

Research Article

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Effect of corrosion on surface degradation of galvanized steel in poultry dung, pig dung and urea solutions using rice straw as an inhibitor

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Abstract: Waste control is a big challenge in industries. The aim of this study is to control degradation of farm structure using rice husk as corrosion inhibitor in pig dung, poultry dung and urea solution environment. The rice straw was subjected to phytochemical analysis. The four variables: rice straw, Pig dung, urea and poultry dung solutions were used to determine the best approach to reduce the corrosion rate of galvanized steel used for farm structures. Time variation used was 3–12 days. The result from the phytochemical analysis showed that rice husk has constituents of a good inhibitor. The result from the variables' mix in S1: A: 40 cm³; B: 40 cm³; C: 10 cm³ and D: 10 cm³ has the highest inhibition efficiency of 88.59%. The SEM result from the best combination showed that passive film was formed which was attributed to the adsorption via rice straw extract. The rice straw used in this study was an effective inhibitor. It is an agricultural waste that was converted into a viable process which is of economic value.

Keywords: corrosion, inhibitor, weight loss, scanning electron microscope, inhibition efficiency

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1 Introduction

Farm wastes and slurries can also be significantly corrosive. Because there are so many different structures, machinery, and fittings used in farming, it's difficult to pinpoint exactly where rust can cause the most damage. The problem is further complicated by the various environments (rural, urban, and coastal), the local "microclimate", the type of farming activity, the seasonal use of certain equipment and technology, and the storage methods used [1]. Galvanising of steel is generally beneficial in resisting corrosion. Maintaining product quality along with healthy environment at an optimal cost is a big challenge for the production engineers and researchers.

The following are some of the most significant advantages of galvanized steel: maintenance costs are lower, very durable, damage resistant and cheaper when compared with other most treated steels [2]. Corrosion failures often relate to the material selection and the environment. Furthermore; details of the material specifications, quality-assurance records, installation and maintenance records, and a history of the environment are all useful resources in resolving corrosion failures [3]. Advances in metallurgy like galvanized steel, is a keystone to modern farming operations by helping farmers to save time and money. Metallic materials play a critical part in a country's economic development and long-term progress in the global economy [4]. Terms of waste management have been widely accepted as a sum of the measure and solution for waste prevention, treatment, recovery, reuse with regard to ecological and economic aspects. However, waste disposal to control landfills should only be a final option if further waste treatment is not economically or technically feasible [5]. Rising amounts of industrial waste are among the main challenges great concern in most cities, today. Based on the management concept "from cradle to grave," the reasonable starting point for solid waste management is to reduce the amount of garbage that needs to be managed (also known as Life Cycle Analysis). The benefits of incorporating waste reduction strategies into municipal solid

waste management (MSWM) constitute the foundation of an emerging global strategy for solid waste management [6, 7, 8, 9]. Owing to the deterioration of metallic materials, the risk of corrosion has risen significantly. Chemicals from chickens and pigs can shorten the life of farm fencing by as much as 14 years on average. When used for fences and gates, galvanised steel has a longer life span than mild steel, according to [10]. Calcium orthoplumbate alkyd primers with a matching top-coat alkyd are much easier to apply to galvanized steel and have been proved to be effective in reducing corrosion. However, this type of inhibitor is expensive and there is need to find an alternative environmentally friendly inhibitor which will be cost effective. It has been found that hazardous concentration of hydrogen sulphide gas may be produced when a mixture of silage effluent and slurry promotes the production of corrosive acids under deposits. Slurries are dung and urine combinations that are composted with litter (usually a mixture of straw or wood shavings) to create farmyard manure. With naturally secreted animal chlorides, which are the principal corrosive components of slurries and farm yard manures, farm yard manure (FYM) ferments while releasing moisture, ammonia, and carbon dioxide [11]. Sulfates, nitrates, chlorides, hydrogen sulfide, and ammonia are among the corrosion-inducing compounds found in poultry, cow, and pig dung. However, the use of hybrid composites including sulfur, fly ash, silica fume, and nanoparticles such as silica can help to slow down the deterioration of concrete structures. Stalls for dairy cattle and piggery are often reinforced with cast-iron and galvanized steel. The cost-effective corrosion prevention approach must be integrated into agriculture to minimize the expense of fixing these farm facilities and also to save cost [13]. Corrosion losses in agriculture have not been quantified in the same manner that they have been in other fields. The first-order costs, including material losses and labor, have been projected to be significant. Although second-order losses caused by corrosion, such as crop loss owing to equipment failure and animal straying, might triple first-order expenditures. [10]. To evaluate the effectiveness of the corrosion prevention practices applied to agricultural equipment manufactured and used in Nigeria farms, it is important to identify the best method of corrosion prevention [1]. The risk of corrosion in the crude oil processing industry in Nigeria has been calculated using the engineering economy method and found to be 77 cents / barrel, and the cost of corrosion in the food and agro processing industries was determined by the costing of the life cycle and the total cost was N22,350,600 [13, 15, 16, 17]. It was reported by [14] that farm implements or equipment are mainly replaced because of wear and corrosion. Furthermore, agricultural crops produce significant volumes

