.719 mm/y at 70% ZB concentration. Decrease in corrosion rate was also observed in HCl solution with respect to concentration to a lesser degree compared to the observation in H2SO4 solution. MS corrosion rate (Table 3) decreased significantly in the presence of ZBM compound in both acids with respect to ZBM concentration and exposure time. The corrosion rate of MS at 672 h (0% ZBM) in H2SO4 solution is 14.713 mm/y while the lowest corrosion rate value was obtained at 50% ZBM concentration (1.330 mm/y). In HCl solution, variation of corrosion rate of MS at specific ZBM concentration and exposure time in comparison to the result obtained at 0% ZBM signifies poor inhibition performance. At 672 h, the corrosion rate of MS at 0% ZBM is 4.194 mm/y while the least corrosion rate value was obtained at 10% ZBM concentration with value of 1.870 mm/y. The corresponding inhibition efficiency values for SB on LCS in H2SO4 and HCl solution is shown in Table 4. The inhibition efficiency data for SB in H2SO4 shows progressive increase in inhibition efficiency with respect to SB concentration and exposure time. However, the peak performance of SB in H2SO4 increased from 36.24% at 10% SB concentration to 50.5% at 70% SB concentration, signifying concentration dependence in H2SO4 solution. SB inhibition performance in H2SO4 is significantly below average performance. In HCl solution, SB performance was relatively effective at lower SB concentration (10% and 30% SB concentration) with values of 56.35% and 67.38%. At higher SB concentrations (50% and 70%), the inhibition efficiency values significantly decreased to 16.4% and 6.72%. These values show SB performance at peak value is at best average at low SB concentrations. Observation of Table 5 shows ZB compound generally performed better than SB in both acids. ZB performance in H2SO4 solution range from 46.79% at 10% SB concentration to 88.32% at 70% SB concentration. In HCl solution, ZB performance at 672 h is not directly proportional to its concentration with final inhibition values of 33.26%, 65.7%, 70.17% and 51.67% at 10%, 30%, 50% and 70% SB concentration. Observation of ZB inhibition efficiency results in HCl from onset of the exposure hours at all concentrations shows visible decrease in inhibition efficiency values till 672 h. The corrosion inhibition performance of ZBM in H2SO4 and HCl solution are shown in Table 6. Data on Table 6 shows ZBM compound performed more effectively than SB and ZB compounds in H2SO4 with final values ranging from 76.96% to 10% ZBM concentration to 88.07% at 70% ZBM concentration. The optimal inhibition efficiency value was obtained at 50% ZBM concentration with value of 90.96%. The inhibition performance of ZBM in HCl solution is at best average with optimal value of 55.4% at 30% ZBM concentration.

Table 1. Data on MS corrosion rate in 0.5M H_2SO_4 and HCl solution at specific SB concentration (n=1).

Solution	0.5 M H_2SO_4					0.5 M HCl				
SB Conc.(%) / Exp. Time (h)	0% SB	10% SB	30% SB	50% SB	70% SB	0% SB	10% SB	30% SB	50% SB	70% SB
48	15.993	22.541	22.483	12.942	7.720	7.217	6.810	4.030	5.793	7.420
96	18.453	19.403	9.582	13.920	9.842	6.001	5.245	3.090	4.843	5.967
144	18.922	18.286	17.795	13.772	10.223	5.421	4.349	2.561	4.550	5.312
192	18.650	17.335	15.545	13.029	9.810	5.124	3.623	2.199	4.359	5.008
240	17.680	16.245	14.199	12.403	9.439	4.845	3.141	1.957	4.082	4.613
288	16.605	14.550	13.407	11.841	9.028	4.663	2.787	1.771	3.872	4.419
336	16.205	14.136	12.662	11.323	8.829	4.604	2.557	1.647	3.785	4.237
384	15.905	13.121	11.989	10.842	8.600	4.531	2.358	1.558	3.722	4.122
432	15.671	12.199	11.316	10.304	8.331	4.369	2.167	1.492	3.630	3.936
480	15.494	11.409	10.663	9.909	8.044	4.379	2.095	1.479	3.623	3.966
528	15.332	10.763	10.189	9.553	7.950	4.386	2.007	1.463	3.644	3.953
576	15.204	10.262	9.739	9.257	7.872	4.383	1.933	1.449	3.662	3.943
624	15.098	9.828	9.358	9.006	7.658	4.238	1.865	1.387	3.548	3.942
672	14.713	9.381	8.971	8.715	7.284	4.194	1.830	1.381	3.506	3.912

Table 2. Data on MS corrosion rate in 0.5M H_2SO_4 and HCl solution at specific ZB concentration (n=1).

