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Evaluation and proposed treatment of corrosion process in bauxite pulp pipeline **Danilo Zim^a, Rafaela F. Carvalhal^a, Matheus P. Paschoalino^a, Otilio Pires^b, Rômulo Rufino^b**

Abstract

Norsk Hydro, one of the major global players in the mining marketplace, has one bauxite ore mine located in Paragominas-PA, Brazil. A special pipeline was built in order to transport the bauxite from the mine to the refining site – the first bauxite pulp pipeline in the world. The estimated lifetime of the pipeline is 25 years. Despite this, an evaluation of both the river water and bauxite pulp's corrosivity was requested. The objective of this study was to report the results obtained for corrosion and corrosion-erosion aspects, as well as propose mitigation actions for each case. For the river water, it was possible to identify the occurrence of localized corrosion. According to results obtained, the highest corrosion protection is achieved with a combination of corrosion inhibitor, oxygen scavenger and pH control. For pulp, it was possible to identify the occurrence of corrosion (C), erosion (E), and synergistic effect (SyCE). Results suggest that (E) is the main component of corrosive process and (SyCE), along with (C), plays a secondary role. In order to have significant corrosion inhibition in the bauxite pulp medium, it was necessary to pre-treat the metal surface. The corrosion inhibition in bauxite pulp using corrosion inhibitor (A) after pre-treatment was 49%, and is comparable to cathodic protection according to laboratory data.

Keywords: corrosion-erosion, pipeline, corrosion inhibitor, bauxite

Introduction

Norsk Hydro, one of major worldwide players in the mining marketplace, has one bauxite ore mine located in Paragominas-PA, Brazil. The bauxite is transported from the Miltônia 3 mine to the refining site in Barcarena-PA via pipeline. The pipeline, which was constructed between 2003 and 2005, is the first bauxite pulp pipeline in the world.

The bauxite pipeline is 242.8 km long, 61 cm (24 inches) of diameter. It is constructed of mild steel and crosses seven localities: Paragominas, Ipixuna do Pará, Tomé-açú, Acará, Mojú, Abaetetuba, and Barcarena. It has eight current rectifiers for external corrosion protection and is buried 1.5 meter under soil.

Before being pumped through the pipeline, bauxite ore is ground and mixed with river water to form a pulp. River water for this purpose is stocked in two main tanks prior to use and does not receive any pretreatment.

The expected lifetime of the pipeline is 25 years; however, in order to ensure the operational integrity of this equipment, Norsk Hydro requested that Nalco (an Ecolab Company) conduct

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an evaluation of both the river water and bauxite pulp from Paragominas-PA's corrosivity. The objective of this study is to report results obtained for corrosion and corrosion-erosion aspects as well propose mitigation actions for each case.

Methodology

Samples of water and bauxite sludge that were utilized in this study were collected from the Miltônia 3 mine located in Paragominas-PA. Essentially, bauxite ore is grinded and mixed with river water in order to form a pulp that can then be pumped through the pipeline. River water is stocked in two main tanks prior to use and does not receive any pretreatment. Consequently, samples of river water from those tanks and bauxite sludge samples were collected after the grinding process.

Samples of river water with a pH in the range of 4.4 to 4.7 were used as received; however, samples of bauxite sludge were vigorously stirred before use and the pH was in the range of 6.8 to 7.4.

The carbon steel that was employed to build the pipeline is API 50L 70X. Tubular coupons made of C1018 mild carbon steel were used for the electrochemical and weight loss measurements, which were the most similar to those used in the laboratory. Coupons dimensions were: outside diameter: 12.0 mm; inside diameter: 6.0 mm; length: 8.0 mm. The tubular coupons received a surface pretreatment just before use. To start, the coupons were dipped for two minutes in acetone, two minutes in xylene, and then an additional two minutes in acetone in order to remove any residual, oily substance. Then the coupons were immersed into concentrated hydrochloric acid (36%) for five minutes. Lastly, the electrodes were copiously rinsed with distilled water and inserted into the rotating cylinder electrode support.

Electrochemical measurements

Electrochemical polarization measurements were performed using an Autolab PGSTAT 302N driven by NOVA 1.7 Software.

For water studies, four conventional glass cells (1000 cm³ in volume, assembled in parallel) were used for the polarization studies. All potential measurements were performed with river water; a standard Ag/AgCl reference electrode and stainless steel rods were used as counter electrodes. Potentiodynamic polarization curves were obtained at a potential scan rate of 1 mV/s from cathodic to anodic region varying 100 mV for each region around Open Circuit Potential (OCP). Corrosion rate measurements were carried out using potentiodynamic polarization curves associated with the Tafel extrapolation method using a Rotating Cylinder Electrode (RCE) (1).

The flow rate of the pulp or water inside the pipeline is 1.7 m/s. To maintain the mass transfer that is verified in the field, the rotation rate of the RCE was determined to be 1107 rpm as is shown in Figure 1 (2).