of residual residues, and crop residues are increasing in tandem with food production.

These unused residues represent not only a waste of resources, but also a missed opportunity for a farmer to increase his or her revenue. Crop leftovers are being used by researchers all over the world to tackle problems in domains such as textile, composite non-woven manufacturing processes (e.g. bamboo). [19]; olystyrene [20]; inhibitors: katemfe [21]; almond fruit extracts [22]; power generation, biogas production, animal feed, compost and manures.

Corrosion is the chemical attack or reaction of metals with their environment that causes them to corrode. It is a persistent and continuous problem, often hard to fully eradicate. The study of galvanized steel corrosion is of tremendous theoretical and practical concern, and has received considerable interest. The best choice for shielding metals and alloys from corrosion is the use of green inhibitors. Organic corrosion inhibitors' environmental toxicity has inspired a search for green corrosion inhibitors, which are biodegradable and environmentally beneficial. [23]. Plant extracts have been successfully used by some academic researchers to prevent metal corrosion in acidic and alkaline environments, such as: *Corchorus olitorium* stem extract as corrosion inhibited the corrosion of mild steel in sulphuric acid [23]; oyewole et al.2021; investigated the characterization of *Ficus exasperata* extract and the optimization of the process variables on inhibition of mild steel in seawater environment [24]; *Delonix regia* extracts reduced aluminum corrosion in hydrochloric acid solutions [25], rosemary leaves were explored as a corrosion inhibitor for the Al + 2.5Mg alloy in a 3 percent NaCl solution at 25°C [26], and El-Etre looked into the effects of *Opuntia* extract on aluminum [27]. The inhibitive effect of the extract of *khilla* (*Ammi visnaga*) seeds on the corrosion of SX 316 steel in HCl solution was determined using weight loss measurements as well as potentiostatic technique. The formation of insoluble complexes as a result of interaction between iron cations and khellin is thought to constitute the mechanism of action [28]. The extracts described above have an inhibitory efficacy of 87-94 percent. Plant shutdowns, waste of important resources, product loss or contamination, decline in efficiency, costly maintenance, and expensive overdesign are all significant consequences of corrosion.

Corrosion often affects the metal's strength and movement and can result in a heavy bill for fixing or replacing the object [29]. Farm wastes and slurries contain many chemicals that often damage farm machinery and ancillary structures [30]. Chemical substances such as pesticides and elements such as manure also led to rust, creating high-risk areas on your farm or ranch. Before rust prevention

advances, farmers and ranchers were left to conventional approaches such as using a wire brush to eliminate rust scaling. Products which are resistant to corrosion can reduce maintenance costs and extend the life of farm implements. [10, 31, 32] stated that no research has been done to estimate how much corrosion losses in agriculture can be avoided, while studies have shown that it may be as high as 50%. Mild steel corrodes more than galvanized steel in farmyard manure, according to results from laboratory studies conducted at ambient temperature [14]. Because galvanized steel is the most often used metallic material in agricultural constructions, it was chosen for this study. In the agricultural sector, it has been noted in the literature that there is a need to control or decrease corrosion attack on metallic components to the bare minimum. The use of rice straw extract as a corrosion inhibitor on galvanized steel in (poultry dung, cow dung, and urea conditions) was investigated in this study.

2 Materials and methods

2.1 Preparation of sample

Landmark University's Mechanical Engineering Laboratory provided the galvanized steel. It was cut into 22 coupons of 19 mm × 22 mm × 2 mm dimensions. The surface was cleaned with emery paper and then rinsed thoroughly with distilled water. It was later dried with acetone and placed in a desiccator. According to laboratory report findings by [14], mild steel corrodes more than galvanized steel at ambient temperature, this is the justification for using galvanized steel.