Solution	**0.5 M H_2SO_4**					**0.5 M HCl**				
ZB Conc.(%) / Exp. Time (h)	**0% ZB**	**10% ZB**	**30% ZB**	**50% ZBZ**	**70% ZB**	**0% ZB**	**10% ZB**	**30% ZB**	**50% ZB**	**70% ZB**
48	15.993	7.972	8.273	4.863	1.385	7.217	0.911	0.843	0.852	0.576
96	18.453	7.972	6.326	4.669	1.385	6.001	0.998	1.012	1.017	1.085
144	18.922	7.979	5.644	4.572	1.385	5.421	1.069	1.079	1.040	1.339
192	18.650	7.984	5.231	4.500	1.385	5.124	1.313	1.141	1.083	1.502
240	17.680	7.986	4.964	4.456	1.385	4.845	1.459	1.161	1.114	1.595
288	16.605	7.990	4.782	4.411	1.385	4.663	1.556	1.192	1.148	1.669
336	16.205	7.993	4.641	4.379	1.265	4.604	1.223	1.208	1.157	1.730
384	15.905	7.998	4.524	4.342	1.525	4.531	1.423	1.458	1.176	1.788
432	15.671	8.008	4.432	4.196	1.697	4.369	1.610	1.426	1.193	1.821
480	15.494	7.994	4.349	4.078	1.612	4.379	1.883	1.411	1.207	1.868
528	15.332	7.978	4.282	3.973	1.722	4.386	2.106	1.391	1.220	1.896
576	15.204	7.947	4.217	3.878	1.716	4.383	2.352	1.454	1.231	1.928
624	15.098	7.892	4.155	3.797	1.768	4.238	2.551	1.451	1.241	1.953
672	14.713	7.828	4.088	3.714	1.719	4.194	2.799	1.439	1.251	1.972

Table 3. Data on MS corrosion rate in 0.5M H_2SO_4 and HCl solution at specific ZBM concentration (n=1).

Solution	**0.5 M H_2SO_4**					**0.5 M HCl**				
ZBM Conc. (%) / Exp. Time (h)	**0% ZBM**	**10% ZBM**	**30% ZBM**	**50% ZBM**	**70% ZBM**	**0% ZBM**	**10% ZBM**	**30% ZBM**	**50% ZBM**	**70% ZBM**
48	15.993	6.907	4.621	3.894	8.340	7.217	4.727	4.563	9.725	8.127
96	18.453	5.318	4.006	3.153	5.362	6.001	3.986	3.705	6.093	5.299
144	18.922	4.718	3.403	2.535	4.149	5.421	3.562	3.271	4.708	4.143
192	18.650	4.490	2.940	2.192	3.446	5.124	3.163	2.909	3.947	3.473
240	17.680	4.272	2.666	1.949	3.020	4.845	2.918	2.612	3.468	3.088
288	16.605	4.069	2.402	1.674	2.572	4.663	2.638	2.249	3.061	2.706
336	16.205	3.944	2.290	1.618	2.429	4.604	2.568	2.220	2.813	2.549
384	15.905	3.989	2.164	1.571	2.272	4.531	2.490	2.153	2.646	2.391
432	15.671	3.901	2.065	1.534	2.149	4.369	2.428	2.101	2.515	2.269
480	15.494	3.659	2.016	1.437	2.022	4.379	2.359	2.038	2.412	2.184
528	15.332	3.617	1.975	1.419	1.944	4.386	2.302	1.987	2.328	2.115
576	15.204	3.582	1.9172	1.404	1.880	4.383	2.255	1.944	2.257	2.058
624	15.098	3.552	1.868	1.391	1.826	4.238	2.215	1.908	2.197	2.009
672	14.713	3.391	1.841	1.330	1.755	4.194	2.170	1.870	2.140	1.961

Table 4. Data on SB inhibition efficiency in 0.5M H2SO4 and HCl solution at specific SB concentration (n=1).