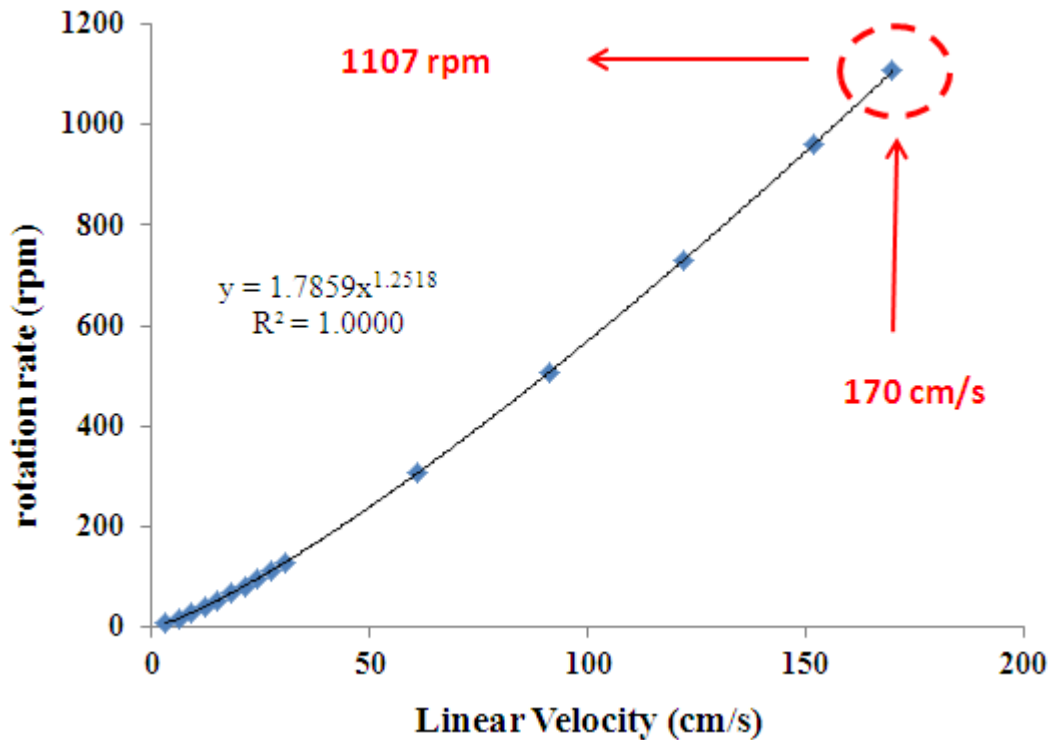


Figure 1 – Correlation between the linear velocity of fluids inside a pipeline of 61 cm of inner diameter and the rotation rate of the rotating cylinder electrode (RCE).

For pulp studies, a conventional polypropylene cell (5000 cm³ in volume), was used for polarization studies and all corrosion rate measurements were carried out using linear polarization resistance technique (LPR). The equipment set to perform the experiments is described in Figure 2 and graphically represented in Figure 3. It was attested that, when a cylindrical coupon was rotated in sand slurry, the sand grain density is greater in the lower part of the apparatus (3). When bauxite sludge is used as the slurry, the solids will concentrate in the bottom of the apparatus. To avoid this effect, a mechanical stirrer was used to improve the homogeneity of the pulp during experiments. All electrodes were protected to prevent erosion due to pulp stirring by using a “V shape” simple polypropylene barrier that allowed pulp to circulate around electrodes without being impinged directly over them. Impeller speed was set at 600 rpm, which guaranteed that no sedimentary accumulation should appear in the bottom of the electrochemical cell.

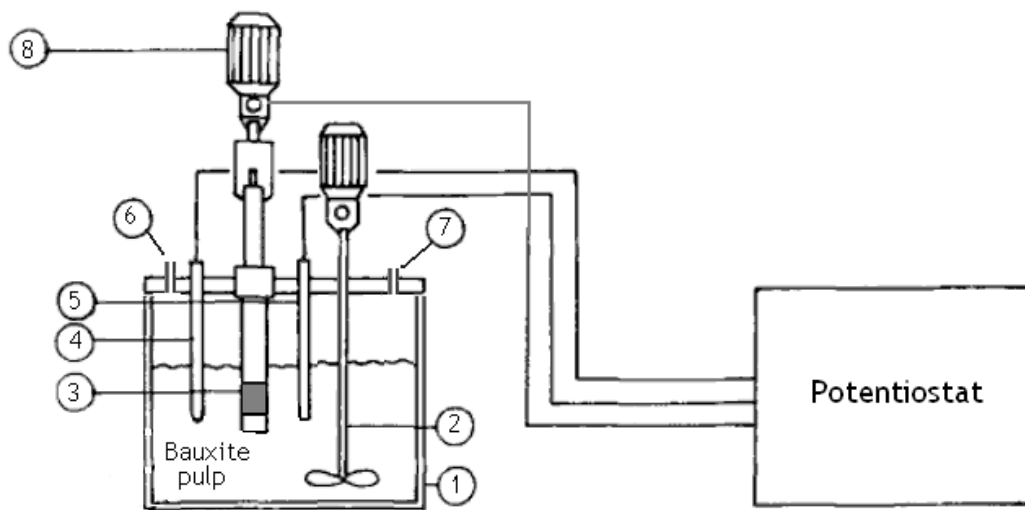


Figure 2 – Schematic diagram of the proposed apparatus to evaluate the corrosion-erosion process in bauxite sludge. (1) 5000 cm³ polypropylene vessel; (2) stirrer just to maintain the homogeneity of the sludge; (3) rotating cylinder working electrode; (4) reference electrode; (5) stainless steel auxiliary electrode; (6) and (7) vents; and (8) electric motor.



Figure 3 –Picture of corrosion cell used to evaluate the corrosion-erosion process in bauxite sludge.

In the presence of bauxite pulp, a standard Ag/AgCl or calomel reference electrode will not perform properly during long term experiments due to membrane clogging, abrasion, and even mechanical fail (braking); consequently, a metallic pseudo-reference electrode was selected to avoid these disadvantages. Both reference systems were compared at similar experimental conditions, using potassium hexacyanoferrate (III) as a probe molecule. The stability of peak potential and current obtained for potassium hexacyanoferrate (III) using metallic pseudo-reference electrode was maintained during 30 voltammetric cycles as can be observed in Figure 4. The formal potential (E°) of potassium hexacyanoferrate (III) is 0.23 V vs. Ag/AgCl and turns to -0.21 V vs. Pt.; consequently, a considerable cathodic shift of 0.43 V must be considered when comparing the results obtained with both electrodes.