2.2 Extract preparation

The rice straw was obtained from Landmark University's Teaching and Research Farm in Omu-Aran, Kwara State. Then sun dried for 2 days to remove the moisture content, then milled to fine powder to increase the surface area and kept for further analysis.

2.3 Phytochemical analyses

The secondary metabolites tannins, saponins, flavonoids, and alkaloids were extracted from milled rice straw using phytochemical analysis.

Table 1: The coupons immersed in composition of: pig dung, poultry dung, rice straw and urea solution contained in beakers for a period of 12 days with 3 days interval.

	S1	S2	S3	S4	S5	S6	S7
A	40	20	30	20	50	0	25
B	40	10	30	20	50	0	25
C	20	40	20	30	0	50	25
D	10	40	20	30	0	50	25

2.4 Corrosive medium

The medium used were solution of: Pig, Urea and Poultry dung; added up to 100 cm³. The pH of pig dung was 7.50; Poultry dung with pH of 5.80 and Urea with pH of 5.0; respectively.

2.5 Weight loss analysis

Weight loss approach was used to test the protective efficiency of the rice straw extract in the acidic environments (urea piggery and poultry). This approach was adapted from [33]. According to Table 1, the coupons were immersed in pig dung, poultry dung, rice straw, and urea solution in beakers for 12 days with 3 days intervals. This was done in triplicate to avoid error.

The initial weight and final weight before and after immersion was used to determine the weight loss as shown in Eq. (1);

$$W = W_b - W_a \quad (1)$$

While the corrosion rate (g/cm²h) was calculated using Eq. (2).

$$CR = \frac{\Delta W}{At} \quad (2)$$

Where ΔW is the weight loss (g) after exposure time t (days), A is the area of the specimen (cm²) and t is the time of exposure in days and CR is the corrosion rate at each exposure time.

IE% is the inhibition efficiency which was calculated using Eq. (3)

$$IE\% = \frac{W_0 - W_1}{W_0} \times 100 \quad (3)$$

$$IE\% = X100 \quad (3)$$

Where, W_1 and W_0 are the weight loss values in presence and absence of inhibitor.

Where:

A represents pig dung,

B rice straw,
C urea,
D poultry dung,
S represents the mix of the 4 variables solution.

3 Results and discussion

3.1 Result of phytochemical analysis of RSE

The presence of metabolites such as saponins, tannins, flavonoids, and glycosides in the RSE made it a good inhibitor, according to the phytochemical study. This result validated [34, 35, 36, 37, 38, 39, 40, 41, 42]'s findings that plant extract is a good inhibitor, as indicated in Table 2.

Table 2: Phytochemical constituents of RSE.

S/N	Substances	Presence
1	saponins	++
2	tannis	+
3	flavonoids	+
4	alkanoids	–
5	phenolics	–
6	glycosides	++

++ Highly present; + moderately present; – absent

3.2 Result of final weight after immersion

The result of the final weight observed is as shown in Table 3. The weight increases with time from 3 days till 12 days for the mix variation s in S1-S7, respectively. Table 3 is result observed. Table 4a–4b showed the results of the corrosion rate and weight loss respectively.

3.3 Result of weight loss, corrosion rate and inhibition efficiency

Most corrosive environment as observed from the result was Mix S3 at 3 days of immersion. The result of the inhibition efficiency is as shown in Table 5. The inhibition efficiency increases with time of inhibition from 3 days till 12 days respectively. The highest inhibition efficiency of 88.59% was observed in S1 ($A=40\text{ cm}^3$, $B=40\text{ cm}^3$, $C=10\text{ cm}^3$, $D=10\text{ cm}^3$) at 12 days. Figures 1–6 indicated the plots of S1-S7 for inhibition efficiency versus time of inhibition while Fig-

Table 3: Result of final weight.

