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Acid conductivity monitoring at demineralization plant: an important performance parameter

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ABSTRACT

The acid conductivity measurement is universally adopted for the monitoring of water-steam cycles as it can detect low level of contaminant on a continuous basis. This paper discusses the monitoring of acid conductivity at the inlet of the demineralization plant for assessing the output of the ion exchangers. An observation of data collected over a period of 14 months shows a strong correlation between output between regeneration (OBR) and acid conductivity. OBR is inversely proportional to acid conductivity with a correlation coefficient of –0.907. A drastic change in acid conductivity was observed when water level of the freshwater reservoir went below a depth of 3.8 m. The present study was undertaken with the intention to develop a simple and rugged method to measure the performance of ion exchangers in service and to find out the root cause of change in water quality after the freshwater reservoir level drops below a certain depth.

Keywords: Cation exchange conductivity; Acid; Ion-exchange resin; Demineralization

1. Introduction

The acid conductivity of make-up, feed water and condensate is the most important single chemical measurement parameter used in steam generating power plants. There are many reasons for the preference for this method. The ASTM standard [1] mentions: “The equipment for this test method can be considered more rugged and adaptable to installation under plant operating than the more accurate laboratory methods such as ion chromatography and atomic absorption.” In boiler water sample, the acid conductivity model assumes the sample is pure water contaminated with hydrochloric acid. The correction algorithm is more complicated than the high purity water correction because the contribution of water to the overall conductivity depends on the amount of acid present. Hydrochloric acid suppresses the dissociation of water, causing its contribution to the total conductivity to change as the concentration of hydrochloric acid changes [2].

Acid conductivity measurement has focussed specially on boiler water samples in steam generating power plants, this background as well as continuing work provide valuable information in demineralization plant from clarified and cation exchanged conductivity measurement.

Present study at Vidarbha Industries Power Ltd (VIPL) has been undertaken to develop a simple and rugged method to measure the performance of the ion exchangers in service, to understand the factors for frequent change in output between regeneration (OBR), and to find out the root cause of change in water quality after the freshwater reservoir level drops below a certain depth.

2. VIPL experience

2.1. Water treatment process and history of reservoir

(a) Clarified water received at open storage reservoir from water treatment plant through pumping system of Maharashtra State Industrial Development Corporation. A government body for industrial development and have water treatment plant for industries. Source of the water is freshwater from Wadgaon Dam. VIPL’s storage reservoir has capacity

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of 75,000 $m^3 \times 2 = 1.5$ lac m^3. Depth of the reservoir is 5 meter and age is 4 years. Water from this reservoir is used for cooling, service water, drinking after processing and demineralization. At the time of designing, it was thought that no treatment is required as its treated clarified water. Our reservoir is not covered and open to sky; as a natural process, vegetation started growing in the reservoir and now it become dense up to 3.8-m depth.

(b) VIPL has introduced chlorination at reservoir sump as pre-chlorination from the beginning; chlorinated water is feed to potable and for demineralization system. Less than 0.2 ppm chlorine is maintained and this residual chlorine is removed before it reaches to ion exchange process.

(c) Demineralization is done by ion exchange process. The ion exchangers stream at VIPL comprises strong acid cation (SAC), degasser, strong base anion (SBA) in series and a mixed bed and ultrafiltration for colloidal silica and organics. Water from reservoir passes through exchangers and get completely demineralized.

2.2. Observation at DM plant

Design parameters required for discussion is considered and shown in Table 1. It was observed that performance of ion exchanger is varying with the season. In India, we have three major seasons, and June to September is considered as rainy season, October to February is considered as winter and March to May is considered as summer. Ionic load and pH is high in summer and lowest in rainy season. It is observed that OBR diminished suddenly in the summer season; on investigating, it was found that ion load varies with low margin but acid conductivity varies substantially. It was also observed that OBR diminishes with drop in reservoir level below 3.8-m depth.