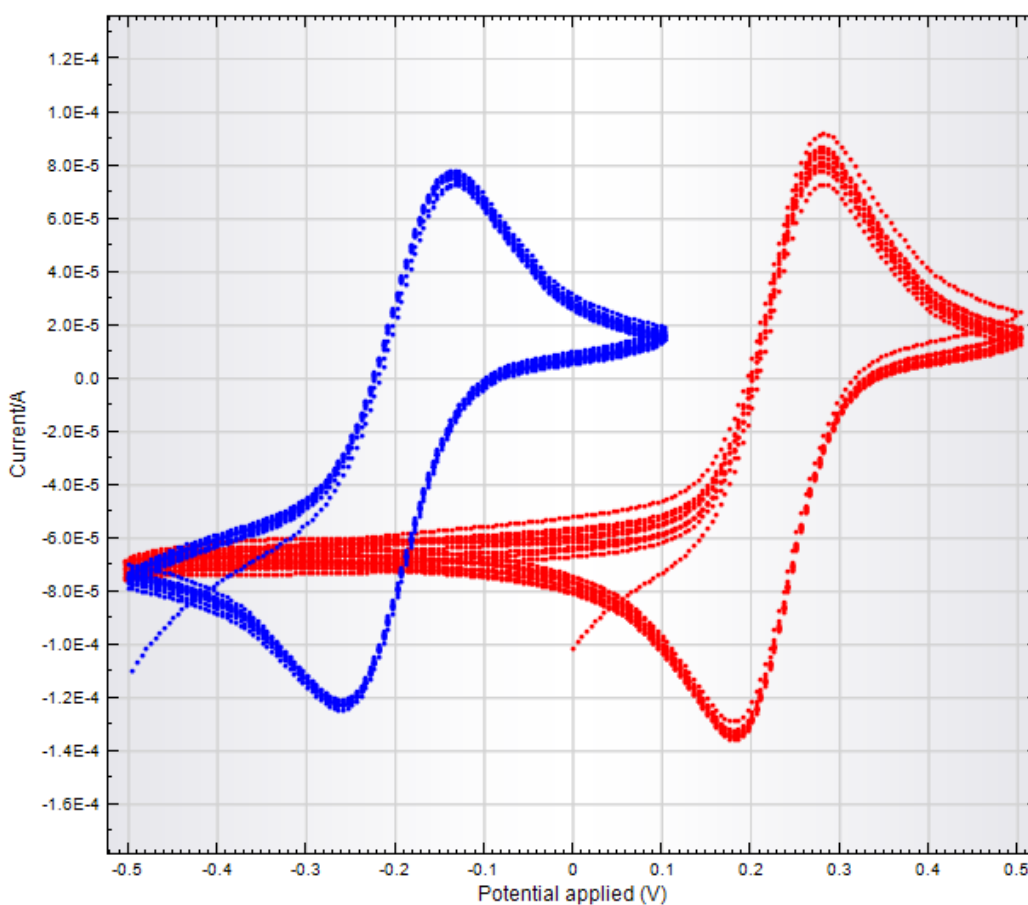


Figure 4 – Cyclic voltammograms of 10 mmol/L Potassium hexacyanoferrate (III) in 0.1 mol/L phosphate buffer, pH 7.0, 20 mV/s, employing a platinum disc working electrode, a 316 stainless steel counter electrode and a Pt bar as a pseudo-reference electrode (●) or an Ag/AgCl standard reference electrode (●).

Experimental design

The corrosion inhibitors that were tested are described in Table 1. pH adjustments were performed using sodium hydroxide or calcium hydroxide (lime) as described. The trials where sodium bisulfite was used as an oxygen scavenger were carried out under exclusion of air by using nitrogen atmosphere.

Table 1 - Classification of corrosion inhibitors that were employed in this work.

Corrosion Inhibitors	Description
(A)	Cathodic Inhibitor + Anodic Inhibitors
(B)	Anodic Inhibitor
(C)	Organic Cathodic Inhibitor
(D)	Organic Cathodic Inhibitor + Anodic Inhibitors

Chemical corrosion due to water quality and mechanical erosion can produce a synergistic effect that, overall, results in even higher global corrosion rates (3, 4, 5). In order to properly evaluate each component individually, a series of measurements were conducted. The first measurement was carried out by measuring mass loss in a coupon and then by measuring the instantaneous corrosion rate when the working electrode is rotated at 1107 rpm. Mass loss corresponds to global corrosion attack while the electrochemical measurement of corrosion corresponds to chemical corrosion.

The last measurement is carried out rotating the working electrode under cathodic protection. The mass loss, in this case, corresponds exclusively to erosion since any electrochemical corrosion is avoided. Working cathodic potential was set at -0.9 V vs. Pt (reference electrode). The cathodic protection potential was chosen according to ASTM Methods that recommend -1.2 V above OCP potential; however, observing that no hydrogen production should be detected, in this case -0.9 V vs. Pt., a brand new working electrode (coupon) was used for each assay. A brief description of each measurement is described in Table 2.

Table 2 - Methodology employed to study the corrosion-erosion process.

Process	Data
Corrosion-erosion (CE)	Can be determined by measuring the total weight loss of the coupon.
Corrosion (C)	The corrosion rate can be determined on the basis of the results of polarization curves.
Erosion (E)	The erosion only rate can be determined by rotating the coupon and then measuring the mass loss following cathodic protection.
Total synergy of corrosion and erosion processes (SyCE)	Can be calculated by the difference of $SyCE = CE - (C+E)$

The determination of corrosion rate by weight loss measurements were performed according to ASTM G1-03 recommendations. Once (CE), (E), and (C) were analyzed for a specific sample of bauxite sludge, corrosion inhibitor performance could be evaluated. Measurement of weight loss and instantaneous electrochemical corrosion using LPR measurements was carried out, keeping the rotating electrode at 1107 rpm. This assay was carried out under the same conditions of the first test; however, this time in the presence of a corrosion inhibitor. The percent protection relative to blank samples can be determined for each chemical according to the following equation:

$$\text{Efficiency of inhibition (\%)} = ((CE - CE_{CI}) \times 100) / CE \quad (\text{equation 1}),$$

where, CE is the corrosion erosion rate without any treatment and CE_{CI} is the corrosion erosion rate determined in the presence of corrosion inhibitor.

Results and Discussion

Investigation using river water

The first trials were carried out using river water. The objective was to compare the corrosion rate achieved with just pH control and the improvement obtained using corrosion inhibitor. pH adjustment was accomplished using sodium hydroxide or lime. The buffer behavior of the samples made it necessary to follow pH for a while before stability has reached. Further pH corrections, along electrochemical measurements, could also be necessary, since the presence of humic acids could be responsible for this phenomenon. Results are displayed in Table 3 and Figure 5.

Table 3 - Corrosion rate obtained for river water and effect of pH control and corrosion inhibitor.

