Technical Note

International Journal of ISSI, Vol. 19(2022), No. 1, pp. 81-85

Investigation on the Water Index Stability in Direct Reduced Iron (DRI) Plant-ARFA Iron and Steel Company

A. Moradian*[1], M. Azizian Sharifabad[2]

[1] Member of the Research and development department, ARFA Iron & Steel Company
[2] Process Engineer in Abtin Steel Technology Company(Astec)

Abstract

Stability and corrosion indices can be used to study the physical and chemical properties of water consumption in industry. In this study, the results of monitoring the machinery and process water distribution circuits in the ARFA DRI plant by using Langelier saturation, Aggressiveness, Ryznar and, Puckorius scaling indices along with corrosion coupon data are investigated. All of data was taken about 10 months. Also all samples examined based on standard methods and indices were calculated by equations presented in literature. The results of Langelier saturation and Aggressiveness indices showed that there is a slight sedimentation tendency in the process and a slight corrosion leaning in the machinery water circuits. Existence of minor corrosion in the machinery water circuit is crucial to avoid the possibility of scale formation on the lobes of compressors as a very expensive important equipment. The calculated indices of the process water showed slight leaning to sedimentation of dissolved solids therefore it is treated for inhibiting scale formation. Also, the corrosion coupons that were used periodically confirmed the above results.

Keywords : Langelier saturation index, Aggressiveness index, Ryznar index, Puckorius Scaling Index.

1. Introduction

Minimizing shutting down and consequently continuing the production process for a longer operational time (considering the optimization of the fixed and variable costs) is a great triumph. Water treatment and distribution system is a crucial part of a direct reduced iron(DRI). Shutting down plants to repair and replace damaged pipes due to corrosion and sedimentation, results in higher costs which is a great problem have always been along with the water distribution systems. Corrosion may have various biological, design and also operational reasons. For example, disregarding the standard reduction potential of metals in the electrochemical series table as a design reason and also temperature, total dissolved solids(TDS), etc. as operational reasons could be considered [1,2].

The most important agents causing corrosion are Cl^-, O_3, SO_4^{2-}, Fe^{2+} and low pH [3]. Also, the combination of positive metal ions with carbonate, bicarbonate, or silica can stick on the surface as a deposition. Furthermore, it reduces the thermal efficiency and in long time set out sub-sediment corrosion. Sediment in water and wastewater distribution lines increases the pressure drop and reduces the pipe life due to sub-sediment corrosion. On the other hand, sedimentation in heat exchangers, boilers and other equipment noticeably increases the energy cost due to a sharp decrement in the heat transfer coefficient. According to limited capacity of water for dissolved solids, increasing the solute, precipitate the excess material as insoluble compounds. This is called the water satura-

**Corresponding author*
Email: Moradian.1363@gmail.com
Address:ARFA Iron and Steel Company, Chadormalu Industrial Complex, Ardakan, Yazd, Iran, postal code 8955165215
1. Ph.D
2. B. Sc

tion point which depends on the properties of water [2,3].

Therefore, in order to suppress corrosion and sedimentation, could be using inhibitors and regulation of calcium hardness or alkalinity and also pH. In this regard, monitoring and controlling the water sedimentation and corrosion potential to reduce the costs is indispensable.

Unfortunately, it is not practical by considering pH only to judge the tendency of sedimentation or corrosion of water. This is related to the complexity of water chemistry and the possibility of different compounds of conversion in the aqueous environment and thus affecting the pH . Hence, in order to minimize the idle time of the plant and consequently related costs, it is necessary to consider the corrosion and water deposition simultaneously which is presented by the water stability indices. The most important and common stability indices are Langelier saturation index(LSI), Aggressiveness index(AI), Ryznar index(RI) and Puckorius Scaling Index (PSI) [4]. In order to have a better vision of water conditions which results in enhanced corrosion control, should use disparate corrosion and stability indices simultaneously [5]. Keeping the indices in the appropriate range results in better heat transfer coefficient in the heat exchangers and lower pressure drop in the pipes which results in enhanced operational conditions. There are several studies about water stability indices. Abbasnia et al. [6], used LSI and AI to evaluate the groundwater stability conditions. Eslami et al. [4], by investigation of the urban water, samples observed the corrosive properties of the water despite the allowable range of pH and temperature, which has consistent with the stability indices results. There are several studies on stability indices, which is mainly focused on the surface and groundwater in nature or urban water [4,6–8], therefore one of the shortcomings of studies is the absence of studies on the indices application in industry.

Our goal in this study is to retain the stability indices in the acceptable range by adjusting the pH and using anti-fouling and corrosion inhibitors. We are looking the minimizing the idle time of the plant by increasing the efficiency of the water treatment using the best range of indices in order to avoid damage to precious equipment such as compressors and heat exchangers.

2. Material & method

2.1. Sampling

Sampling was done for 10 months, once per day for 2 types of water (process and machinery) used in the DRI plant. The parameters such as turbidity, TDS and electrical conductivity (EC) were determined according to standard methods. Also, pH and temperature values of each sample were measured in-situ [1].