Table 1
Design parameters of the DM plant based on input water quality analyzed in the year 2008

Parameters	Unit	Value
pH	–	7.6
Electrical conductivity	µS cm	360
Total cation	ppm as $CaCO_3$	217
OBR (SAC)	m^3	900

Table 2
Specific electrical conductivity of electrolytes

Salt concentration	Nacl µΩ cm	NaOH µΩ cm	H_2SO_4 µΩ cm	HCl µΩ cm	CO_2 µΩ cm
1 mg L	2.2	6.2	8.8	11.7	1.2
3 mg L	6.5	18.4	26.1	35.0	1.9

2.3. Acid conductivity measurement

The electrical conductivity is used to measure the concentration of mineral salts in solution. Electrical conductivity depends on the degree to which these salts dissociate

Table 3
Performance of DM plant as OBR at different ionic load and cation exchange conductivity

S. No	Month and year	Average Ionic load mg L as $CaCo_3$	Average strong acid cation exchange conductivity µS cm	Average OBR (SAC) µS cm	Correlation coefficient
1	Apr-14	248	675	801	
2	May-14	257	710	772	
3	Jun-14	251	801	787	
4	Jul-14	239	743	810	
5	Aug-14	212	565	939	
6	Sep-14	209	540	963	
7	Oct-14	209	557	953	
8	Nov-14	210	562	932	−0.907
9	Dec-14	212	607	921	
10	Jan-15	216	599	911	
11	Feb-15	232	623	855	
12	Mar-15	240	727	809	
13	Apr-15	269	780	739	
14	May-15	249	776	787	
15	Jun-15	245	851	795	

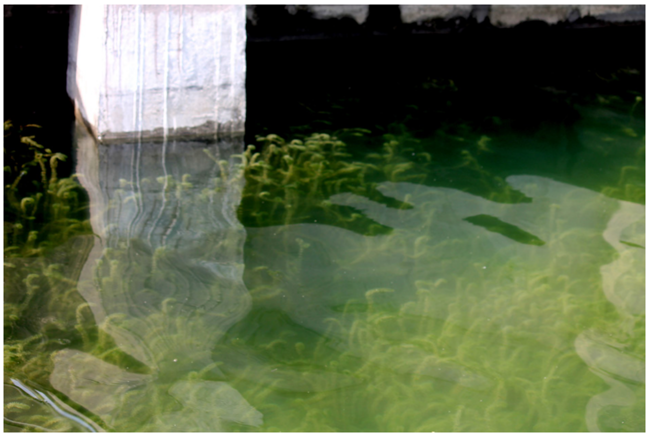

Fig. 1. Vegetation at VIPL reservoir up to 3.8 meter depth.

into ions. This effect is more pronounced when the sample passes through an acid cation exchanger that transforms anions into the corresponding acids. The specific electrical conductivity of electrolytes is shown in Table 2 [3].

From the above-mentioned data, it is concluded that the acid conductivity value is difficult to predict as the clarified water from reservoir contains a variable amount of cations and anions. But Hydrogen ion is seven times as conductive as other ions; therefore, acid conductivity gives a higher value based on cations in input clarified water irrespective of anions like sulfate, chloride and nitrates. Contaminant corrosive salts are converted to their respective acids which are typically three times as conductive as the original salt because of the highly conductive hydrogen ion. The simplicity and detection sensitivity have made cation conductivity the most widely used measure of contamination in the cycle [4].

Design Ionic load of the demineralization system is 217 mg L and specific conductivity is 360–370 µS cm which corresponds to cation exchange conductivity is around 600–650 µS cm.

2.4. Water quality in the reservoir

It was observed that ionic load and OBR are inversely proportional, which is a known fact; from these data, it is observed that cationic conductivity shows very important relation, which is also inversely proportional; Moreover, it is very convenient tool for the DM plant operator to judge the OBR output. The correlation coefficient is –0.907, which indicates that there is strong correlation. The parameters are shown in Table 3. It was observed that our water quality degrades (ionic load increases) whenever water level was goes below 3.8 m of the reservoir. The reason of high ionic load is attributed to high vegetation which was identified as *Hydrilla Verticillata*. It was observed that reservoir was infested with this Aquatic plant. This plant is slender, branched leafy submerged aquatic weed that grows up to 45 cm in length and has fibrous roots. It grows as dense mass in ponds and lakes all over India. Gnanasekaran and Wasekarhas investigated the change in aquatic pH with the growth of *Hydrilla Verticillata*. The pH of the natural water

