Near-zero effluent discharge from an ion-exchange regeneration process by using a brine-recovery system and fly-ash filter bed

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Abstract  The double sulphitation process has been used successfully by a majority of factories in the Indian sugar industry. After the development of the DRPIE (defco remelt phospho-flotation ion exchange) process, we, like most sugar factories, looked to change to this process. We hesitated due to the generation of more effluent from the ion-exchange columns. To solve this problem, we installed a brine-recovery system (based on double-stage nanofiltration) for recovery of the brine and reuse to successfully regenerate our ion-exchange resin. From this process we can recover 80% of the brine; the other 20% is sent to a fly-ash multi-bed filter bed to recover another 15% of the brine as permeate brine. We can now recover 95% of the brine from the spent brine and have reduced the load on the effluent treatment plant. The approximate quantity of this saved brine is 43 m$^3$/day and results in a saving in salt of around 3,000 kg/day at the full crush rate.

Key words  Zero effluent discharge, brine recovery, fly-ash filter, ion exchange

INTRODUCTION

The double sulphitation process has been used successfully by a majority of Indian sugar factories. Following the development of the DRPIE (defco remelt phospho-flotation ion exchange) process, most sugar factories are looking to adopt this process but hesitate due to the generation of more effluent from the ion-exchange columns. To solve this problem, we installed a brine-recovery system (based on double-stage nanofiltration) for the recovery and reuse of brine to successfully regenerate our ion-exchange resin.

BRINE-RECOVERY SYSTEM

Our installed capacity of the refinery is 650 t/day and our brine-recovery system capacity is 6.5 m$^3$/h. With this combination our rejected brine quantity remains around 1.3 m$^3$/h. Table 1 gives details of the brine flows, and Figure 1 shows the change in colour from the feed brine to the final permeate.

Table 1. Laboratory analyses of the brine flows through the brine-recovery system.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Flow rate m$^3$/h</th>
<th>pH</th>
<th>Turbidity NTU</th>
<th>Conductivity mS/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spent brine</td>
<td>6.5</td>
<td>11.00-11.5</td>
<td>30-40</td>
<td>7200-7800</td>
</tr>
<tr>
<td>First permeate</td>
<td>4.5</td>
<td>7-8</td>
<td>0.2-0.5</td>
<td>5700-6000</td>
</tr>
<tr>
<td>First retentate</td>
<td>2</td>
<td>7-8</td>
<td>40-50</td>
<td>6500-7000</td>
</tr>
<tr>
<td>Second permeate</td>
<td>0.7</td>
<td>7-7.5</td>
<td>7-10</td>
<td>5500-6000</td>
</tr>
<tr>
<td>Final retentate</td>
<td>1.3</td>
<td>7-8</td>
<td>70-75</td>
<td>6000-7000</td>
</tr>
</tbody>
</table>

Figure 2 shows a flow diagram of the brine-recovery system. The brine-recovery system is situated on the roof of the three brine-storage tanks, which are made of reinforced concrete. The first tank is used as the holding tank for spent brine from the ion-exchange columns. The contents of this tank are fed to the brine-recovery system. The second tank contains permeate from the first-stage nanofiltration unit, which goes to the brine preparation tank for re-use. The third tank collects retentate from the first-stage nanofiltration for further treatment through the second-stage nanofiltration unit.
**Fig. 1.** Colour change from the feed brine to the permeate after passing through the brine-recovery system.

**Fig. 2.** Flow diagram for the brine-recovery system.

Before feeding the brine to the first-stage nanofiltration unit we ensure that the temperature is below 40°C and the pH is not more than 7; the latter is maintained by HCl through on-line dosing. The pressure difference between inlet and outlet
at the nanofiltration modules should be not more than 690 kPa. If the pressure difference exceeds this limit, the plant is stopped and a clean-in-place is initiated.

The brine retentate going to the second-stage nanofiltration is also kept below 40°C and pH 7. However, the pressure difference between inlet and outlet is kept below 390 kPa. If this limit is reached, a clean-in-place is initiated. The permeate from the second stage is mixed with spent brine from the IX columns and becomes the feed to the first-stage nanofiltration. The retentate from the second stage is sent to the fly-ash filter bed.

**FLY-ASH MULTI-BED FILTER**

The brine retentate from the second nanofiltration unit is passed through a fly-ash filter that works as a multi-bed filter. The top layer of this bed is the fly ash bed (600 mm) and is supported by a bed of pebbles and gravel (1 m). The size of the pebbles and gravel increases gradually from top down. The average size of the particles in each of the pebble and gravel layers is (from top to bottom): 3-8 mm, 8-16 mm, 16-25 mm and 25-40 mm. The height of each layer is fixed at 250 mm. The brine enters at the top and filtered brine from the fly-ash multi-bed filter is used as feed to the first stage of the brine-recovery system. The fly ash is replaced after each batch of brine retentate has been treated. Analysis details of the flow through the multi-bed are given in Table 2.