S/N	Initial weight	Final weight			
		3 days	6 days	9 days	12 days
S1	5.4745	5.4680	5.4565	5.4689	5.4626
S2	4.9236	4.9172	4.9167	5.4689	4.9065
S3	5.4508	5.4459	5.4362	5.4359	5.4297
S4	5.3044	5.2882	5.3026	5.2933	5.2871
S5	5.4122	5.4956	5.3986	5.3961	5.3931
S6	5.3852	5.3656	5.3641	5.3637	5.3558
S7	5.3331	5.3179	5.3155	5.3086	5.2917

ures 8 and 9 are for plots of Inhibition efficiency versus S(S1-S7) and Plot of inhibition efficiency versus time of inhibition, respectively. However; in mix S1 and S4, Inhibition efficiency increases with temperature from 3 days to 6 days but reduced at 9 days while highest inhibition efficiency was in 12 days. It was reported by [42, 43, 44] that infusing silica fumes into the steel rods during the production phase of the galvanized steel has proven to have more protective benefits compared to steel rods, without silica fumes. This supported the findings in this study since silica is one of the major proximate constituent of rice straw as reported in the literature. This means this study can be replicated and used by agricultural sector, to combat corrosion on farm structures in Nigeria; since it is a cost-effective approach.

Table 4a: Corrosion rate (CR).

S	3 days	6 days	9 days	12 days
S1	0.000524	0.000726	0.00151	0.00240
S2	0.00516	0.00278	0.00409	0.00345
S3	0.00395	0.00589	0.00401	0.00426
S4	0.00131	0.00726	0.00299	0.00349
S5	0.00530	0.00548	0.00433	0.00385
S6	0.00158	0.00851	0.00578	0.00593
S7	0.00122	0.00710	0.00659	0.00835

Inhibition efficiency increases with time from 3 till 12 days in S2; S3; S5 and S6 respectively. Furthermore, in S7 Inhibition decreases from what was observed in 3 days with the result in 6 days and then it increases in 9 and 12 days, respectively.

Table 4b: Weight loss α_w .

S/N	3 days α_w	6 days α_w	9 days α_w	12 days α_w
S1	0.0065	0018	0.0056	0.0119
S2	0.0064	0.0069	0.0152	0.0171
S3	0.0049	0.0146	0.0149	0.0211
S4	0.0162	0.0018	0.0111	0.0173
S5	0.0066	0.0136	0.0161	0.0191
S6	0.0196	0.0211	0.0215	0.0294
S7	0.0152	0.0176	0.0245	0.0414

Table 5: Result of inhibition efficiency (%).

S/N	3 days	6 days	9 days	12 days
S1	11.87	21.01	10.22	88.59
S2	13.00	14.01	30.87	34.70
S3	9.0	26.79	27.30	38.70
S4	30.5	34.00	20.92	32.60
S5	12.20	25.12	29.70	35.30
S6	36.00	39.18	40.00	84.60
S7	36.40	33.00	46.34	78.20

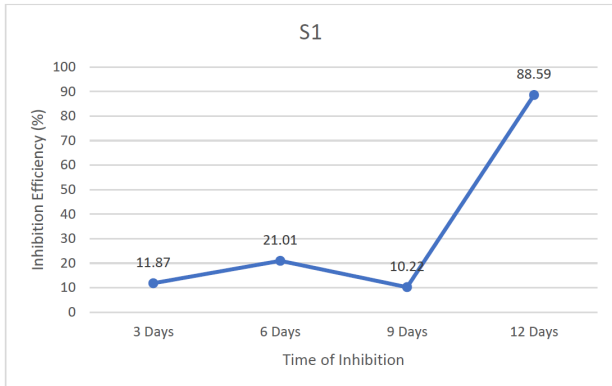


Figure 1: Plot of S1 (Inhibition efficiency versus Time of inhibition (days)).

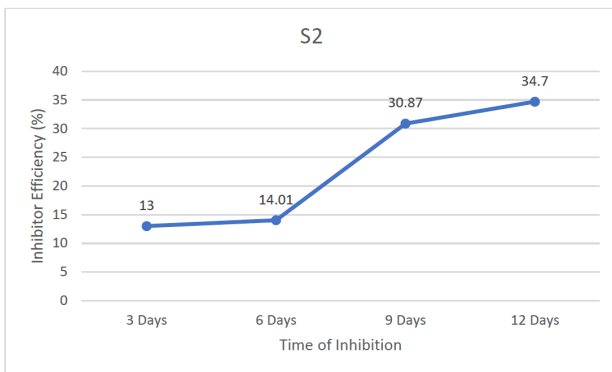


Figure 2: Plot of S2 (Inhibition efficiency (%) versus Time of inhibition (days)).