2.2. Corrosion and deposition coupons

In order to examine the water distribution system of the DRI plant, coupons were used made of material pipe installed in the plant. The coupons were removed after a period between 40-60 days, and tested by the techniques given in standard methods [1].

2.3. Indices Calculation

The stability indices values were calculated based on the following equations. Due to the results which showed low mean absolute relative residue (MARR) and also it is useful to display all data in one figure, arithmetic mean values for each month have been reported. The negative LSI of water is assigned to corrosive and positive values indicate the tendency to sedimentation. The zero value of this parameter shows stability of the water sample. The LSI is a model that shows the degree of water saturation conditions relative to calcium carbonate by using the pH, calcium hardness, temperature and alkalinity as major variables. The RI shows the relationship between calcium carbonate saturation and precipitated layer formation quantitatively. In other words, LSI and RI show the difference between actual and saturated pH when the sample is saturated by calcium carbonate. There are equations 1 to 10 which could be used to calculate the indices [9].

$$A = (-1 + \log(TDS))/10 \quad \text{Eq. (1)}$$

$$B = -13.12\log(273 + ℃) + 34.55 \quad \text{Eq. (2)}$$

$$C = \log(Ca^{2+}) - 0.4 \quad \text{Eq. (3)}$$

$$D = \log(Alk_M) \quad \text{Eq. (4)}$$

$$pH_s = (9.3 + A + B) - (C + D) \quad \text{Eq. (5)}$$

$$pH_{eq} = 1.465\log(Alk_M) + 4.54 \quad \text{Eq. (6)}$$

$$LI = pH - pH_s \quad \text{Eq. (7)}$$

$$RI = 2pH_s - pH \quad \text{Eq. (8)}$$

$$AI = pH + \log((Ca - H) \times Alk_M) \quad \text{Eq. (9)}$$

$$PI = 2pH_s - \mathrm{pH}_{eq} \quad \text{Eq. (10)}$$

In the above formulas A, B, C and D are the coefficients of TDS in mg/lit, temperature in °C, calcium hardness and total alkalinity in mg $CaCO_3$/lit, respectively.

The RI was obtained by experimental observations of corrosion rate and layer formation in iron pipes. For values calculated higher than 7, water is corrosive and for AI less than 6, water tends to precipitation and it is considered neutral for the AI between the value of 6 and 7. The AI is more effective in asbestos cement pipes. The

effect of calcium concentration, alkalinity and pH on the tendency of corrosion and sedimentation of water can be investigated. The PSI shows the buffering capacity of water and expresses the maximum amount of sedimentation that indicates the balance in the characteristics of water. This index is experimental and the numerical values obtained from its relation are the same as the RI. For a PSI value higher than 6, the water is corrosive, and for values, less than 6, dissolved solids in water have a tendency to precipitation. The above explanations could be summarized in Table 1 [6,7,10–12].

2.4. Chemicals

Cooling water stabilizer was used from the EN-2101 supplied by Energy Semnan Chemical Company that is a mixture of highly active organic and inorganic corrosion inhibitors for pipes with a 1440 kg/m^3 density and a pH of about 12. Also, in order to prevent microbial contamination and water flocculation in the clarifier; biocide and flocculent with the EN-262 and EN-AP9020, were supplied by Energy Semnan Chemical Company.

3. Results and Discussion

3.1. Corrosion and stability indices

There are two main approaches that could be considered about the types of water: process water is preferred slightly to sedimentation and machinery water slightly to a corrosive state. The compressors are the most expensive equipment using water, therefore it is necessary that the machinery water tends to be corrosive to avoid the possibility of sediment formation in the inner compressor casing and lobes. Specifically, for machinery water, the values of the LSI indicate that leaning to corrosion property, which is confirmed by the values of the aggressive index. Figure 1 is shown the calculated indices which are based on equations 1-10.

Table 1. Water indices various states.

Index	value	Water state
LSI	LSI>0	Saturated
	LSI=0	Neutral
	LSI<0	Corrosive
RI	RI<6	Leaning to sediment
	6<RI<7	Neutral
	7<RI	Corrosive
PSI	PSI<6	Leaning to sediment
	PSI>6	Leaning to aggressive
AI	AI<10	Intensively aggressive
	10<AI<12	Moderately aggressive
	AI>12	saturated

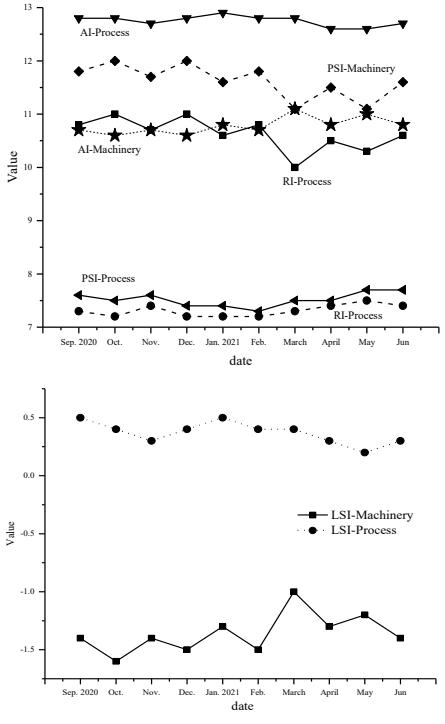

Fig. 1. The value of calculated indices time on stream for water distribution system.