Solution	**0.5 M H_2SO_4**				**0.5 M HCl**			
SB Conc. (%) / Exp. Time (h)	**10% SB**	**30% SB**	**50% SB**	**70% SB**	**10% SB**	**30% SB**	**50% SB**	**70% SB**
48	-40.94	-40.58	19.08	51.73	5.64	44.16	19.73	-2.82
96	-5.14	-6.12	24.57	46.67	12.59	48.51	19.29	0.56
144	3.36	5.96	27.22	45.97	19.77	52.77	16.08	2.03
192	7.05	16.65	30.14	47.40	29.3	57.09	14.93	2.27
240	8.12	19.69	29.85	46.61	35.19	59.62	15.75	4.8
288	12.38	19.26	28.69	45.63	40.24	62.02	16.97	5.23
336	12.77	21.86	30.13	45.52	44.42	64.23	17.79	7.97
384	17.50	24.62	31.83	45.93	47.97	65.61	17.85	9.03
432	22.16	27.79	34.25	46.84	50.41	65.85	16.9	9.90
480	26.32	31.14	36.01	48.05	52.15	66.22	17.26	9.42
528	29.8	33.54	37.69	48.00	54.24	66.65	16.91	9.86
576	32.50	35.95	39.12	48.22	55.89	66.94	16.46	10.08
624	34.90	38.02	40.35	49.29	56.00	67.28	16.28	7.00
672	36.24	39.03	40.76	50.5	56.35	67.38	16.4	6.72

Table 5. Data on ZB inhibition efficiency in 0.5M H_2SO_4 and HCl solution at specific ZB concentration (n=1).

Solution	0.5 M H_2SO_4				0.5 M HCl			
ZB Conc. (%) / Exp. Time (h)	10% ZB	30% ZB	50% ZB	70% ZB	10% ZB	30% ZB	50% ZB	70% ZB
48	50.15	48.27	69.59	91.34	87.38	88.32	88.19	92.01
96	56.80	65.72	74.7	92.49	83.37	83.13	83.05	81.92
144	57.83	70.17	75.84	92.68	80.29	80.11	80.82	75.30
192	57.19	71.95	75.87	92.57	74.39	77.74	78.88	70.70
240	54.83	71.93	74.8	92.17	69.89	76.05	77.01	67.08
288	51.88	71.20	73.44	91.66	66.62	74.45	75.38	64.21
336	50.67	71.36	72.98	92.19	73.43	74.76	74.87	63.42
384	49.71	71.56	72.70	90.41	68.60	67.62	74.05	60.54
432	48.60	71.72	73.23	89.17	63.14	67.36	72.7	58.31
480	48.38	71.91	73.66	89.59	56.99	67.77	72.43	57.34
528	47.97	72.07	74.08	88.77	51.97	68.29	72.19	56.71
576	47.73	72.26	74.49	88.71	46.35	66.83	71.92	56.02
624	47.73	72.48	74.85	88.29	39.80	65.77	70.71	53.93
672	46.79	72.22	74.76	88.32	33.26	65.7	70.17	51.67

Table 6. Data on ZBM inhibition efficiency in 0.5M H_2SO_4 and HCl solution at specific ZBM concentration (n=1).

Solution	0.5 M H_2SO_4				0.5 M HCl			
ZBM Conc. (%) / Exp. Time (h)	10% ZBM	30% ZBM	50% ZBM	70% ZBM	10% ZBM	30% ZBM	50% ZBM	70% ZBM
48	56.81	71.11	75.65	47.85	34.50	36.78	-34.77	-12.62
96	71.18	78.29	82.91	70.94	33.58	38.26	-1.53	11.7
144	75.07	82.01	86.60	78.07	34.31	39.67	13.16	23.59
192	75.93	84.24	88.25	81.52	38.28	43.24	22.97	32.23
240	75.84	84.92	88.98	82.92	39.78	46.10	28.43	36.27
288	75.50	85.53	89.92	84.51	43.42	51.77	34.35	41.97
336	75.66	85.87	90.02	85.01	44.21	51.79	38.89	44.63
384	74.92	86.4	90.13	85.72	45.06	52.49	41.61	47.22
432	75.11	86.82	90.21	86.28	44.42	51.91	42.42	48.07
480	76.37	86.98	90.72	86.94	46.13	53.45	44.91	50.11
528	76.41	87.12	90.75	87.32	47.51	54.70	46.93	51.77
576	76.44	87.39	90.77	87.63	48.56	55.65	48.51	53.06
624	76.47	87.63	90.79	87.91	47.75	54.99	48.15	52.60
672	76.96	87.49	90.96	88.07	48.26	55.4	48.96	53.25