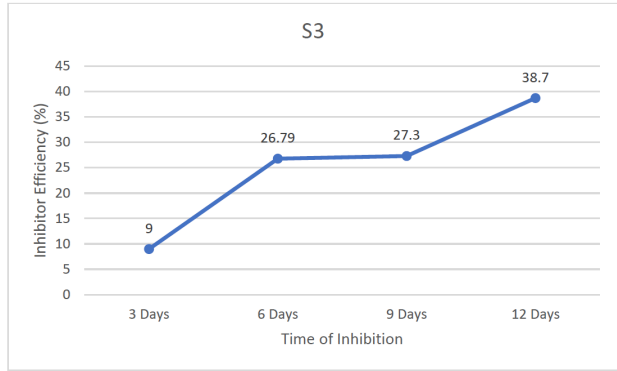


Figure 3: Plot of S3 (Inhibition efficiency versus Time of inhibition (days)).

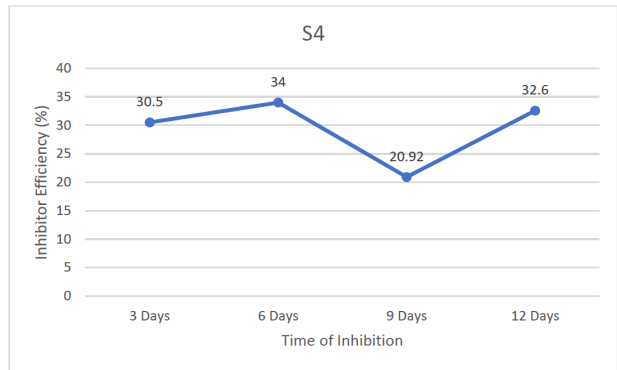


Figure 4: Plot of S4 (Inhibition efficiency versus Time of inhibition (days)).

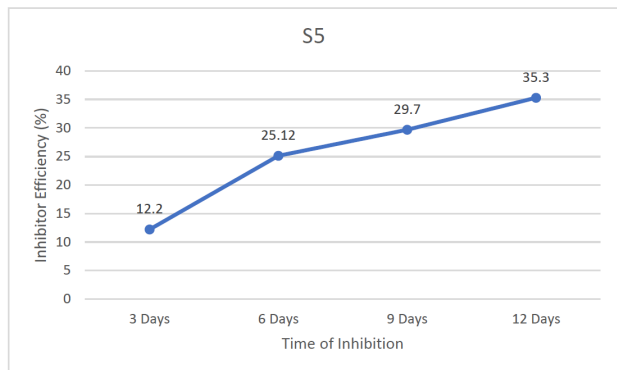


Figure 5: Plot of S5 (Inhibition efficiency versus Time of inhibition (days)).

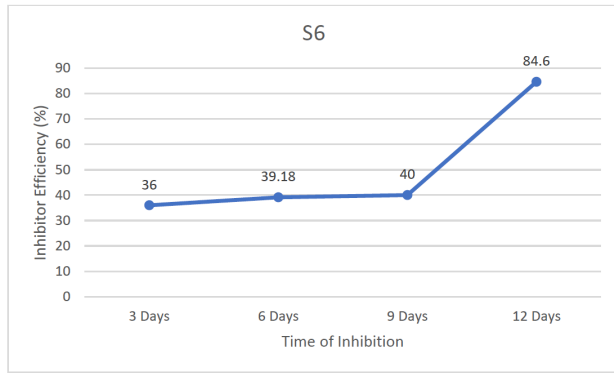


Figure 6: Plot of S6 (Inhibition efficiency versus Time of inhibition (days)).

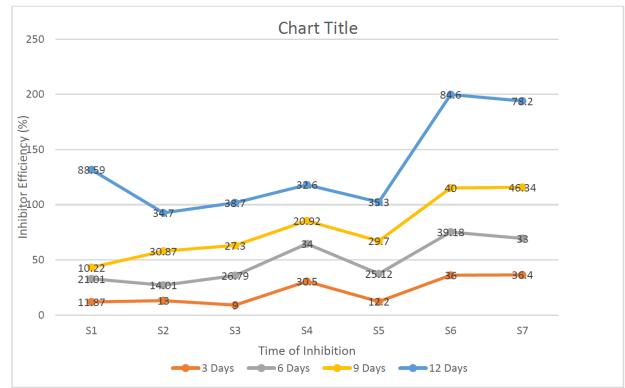


Figure 9: Plot of Inhibition efficiency versus Time of inhibition (days).