### Table 2. Laboratory analysis data for the brine after fly-ash filtration.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Flow rate m³/h</th>
<th>pH</th>
<th>Turbidity NTU</th>
<th>Conductivity mS/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permeate</td>
<td>0.9</td>
<td>6.5-7.0</td>
<td>10-15</td>
<td>4500-5000</td>
</tr>
<tr>
<td>Final Reject</td>
<td>1.3</td>
<td>7-8</td>
<td>70-75</td>
<td>6000-7000</td>
</tr>
</tbody>
</table>

**COSTS OF THE BRINE-RECOVERY SYSTEM**

The cost of the chemicals is INR 850 per day with a daily operational cost of INR 3,350 – this is offset by a saving of salt of INR 9,900 per day, giving a net saving of INR 5,700 per day. In addition, the flow of highly polluting effluent is reduced by 45 m³ per day.

**CONCLUSIONS**

Global market demand is forcing the Indian sugar industry to change sugar-production processes from sulphitation to refining. In India there is much scope for change, but in refineries the ion-exchange process has the drawback of disposal of the brine effluent. This paper presents a solution to the problem where the effluent flow has been reduced to just 5% of the original output by using a brine-recovery system involving two stages of nanofiltration followed by a fly-ash filter.

**ACKNOWLEDGEMENTS**

We are sincerely thankful to the management of Triveni Engineering & Industries Ltd and our special thanks go to Mr Tarun Sawhney V.C.M.D of the company for his encouragement. We are also thankful to C.M.D. Mr D. M. Sawhney who remained very helpful and co-operative in the work. Thanks automatically go to our colleagues and assistants who have made many repeated efforts in collecting samples, analyzing data, and preparing drawings for the system.

**Rejets d’effluents de régénération d’échangeurs d’ions proche de zéro % en utilisant un système de récupération du sel et une filtration à travers des cendres volantes**

Résumé. La sulfatation double a été utilisée avec succès par la majorité des usines de l’industrie sucrière indienne. Après le développement du processus DRPIE (defco refonte phospho-flottation échange d’ions), nous avons, comme la plupart des usines à sucre, voulu adopter ce processus. La présence de l’effluent des colonnes échangeuses d’ions a causé des hésitations. Pour résoudre ce problème, nous avons installé un système de récupération du sel (basé sur deux étapes de nano filtration) et sa réutilisation pour régénérer les résines, avec succès. Ce processus, nous permet de récupérer 80 % de la saumure ; 20 % est envoyé vers une filtration sur cendres
volantes pour récupérer 15 % de la saumure. On peut maintenant récupérer 95 % de la saumure usée, ce qui réduit la charge au traitement des effluents. La quantité approximative de cette saumure sauve est 43 m$^3$/jour ; elle se traduit par une économie en sel d’environ 3 000 kg par jour d’opération.

**Mots-clés:** Zéro rejet d’effluents, filtre de cendres volantes, récupération de saumure, échange d’ions

Descarga de efluente próxima a cero de un proceso de regeneración de intercambio iónico usando un sistema de recuperación de salmuera y lecho filtrante de cenizas volantes (fly-ash)

**Resumen.** El proceso de doble sulfitación fue usado exitosamente por la mayoría de las fábricas azucareras en India. Después del desarrollo del proceso fosfo-flotación-intercambio iónico, se decidió hacer modificaciones a este proceso. Se dudó debido a la generación de más efluente por las columnas de intercambio iónico. Para solucionar este problema, se instaló un sistema de recuperación de salmuera basado en nanofiltración en dos etapas para recuperar la salmuera y reutilizar para regenerar con éxito la resina de intercambio iónico. De este proceso se puede recuperar 80% de salmuera, el resto es enviado a un filtro de lecho filtrante de cenizas volantes (fly-ash) para recuperar otro 15% de salmuera. Se pudo recuperar 95% de salmuera agotada y se redujo la carga en la planta de tratamiento de efluente. La cantidad aproximada de salmuera ahorrada fue de 43 m$^3$/día y resultó en un ahorro de sal de aproximadamente 3000 kg por día de molienda a máxima capacidad.

**Palabras clave:** Descarga de efluente cero, recuperación de salmuera, filtro de cenizas volantes, intercambio iónico