Table 4
Specific conductivity, cation exchange conductivity and reservoir level

Date	Specific water conductivity in µS cm	Cation exchange conductivity in µS Cm	Reservoir level in meters
02.04.15	472	740	3.65
04.04.15	470	990	3.54
08.04.15	469	958	3.45
10.04.15	473	974	3.52
12.04.15	480	1018	3.25
14.04.15	473	834	3.85
16.04.15	460	737	4.2
18.04.15	463	710	4.26
20.04.15	461	720	4.34
22.04.15	456	720	4.4
24.04.15	461	713	4.28
26.04.15	462	723	4.32
28.04.15	460	710	4.24
29.04.15	453	710	4.05
30.04.15	440	719	3.8
Average	465.21	804.5	3.95
01.05.15	465	720	3.85
02.05.15	459	717	3.89
04.05.15	489	857	3.71
06.05.15	466	781	3.59
08.05.15	471	898	3.82
09.05.15	470	889	3.6
11.05.15	487	860	3.7
13.05.15	479	983	3.4
15.05.15.	472	764	3.59
17.05.15	471	855	3.95
19.05.15	477	761	4.16
20.05.15	468	736	4.29
21.05.15	467	760	4.1
23.05.15	455	765	4.37
25.05.15	461	750	4.63
27.05.15	469	765	4.66
29.05.15	469	769	4.51
Average	470.29	801.76	3.98
02.06.15	464	757	4.27
04.06.15	474	776	4.28
06.06.15	468	871	4.4
08.06.15	490	960	3.8
10.06.15	460	828	3.76
12.06.15	565	910	3.6
13.06.15	607	1091	3.65
14.06.15	596	965	3.9
15.0 6.15	481	863	4.25
18.06.15	476	827	4.9
22.06.15	460	810	4.84
25.06.15	450	772	4.98
28.06.15	430	765	4.72
29.06.15	411	716	4.85
Average	488	850.78	4.3

Table 5
Correlation coefficient between specific conductivity and reservoir level and CEC and reservoir level of month April 2015 to June 2015

Specific conductivity µS cm	Reservoir level	Correlation coefficient	Cation exchange conductivity µS cm	Reservoir level	Correlation coefficient
465.21	3.95		804.50	3.95	
470.29	3.98	–0.99	801.76	3.98	–0.99
488	4.3		850.78	4.3	

was 7.5, when analyzed for Ca^{2+}, Mg^{2+}, K^+, Na^+ by AAS their contents were 2, 9.7, 43 and 50 µg ml, respectively. After keeping the plant in it over a period of 6 h at a light intensity of about 46.5 lm m^2, the pH had increased to 8.87. While the amounts of Ca^{2+}, Mg^{2+}, K^+ is same, an increase in the amount of sodium to 61 µg ml was observed. Hence, the rise in pH is attributed to sodium hydroxide secreted by the plant [5]. This plant is major contributor for high pH, and increase in hardness might be the effect of algae and other vegetation and silt or dust, ash accumulated in the last couple of years which gets deposited, and freshwater or rain water is only diluting this reservoir water.

It was observed that total hardness of VIPL reservoir water increases from 140 mg L as $CaCO_3$ in rainy season and reaches up to 180 mg L as $CaCO_3$ when reservoir level was below 3.8 m in summer season. This indicates that there is contribution of all cations, which replaces hydrogen from cation exchanger and makes contribution in acid conductivity. With this observation, the study has started from April 2015 to record the water level of the reservoir and cation conductivity; three months data from April 2015 to June 2015 have shown that there is increase in specific conductivity and acid conductivity with the decrease in reservoir level with good correlation factor with 0.99. This contamination in reservoir has helped us in providing clue for real-time monitoring and predicting DM plant performance and vis-à-vis chemical consumption; data are shown in Tables 4 and 5.

Cation or acid conductivity is dominated by the hydrogen ion which is about seven times as conductive as other ions (except hydroxide, which has a suppressed concentration at the low pH in the sample at this point), so it makes little difference from just what the mix of anions is among chlorides, bicarbonates, sulfates or others [4].

3. Conclusion

High correlation coefficient between acid conductivity and OBR indicates that they are interrelated. Monitoring of acid conductivity at demineralization plant can give an immediate picture of any change in input water quality with respect to its ionic load as conductivity is linear with concentration. Moreover, it is an easy tool for the operator to assess the change in input water quality and to predict the output of the ion exchanger at the DM plant with the measurement of a single parameter. The reason for high ionic load and acid conductivity at water levels in the reservoir below 3.8-m depth is due to the high growth of *Hydrilla Verticillata*, silt and algae. The acid conductivity showed decreasing trends when the reservoir was refilled with 1 m (to reservoir level 4.8 m) or 30,000 m^3 of freshwater. As a result, it is also concluded that *Hydrilla Verticillata*, algae and the silt deposited in the reservoir have a high impact on the water quality with respect to its ionic load and the performance of the DM plant.

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