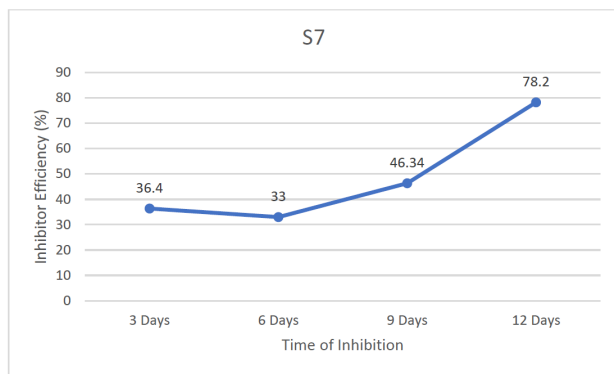


Figure 7: Plot of S7 (Inhibition efficiency versus Time of inhibition (days)).

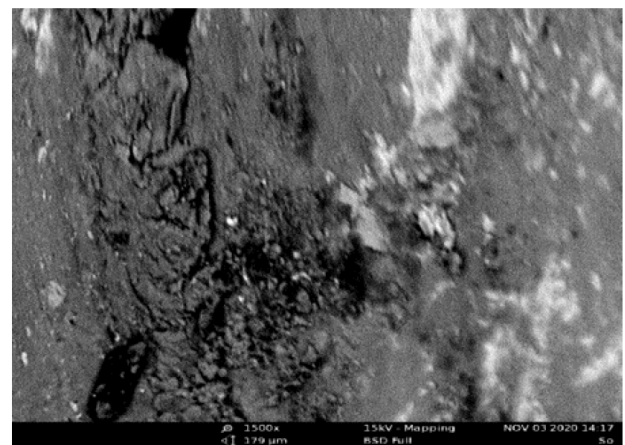


Figure 10: SEM Result of the blank mild steel.

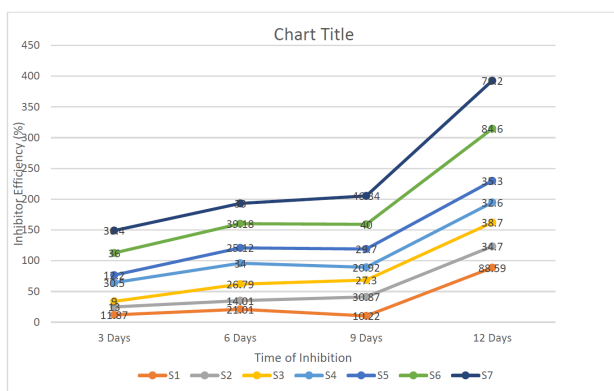


Figure 8: Plot of Inhibition efficiency (%) versus Time of inhibition (days).

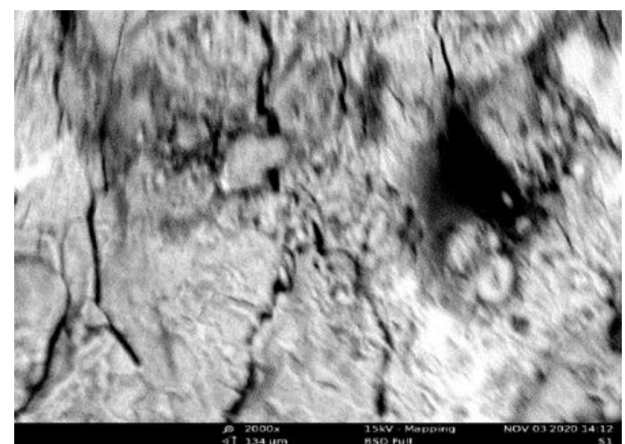


Figure 11: SEM result of the mild steel with the highest IE.

4 Conclusion

Rice straw contained the major constituents, which made it a good inhibitor. The SEM result showed that outer film layer was formed on the mix S1 after the immersion time for 12 days with the highest inhibition. The mix S3 gave the lowest inhibition efficiency because it contained more concentration of the corrosive constituents which would have contributed to higher corrosion of the test mix. The level of sensitivity to corrosion and degradation of a material used in the building of farm structures affects their service life. Degradation of agricultural constructions is unavoidable, but it can be managed through material selection. It can be concluded that the mix of S1 was the best composition for solving corrosion challenges on farm structures.

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