Studied System	Corrosion Rate (mm/yr)	pH	Efficiency of inhibition (%)
River Water	0.259	4.2	-
River Water + (D) (30 mg/L)	0.073	3.9	71.6
River Water + (B) (30 mg/L)	0.071	3.7	72.6
River Water + NaOH	0.054	7.1	79.0
River Water + Lime	0.024	7.1	90.9
River Water + NaOH + (D) (30 mg/L)	0.034	7.1	87.0
River Water + Lime + (D) (30 mg/L)	0.031	7.1	88.2
River Water + NaOH + (B) (30 mg/L)	0.045	7.1	82.6
River Water + Lime + (B) (30 mg/L)	0.064	7.1	75.4

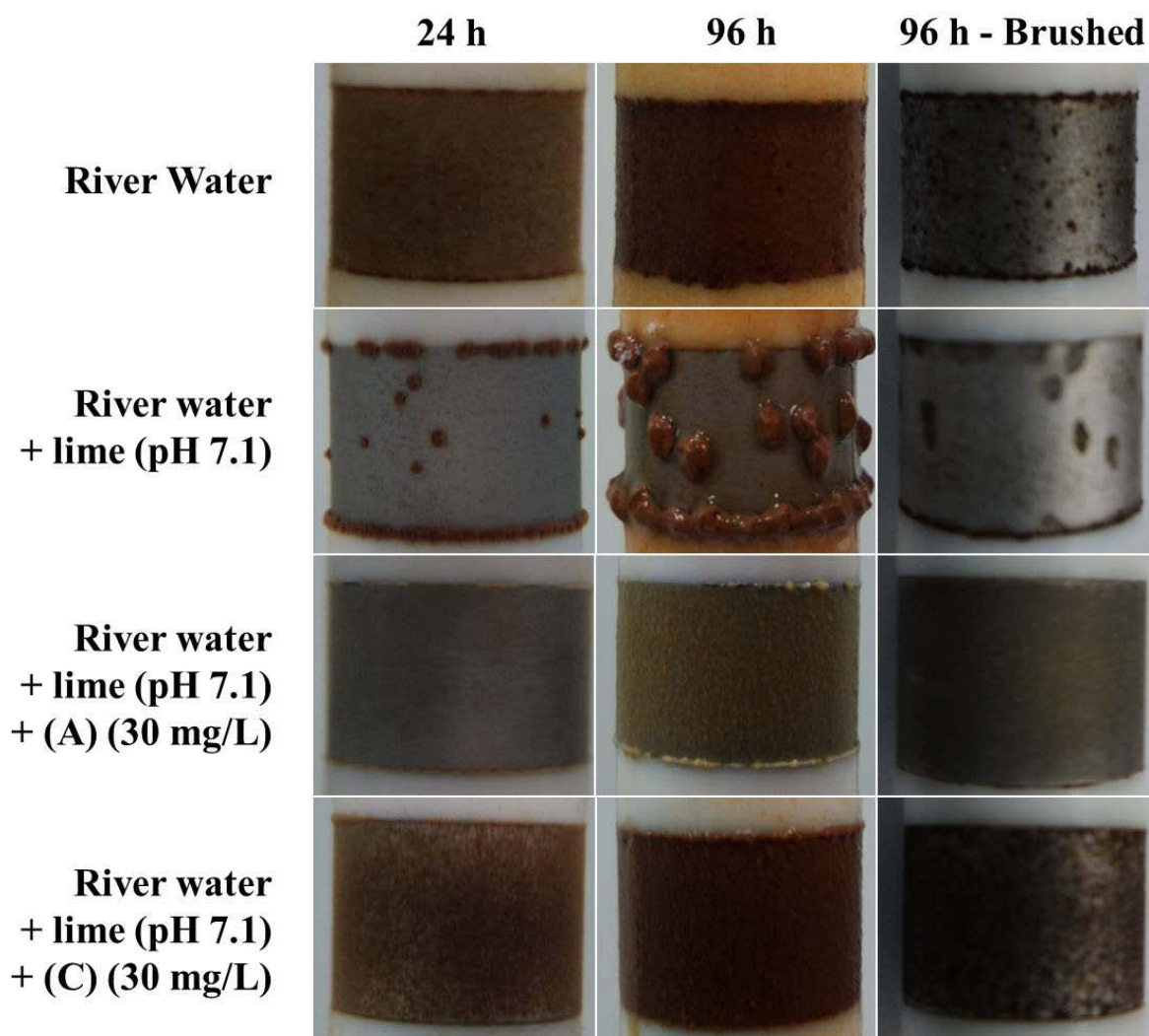


Figure 5 - Surface photographs for RCE coupons after 24 and 96 hours of experiment under different treatments in Paragominas river water.

Results shown in Table 3 clearly demonstrate that pH control can significantly lower the corrosion rate. Usable results are also obtained when only the corrosion inhibitors are used. The best improvements, however, are obtained when the pH control and corrosion inhibitor are used together.

An intriguing result was obtained using just a pH control with lime. The lower corrosion rate that was observed first during measurements led to additional trials in order to verify the experimental values. Values obtained in subsequent tests were 0.021 mm/year and 0.034 mm/year confirming previously obtained values. Despite this, the higher amount of corrosion products deposited upon the surface of the coupon and in the bottom of electrochemical cell raised strong doubts about the effectiveness of this condition to mitigate the corrosion process.

So far there is no irrefutable explanation for the low value observed for the corrosion rate in this instance, but, clearly, there is a heterogeneous non adherent film that has been formed on some spots on the metal's surface and probable localized corrosion is taking place. Figure 6 illustrates the aspect of electrodes after trials.