The machinery water is adjusted to a corrosive state to prevent the possibility of sediment formation, and on the other hand, anti-corrosion materials are used to control water corrosion properties. The phosphate concentration of the inhibitor was optimized in different amounts and adjusted in the machinery water distribution system. However, it should be noted that the pipes roughness could prevent the formation of a homogeneous and integrated protective layer. In the long time, it may cause pipes perforation and the entry of iron ions II (corrosion agents) into the stream which is unfavorable.

Because in most cases, the pH value in this study is less than or equal to 8, the PSI is not a good criteria for judgement about sedimentation or corrosion, however its values have been calculated and reported [10].

In the case of the RI, the results of the AI and LSI based on the corrosion properties of machinery water are also confirmed. It should be noted that in the case of process water, it is preferable to water deposition properties. This may result in operation continuously over the years. The data in Tables 2 and 3, taking into account the performance of the system over a period of nearly ten years without a shutting-down of the reformer, is evidence of this claim. As can be seen from Table 2, the slightly positive LSI for process water, indicates the potential of water to precipitation [6,7,10].

3.2. Corrosion coupon results

Table 3 shows the results related to machinery water coupons. It can be seen that the MPY parameter is relatively high which is related to the corrosion property of water that has consistency with the stability indices listed in Table 2.

4. Conclusion

According to the results of experiments and studies, it was found that the machinery water circuit has a slight corrosion property and the process water has a small deposition property. Therefore, it is necessary to use inhibitors and anti-corrosion agents in the machinery distribution system. Also, process water which leaning to sedimentation of dissolved solids, must be carefully monitored for scale formation. The existence of slight corrosion property of the machinery water is very important to avoid the possibility of scale formation on the compressor lobes. Suitable water treatment and operation lead to continuous production for a remarkable period of nearly 10 years.

Acknowledgment

This work was supported by ARFA iron & steel company and ABTIN Steel Technology Company(ASTEC), Ardakan, Yazd, Iran.

Table 2. The Values of LSI, PSI, AI and RI indices for process and machinery water.

	RI		A.I		PSI		LSI	
	Machinery	Process	Machinery	Process	Machinery	Process	Machinery	Process
September 2020	10.8	7.3	10.7	12.8	11.8	7.6	-1.4	0.5*
October	11.0	7.2	10.6	12.8	12.0	7.5	-1.6	0.4
November	10.7	7.4	10.7	12.7	11.7	7.6	-1.4	0.3
December	11.0	7.2	10.6	12.8	12.0	7.4	-1.5	0.4
January 2021	10.6	7.2	10.8	12.9	11.6	7.4	-1.3	0.5
February	10.8	7.2	10.7	12.8	11.8	7.3	-1.5	0.4
March	10.0	7.3	11.1	12.8	11.1	7.5	-1.0	0.4
April	10.5	7.4	10.8	12.6	11.5	7.5	-1.3	0.3
May	10.3	7.5	11.0	12.6	11.1	7.7	-1.2	0.2
Jun	10.6	7.4	10.8	12.7	11.6	7.7	-1.4	0.3

*The Mean Absolute Relative Residue (MARR)< 5% in all cases

Table 3. The corrosion coupon in machinery water circuit.

Time period(day)	MPY
62	1.52
68	1.01
60	1.81
58	1.52
103	1.30

References

[1] W. G. Walter, Standard methods for the examination of water and wastewater (11th ed.). American Journal of Public Health and the Nations Health vol. 51 (1961).
[2] A. Reyes, et al: Int. Biodeterior. Biodegrad. 61(2008), 135.
[3] J. E. Singley: J. Am. Water Work. Assoc. 73(1981), 579.
[4] F. Eslami, et al: Desalin. Water Treat. 179(2020), 19.
[5] K. Vairavamoorthy, et al: Environ. Model. Softw. 22(2007), 951.
[6] A. Abbasnia, et al. : Data Br. 16(2018), 182.
[7] M. Mirzabeygi, et al. : Desalin. Water Treat. 57(2016), 25918.
[8] V. Alipour, et al: J. Water Health 13(2015), 203.
[9] M. Shah, et al: Groundw. Sustain. Dev. 12(2021), 100535.
[10] M. F. Davil, et al. : World Appl Sci J 7(2009), 11.
[11] J. C. Egbueri: Environ. Dev. Sustain. 23(2021), 591.
[12] W. F. Langelier: J. Am. Water Works Assoc. 110(2018), 68.