3.2. Statistical evaluation

Statistical evaluation through analysis of variance (ANOVA) was done to assess the statistical relevance of SB, ZB and ZBM inhibitor concentrations and exposure time (sources of variation) on their inhibition performance (inhibition efficiency) in H2SO4 and HCl solution. Technically, from the electrochemical point of view inhibitor concentration and exposure time influence the performance of corrosion inhibitors. However, from the statistical perspective, the extent or degree to which the sources of variation are presented by the statistical relevance factor. The statistical relevance factor is meaningful if the mean square ratio is greater than the theoretical significance factor. The theoretical significance factor is the threshold minimum for which the statistical relevance factor is statistically important and meaningful. These variables or parameters are shown in Tables 7 and 8. Table 7 shows the ANOVA analysis of SB, ZB and ZBM compound in H2SO4 solution while Table 8 shows the ANOVA analysis for the compounds in HCl solution. Observation of the statistical relevance values in Table 7 shows inhibitor concentration significantly influence the inhibition performance of ZB and ZBM compounds compared to exposure time with values of 98.37% and 94.57%. The corresponding values for exposure time at 0.71% and 3.81% are significantly small. However, the values obtained for mean square ratio (inhibitor concentration and exposure time) is greater than the theoretical significance factor. Thus exposure time is statistically relevant to the performance of ZB and ZBM compounds at a very small degree compared to the overwhelming importance of inhibitor concentration. The statistical relevance value for SB inhibitor concentration and exposure time are 65.96% and 25.20%, showing that exposure time influences the inhibition performance of SB at significantly higher degree than ZB and ZBM compounds. The results show that the performance of ZB and ZBM compounds in H2SO4 solution are concentration dependent and varies more with concentration than exposure time compared to SB compound where concentration and exposure time influences its performance. In HCl solution, the statistical relevance of ZBM exposure time at 58.4% is greater than the corresponding value for concentration at 32.46%. This shows the inhibition performance of ZBM varies significantly with time though its concentration is also influential to a significant degree. Similar observation was observed for ZB where the effect of exposure time and concentration at 41.51% and 38.14% counterbalanced each other. These observations significantly contrast the values obtained for SB compound where SB concentration overwhelmingly influenced the performance of SB compound at statistical relevance value of 95.75% compared to exposure time at 2.38%, though the value for exposure time is statistical relevance, it still negligible to a certain degree compared to concentration.

Table 7. Statistical analysis (ANOVA) for SB, ZB and ZBM inhibition performance on MS in 0.5 M H_2SO_4 solution at 95% confidence level.

SB Compound						
Source of Variation	**Sum of Squares**	**Degree of Freedom**	**Mean Square**	**Mean Square Ratio (F)**	**Theoretical Significance Factor**	**Statistical Relevance (%)**
Inhibitor Conc.	3981.1	3	1327.0	74.69	2.92	65.96
Exposure Time	1521.1	10	152.1	8.56	2.17	25.20
Residual	533.0	30	17.8			
Total	6035.2	43				
ZB Compound						
Source of Variation	**Sum of Squares**	**Degree of Freedom**	**Mean Square**	**Mean Square Ratio (F)**	**Theoretical Significance Factor**	**Statistical Relevance (%)**
Inhibitor Conc.	8929.3	3	2976.4	1076.5	2.92	98.37
Exposure Time	64.7	10	6.5	2.3	2.17	0.71
Residual	83.0	30	2.8			
Total	9076.9	43				
ZBM Compound						
Source of Variation	**Sum of Squares**	**Degree of Freedom**	**Mean Square**	**Mean Square Ratio (F)**	**Theoretical Significance Factor**	**Statistical Relevance (%)**
Inhibitor Conc.	1208.9	3	403.0	582.2	2.92	94.57
Exposure Time	48.7	10	4.9	7.0	2.17	3.81
Residual	20.8	30	0.7			
Total	1278.4	43				

Table 8. Statistical analysis (ANOVA) for SB, ZB and ZBM inhibition performance on MS in 0.5 M HCl solution at 95% confidence level.