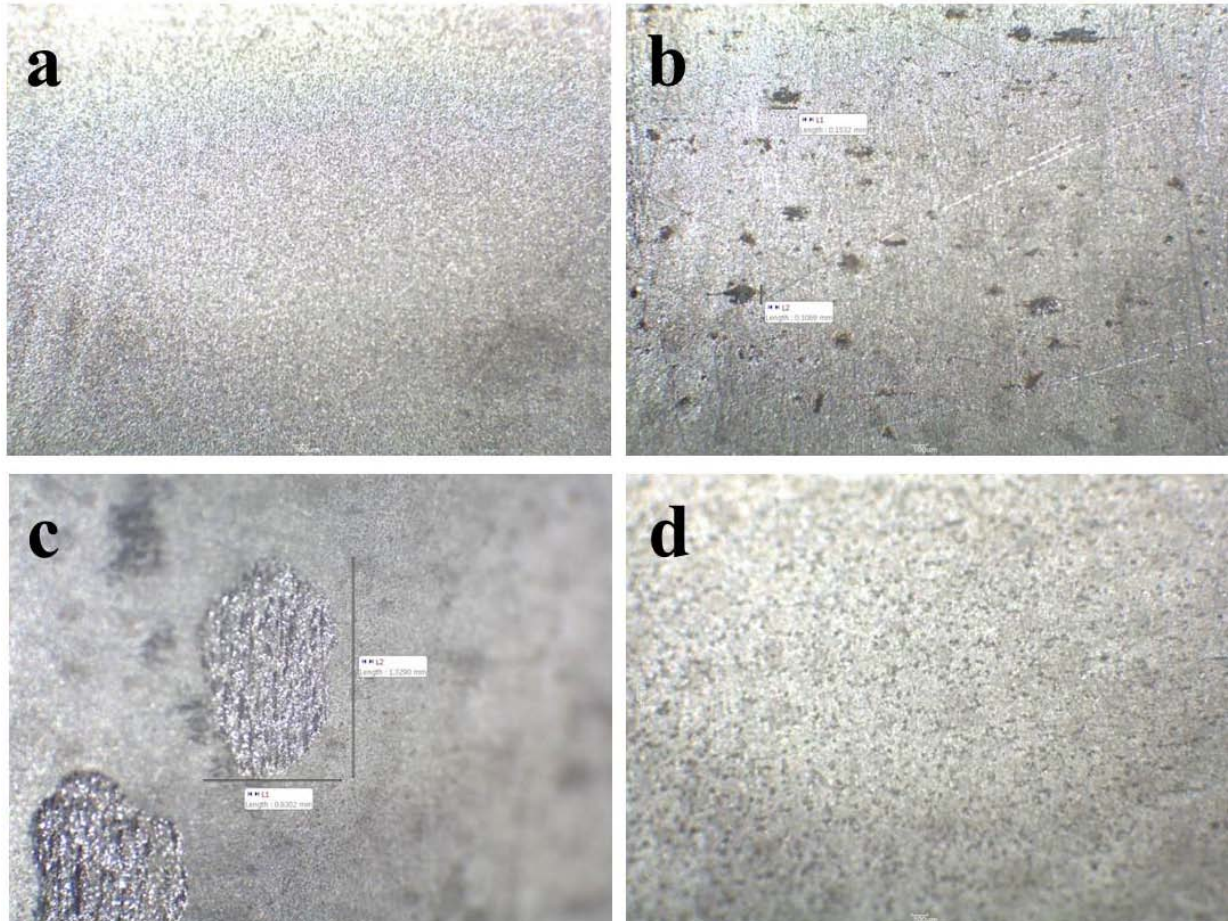


Figure 6 – Comparison between surface microscopies (40x magnification) of coupons under different conditions: (a) virgin electrode; (b) river water as is; (c) pH adjustment (7.1) with lime and (d) corrosion inhibitor (A) 30 mg/L along with pH adjustment (7.1) using lime.

It is important to observe that there is no abrasion effect taking place during this kind of trial. Bauxite pulp passing through the pipe can affect results by stripping the protective layers over the internal surface of the pipeline. However, from the point of view of simple corrosion mitigation, the use of a corrosion inhibitor along with pH control is a good strategy to ensure the integrity of the asset.

The influence of corrosion inhibitor concentration and the time it takes to form a protective coating (t_{eq}) were also studied, results are shown in Table 4. As expected, the longer the time to form a protective coating the better the protection promoted by the corrosion inhibitor. A trial using corrosion inhibitor (B) exhibited the same behavior – increasing the concentration of corrosion inhibitor enhances protection effectiveness of the tested products.

Table 4 - Corrosion rate obtained for river water and effect of corrosion inhibitor dosage and contact time.

Studied System	Corrosion Rate (mm/yr)	pH	Efficiency of inhibition (%)
River Water	0.259	4.2	-
River Water + Lime + (D) (30 mg/L, $t_{eq} = 3$ h)	0.031	7.1	88.2
River Water + Lime + (D) (100 mg/L, $t_{eq} = 3$ h)	0.020	7.1	92.4
River Water + Lime + (D) (100 mg/L, $t_{eq} = 12$ h)	0.009	7.1	96.5

These results suggest that a higher concentration of corrosion inhibitor can be used at the beginning of water treatment in order to promote a more uniform coverage of internal pipeline surface.

Different corrosion inhibitors were tested for this application. Selection criteria took into consideration the use of anodic, cathodic, and anodic/cathodic inhibitors. Results varying corrosion inhibitors are presented in Table 5.

Table 5 - Corrosion rate obtained for river water and effect of different corrosion inhibitors under pH control with lime. The corrosion inhibitor tested concentration was 30 mg/L.

Studied System	Corrosion Rate (mm/yr)	pH	Efficiency of inhibition (%)
River Water	0.259	4.2	-
River Water + Lime + (D)	0.031	7.1	88.2
River Water + Lime + (B)	0.064	7.1	75.4
River Water + Lime + (C)	0.027	7.1	89.6
River Water + Lime + (A)	0.018	7.1	93.1

According to laboratory trial results, the most effective product is (A), an anodic/cathodic inhibitor. In addition, (D) and (C) also promoted reasonable protection, above 88%.

Another aspect that should be taken into account when an anticorrosive treatment is applied at an industrial scale is the possibility of fluctuations in the composition of the medium due to seasonality. A water sample was taken during the dry season and subjected to corrosion tests using carbon steel coupons in order to verify the dosage of inhibitor necessary to avoid localized corrosion. The pH adjustment was accomplished using lime. Once again, buffer behavior of the samples made it necessary to track the pH for a while before stability was obtained. Results of the corrosion rate, along with the time, are shown on the Figure 7.

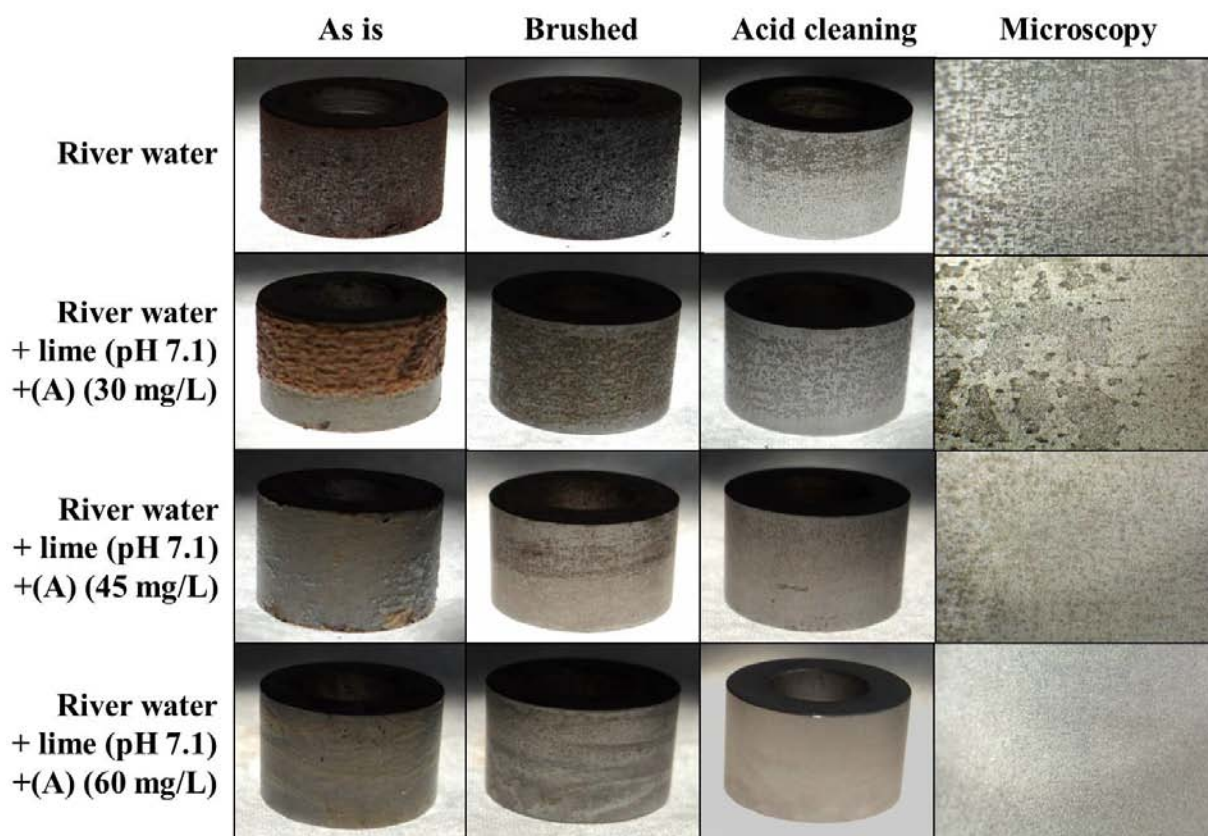


Figure 7 - Surface photographs and microscopy (40x magnification) for RCE coupons after 19 hours of experiment for different dosages of corrosion inhibitor (A) in Paragominas river water.

Analysis of the surface at the end of the trials using river water sampled during dry season indicates that for this sample it was necessary apply 60 mg/L of corrosion inhibitor which is double dosage than previously used.

Before this work, there was a previous study carried out by a pipeline manufacturer which recommends the use of sodium bisulfite as an oxygen scavenger to prevent corrosion. The study also recommends the use of a biocide to avoid under deposit corrosion caused by microorganisms. The last batch of trials was performed to confirm the role of sodium bisulfite, and investigate any possible synergetic effect with corrosion inhibitor and pH control. Results are shown in Table 6.

Table 6 - Corrosion rate obtained under nitrogen atmosphere and pH control with lime for river water treated with bisulfite and corrosion inhibitor (A).

Studied System	Corrosion Rate (mm/yr)	pH
River Water + Bisulfite (130 mg/L)	0.1437	3.64
River Water + Lime + Bisulfite	0.0624	7.12
River Water + Lime + Bisulfite + (A) (30 mg/L)	0.0151	7.02
River Water + Lime + Bisulfite + (A) (100 mg/L)	0.0073	7.06

The trial results have confirmed that the use of sodium bisulfite can reduce corrosion rate as indicated by the pipeline constructor; however, this is not, by far, the best option available. Simple pH adjustment along with the addition of an oxygen scavenger has a much more improved performance.

According to these results, the highest corrosion protection is achieved when all treatments are combined. The best corrosion inhibition program found to reduce corrosion in the laboratory trials was the simultaneous use of a corrosion inhibitor and oxygen scavenger along with pH control.

Investigation using pulp

The first trials using bauxite pulp were carried out using a sample shipped from Paragominas-PA that took three weeks to arrive at the laboratory. The pulp was vigorously agitated before use in order to avoid any discrepancy from the original sample. However, the pH of this pulp was 4.97, which is considerably lower than the usual value associated with Paragominas bauxite pulp, since the pH of fresh pulp usually is around 7.0. Despite this, it was decided to proceed with the sample as received in order to obtain a broader knowledge about this system.

The second set of experiments was carried out after the pulp pH was adjusted. Adjustment of pH was carried out using sodium hydroxide to reach a pH value of 7.0. Once again, the pulp was vigorously agitated before sampling.

The third and last set of experiments was carried out using fresh pulp from Paragominas without any previous treatment. This sample of pulp was shipped directly from Paragominas to the laboratory where it was promptly used. Some difference in original pH was observed, since this sample arrived with a pH of 6.5.

There results obtained for corrosion erosion (CE), corrosion (C), erosion (E), and calculated synergic process (SyCE) for each pulp sample are shown in Table 7.

Table 7 - Results for corrosion erosion (CE), corrosion (C), erosion (E), and calculated synergic process (SyCE) for different samples of bauxite pulp from Paragominas.