SB Compound						
Source of Variation	**Sum of Squares**	**Degree of Freedom**	**Mean Square**	**Mean Square Ratio (F)**	**Theoretical Significance Factor**	**Statistical Relevance (%)**
Inhibitor Conc.	23226.7	3	7742.2	511.04	2.92	95.75
Exposure Time	576.9	10	57.7	3.81	2.17	2.38
Residual	454.5	30	15.1			
Total	24258.1	43				
ZB Compound						
Source of Variation	**Sum of Squares**	**Degree of Freedom**	**Mean Square**	**Mean Square Ratio (F)**	**Theoretical Significance Factor**	**Statistical Relevance (%)**
Inhibitor Conc.	1836.4	3	612.1	20.4	2.92	41.51
Exposure Time	1687.6	10	168.8	5.6	2.17	38.14
Residual	900.4	30	30.0			
Total	4424.4	43				
ZBM Compound						
Source of Variation	**Sum of Squares**	**Degree of Freedom**	**Mean Square**	**Mean Square Ratio (F)**	**Theoretical Significance Factor**	**Statistical Relevance (%)**
Inhibitor Conc.	732.6	3	244.2	35.5	2.92	32.46
Exposure Time	1318.1	10	131.8	19.2	2.17	58.40
Residual	206.2	30	6.9			
Total	2257.0	43				

Statistical data for mean, standard deviation (SD) and margin of error for the calculated values of SB, ZB and ZBM inhibition efficiencies from H2SO4 and HCl solutions are shown in Table 9. The degree of variation of between the inhibition efficiency values of the compounds from mean value is given by SD. Observation of SD values for SB compounds in both acids shows significant decrease with respect to concentration i.e. the amount of variation from mean value decreases with increase in concentration. This phenomenon is due to availability of more SB molecules to counteract the action of the corrosive species. However, the margin of error for SB in H2SO4 solution shows the inhibition efficiency values obtained were completely below 60% while the value obtained in HCl shows that only 16% of the inhibition efficiency data is above 60% inhibition performance with margin of error at +9.62%. The SD values obtained for ZB in H2SO4 is significantly lower than the values obtained in HCl due to decrease in the extent of variation from mean value. The margin of error for ZB in both acids at +11.6% and +10.4% occurs with 73% and 80% of ZB inhibition efficiency values above 60% inhibition. This value is a significant improvement compared to the values obtained for SB compound. 96% of ZBM inhibition efficiency values obtained in H2SO4 solution were above 60% inhibition performance with margin of error of +4.86%. This data significantly contrasts the performance of ZBM in HCl solution where none of the inhibition efficiency values were above 60% inhibition performance.

Table 9. Statistical data for mean, standard deviation (SD) and margin of error for the inhibition efficiency values of SB, ZB and ZBM compounds in 0.5 M H_2SO_4 and HCl solution.

SB Compound					**SB Compound**				
Concentration	10%	30%	50%	70%	**Concentration**	10%	30%	50%	70%
SD	20.27	21.27	6.31	1.86	**SD**	17.09	7.62	1.30	4.04
Mean	14.07	19.06	32.12	47.6	**Mean**	40.01	61.02	17.04	5.86
Margin of Error	±0%	**Proportion above 60% inhibition efficiency**		0%	**Margin of Error**	±9.62 %	**Proportion above 60% inhibition efficiency**		16%
ZB Compound					**ZB Compound**				
Concentration	10%	30%	50%	70%	**Concentration**	10%	30%	50%	70%
SD	3.89	6.38	1.59	1.73	**SD**	16.37	7.22	5.21	11.55
Mean	51.16	69.63	73.93	90.6	**Mean**	63.96	73.14	75.88	64.94
Margin of Error	±11.60%	**Proportion above 60% inhibition efficiency**		73%	**Margin of Error**	±10.4 %	**Proportion above 60% inhibition efficiency**		80%
ZBM Compound					**ZBM Compound**				
Concentration	10%	30%	50%	70%	**Concentration**	10%	30%	50%	70%
SD	5.19	4.61	4.26	10.8	**SD**	5.45	6.81	23.94	19.12
Mean	74.19	84.41	88.33	81.48	**Mean**	42.56	49.01	30.21	38.13
Margin of Error	±4.86%	**Proportion above 60% inhibition efficiency**		96%	**Margin of Error**	±0%	**Proportion above 60% inhibition efficiency**		0%

4. Conclusion

Zinc bromide displayed the most effective inhibition performance on mild steel in 0.5 M H2SO4 solution compared to Zinc benzoate which had the most effective performance in HCl solution. Generally, the inhibition effect of the compounds varied exposure time. Statistical evaluation through analysis of variance assessed the statistical relevance of inhibitor concentrations and exposure time on their inhibition performance in both acid solutions with data showing that inhibitor concentration strongly influenced the performance of the inhibitors. The statistical values for exposure time were negligible but statistically relevant when compared to the theoretical significance factor. Statistical data for standard deviation and margin of error for the calculated values of the inhibition efficiencies of the compounds showed the degree of variation of between the inhibition efficiency values by the calculated margin of error.

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