Pulp	CE (mm/yr)	E (mm/yr)	C (mm/yr)	SyCE (mm/yr)
pH 4.97, treated	7.52	4.15	0.14	3.23
pH 7.00, treated	2.25	2.00	0.05	0.20
pH 7.00, fresh	1.40	0.76	0.04	0.60

As observed in the results obtained for three test samples, higher corrosion rates were obtained at lower pH values, as expected. When the pH of treated pulp is increased to 7.0, all corrosion rates are reduced. This is not surprising where electrochemical corrosion (C) is concerned, but it is for erosion (E). One point that can explain such behavior is the change rheological properties of bauxite pulp. A reduction in viscosity for the same sample of pulp, which had its pH raised from 4.97 to 7.00, has been observed and, therefore, this lower viscosity pulp might be less abrasive to the metallic electrode under test conditions. However, it is important to remember that these values should be considered with some caution since localized corrosion was observed; the electrochemical corrosion rate calculated based on a Tafel plot may not be as accurate as desired.

A fresh sample of bauxite pulp was obtained from Paragominas. Trials with this sample should help to better characterize the system regarding to corrosion issues. As can be observed in Table 8, the electrochemical corrosion rate obtained for this sample, as well as the sample of old pulp with an adjusted pH 7.00, are very similar (i.e., 0.04 and 0.05 mm/year). These electrochemical corrosion values are in accordance with values obtained in using Paragomina's river water after a pH adjustment to 7.1.

On the other hand, corrosion erosion and erosion only measurements are lower using fresh pulp than those values obtained using treated pulp at pH 7.00. Once again, the rheological properties of pulp could be responsible for such differences since viscosity of samples were distinctly different. Viscosity of fresh pulp was apparently lower than treated the pulp at the same pH.

All studied samples presented similar behavior; erosion was always the major component in erosion corrosion process. In fact, the erosion process was at least 19 times higher than electrochemical corrosion, as was observed for fresh pulp, and reached up to 40 times the rate of corrosion for treated pulp at pH 7.00. These values provide strong evidence that the dominant component for the entire erosion process and this component will drive the behavior of this system.

Since localized corrosion was observed in trials using river water and pulp, it became clear that a Tafel plot would not be a suitable method to monitor the performance of anticorrosive additives in bauxite pulp; consequently, for these experiments, the preferred evaluation method was mass loss balance and visual surface analysis.

Performance evaluation of corrosion inhibitor (A) in bauxite pulp was accomplished by dosing this additive at 60 ppm and 300 ppm in fresh pulp. The mass loss data balance, as well surface visual analysis, was compared with the trial in absence of an anticorrosive. The results are shown in Table 8 and Figure 8.

Table 8 - Corrosion rates for bauxite pulp and effect of corrosion inhibitor (A).

Treatment	Corrosion rate (mm/yr)	Corrosion inhibition (%)
Untreated	2.78	-
(A) (60 mg/L)	2.36	15
(A) (300 mg/L)	2.22	20

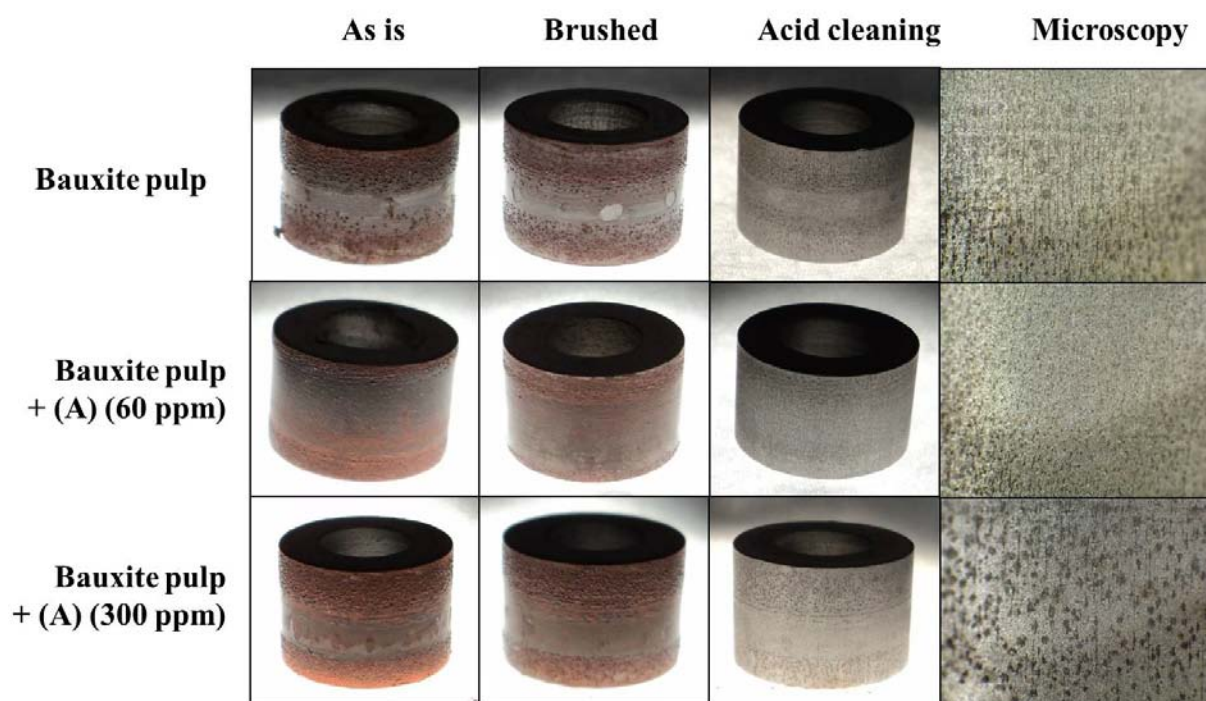


Figure 8 - Surface photographs and microscopy (40x magnification) for RCE coupons after 19 hours average of experiment for different dosages of corrosion inhibitor (A) in bauxite pulp.

Corrosion inhibitor (A) presented a modest corrosion inhibition, with the best performance achieved at 300 ppm, reaching only 20%. The coupon's surface shows clear signs of localized corrosion even in the presence of the inhibitor. The electrode surface presented similar characteristics observed for river water corrosion, but, in this case, some scratches were also present. This observation suggests that erosion may be part of the whole corrosion phenomenon.

Since the usual addition of corrosion inhibitor does not completely mitigate mass loss, it was necessary to adopt a different strategy in order to improve performance under bauxite pulp pumping conditions. Taking into account previous data already mentioned and surface

characteristics of electrodes at the end of the trials, there is strong evidence that supports the idea that erosion plays a major role in the corrosion process. One possibility for reducing this effect is the adoption of a pre-treatment procedure to prevent both corrosion and erosion.

In order to verify this hypothesis, a metallic coupon was pre-treated under particular conditions currently under patent submission process and then submitted to corrosion trials using bauxite pulp with corrosion inhibitor (A), about 60 ppm after pH adjustment to 7.0-7.2 with $\text{Ca}(\text{OH})_2$. The test results were then compared to the results obtained earlier for untreated pulp, under cathodic protection conditions. Results obtained for untreated pulp cover the effect of chemical corrosion, erosion, and synergy (if any exists). While results obtained under cathodic protection conditions should eliminate chemical corrosion and, therefore, synergy. Results obtained after pre-treat the electrode are shown in Table 9 and Figure 9.

Table 9 - Corrosion rates for bauxite pulp and effect of corrosion inhibitor (A) after pre-treatment.

Treatment	Corrosion rate (mm/yr)	Corrosion inhibition (%)
Untreated	2.78	-
Pre-treatment and (A) (60 mg/L)	1.42	49*
Cathodic polarization	1.05	62

* Average of two trials, 46% and 52%, respectively.

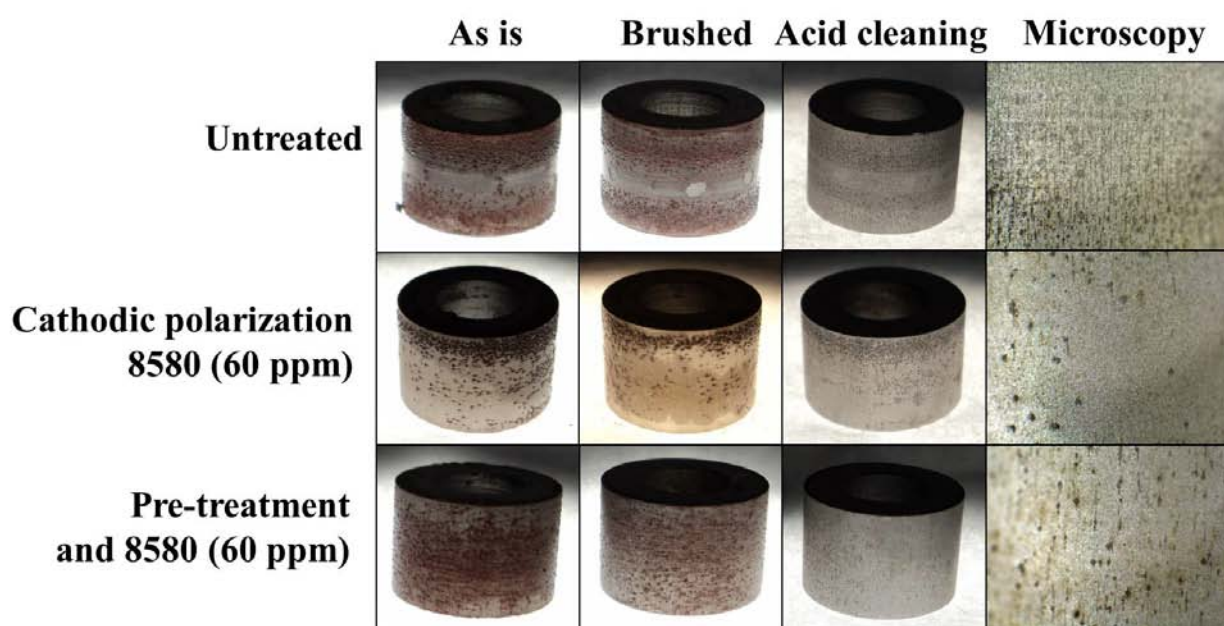


Figure 9 - Comparison between surface photographs and microscopy (40x magnification) for RCE coupons after 19 hours of experiment using corrosion inhibitor (A) in bauxite pulp.

Results obtained from pre-treat the metal surface before the application of corrosion inhibitor (A) in the bauxite pulp clearly reduces the total corrosion. The level of corrosion inhibition achieved was 49% (average of two runs 46% and 52%, respectively). Surface analysis corroborates this evidence. The pre-treated surface was less affected than the untreated sample and is comparable with cathodic polarization. The results obtained for cathodic polarization also suggests the erosion was still taking place for this pulp sample.

All results presented in this report are valid so long as the rheological and chemical characteristics of the pulp and the water are maintained. At industrial level, the results may vary due regular process fluctuations, such as pulp granulometry, large size particles in pulp, rain seasonality, etc.

These data is valid for laboratory scale and must be confirmed at pilot or industrial scale in order to be validated and optimized.

Conclusions

A study was carried out that tracked the corrosion properties of river water and corrosion-erosion of bauxite slurry that are transported through a carbon steel pipeline from Paragominas-PA to Barcarena-PA along 242.8 km.

For river water, it was possible to identify the occurrence of localized corrosion. According to obtained results, the highest corrosion protection is achieved with the simultaneous use of a corrosion inhibitor, oxygen scavenger along with pH control. The use of corrosion inhibitor (A) (60 mg/L) at a controlled pH (7.0-7.2 using lime) presented satisfactory corrosion inhibition. This combination was able to reduce both the corrosion rate measured by LPR and localized corrosion according the surface analysis.

For pulp, it was possible to identify the occurrence of corrosion (C), erosion (E), and synergistic effect (SyCE). Results suggest that E is the main component of corrosive process, and SyCE along with C plays a secondary role. The use of corrosion inhibitors that only act over SyCE and C do not sufficiently reduce the corrosion process. In order to have a significant corrosion inhibition in the bauxite pulp medium, it was necessary to pre-treat the metal surface. The corrosion inhibition in bauxite pulp using corrosion inhibitor (A) after pre-treatment was 49%. This is comparable to cathodic protection according to laboratory data.

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