Alternative treatment technologies for distillery effluent to achieve zero discharge

MK Gaur

Balrampur Chini Mills Ltd, India; mk.gaur@bcml.in

Abstract  Sugarcane is an energy plant and after the production of sugar each and every product has some energy value. Out of these by-products, the distillery is one of the most valuable industry producing ethanol, which is an environment friendly energy source. During this process the waste liquid generated is called spent wash, or vinasse. This is highly polluting, having high COD and BOD values and is a serious environmental threat if it is discharged untreated. Different technologies are available to treat the spent wash and from time to time technology has been upgraded. Initially, it was treated through lagooning, anaerobic digestion, aerobic digestion, composting, and ferti-irrigation but a recent trend is through evaporation and incineration technologies. Each technology has some merits and drawbacks and the aim should be to adopt the most suitable technology to treat the effluent, considering technical and economic aspects. This work elaborates on the complete system of zero discharge in different cases with their advantages and difficulties.

Key words  Spent wash, zero discharge, vinasse, recycling, biogas, distillery effluent

INTRODUCTION

Sugarcane is a C4 plant that fixes carbon effectively and can store approximately 1% of the solar radiation incident on it per year. That is why sugarcane is an energy plant and each one of its components has an energy value. The total above-ground cane mass, not including detached leaves, has following average composition: 1,000 kg fresh cane balance has 140 kg bagasse: 160 kg Brix (total soluble solids, i.e sucrose, glucose, fructose): 90 kg of attached tops and leaves; 610 kg of water. Approximately 190 kg detached leaves are left in field are not included in this balance.

The sugarcane plant is the major raw material for sugar production. During the processing of sugar, different by-products are generated and these have high energy and nutrient values. The energy extracted by different means is recycled to be used in processing and, in the same way, nutrients are also recycled back to cane fields. Figure 1 shows that each and every by product of the sugar industry can be utilized efficiently and can produce energy and nutrients.

Here, I mainly emphasize the distillery industry, which uses the by-product molasses, press mud and part of the bagasse. In the future it may use cane tops and leaves, which are currently used for energy purposes, and may be converted to ethanol by cellulosic conversion and fermentation (Fig. 2).

The distillery industry produces ethanol, which an environment friendly energy product and it is used not only as a fuel for mixing in petrol but also it is a major substrate for production of diverse chemicals. The major challenges in the distillery industry are how to handle the effluent and achieve zero discharge. The distillery effluent, called spent wash or vinasse, is highly pollutant in terms of low pH, high COD and BOD values, high salt concentration, and dark brown colour due to melanoidin. It is a major threat to the environment if it is discharged untreated. Apart from alcohol production, it is equally important to effectively and economically treat the spent wash and achieve zero discharge.

The selection of the appropriate treatment technology is based on:
- The size of the distillery;
- If a sugar factory is attached or it is a stand-alone distillery;
- Land availability near the distillery;
- CAPEX and OPEX;
- Energy availability.

Different alternatives for the treatment of spent wash are given in Figure 3. To better analyse the use of different technologies and their advantages and drawbacks, some cases are considered.
Fig. 1. Sugarcane products and by-products.

Fig. 2. Distillery industry and use of its by-products.
Case 1 – A medium size distillery of 50-75 kL/d attached to a sugar mill of 8,000-10,000 t cane/d and with sufficient land surrounding the distillery

Anaerobic digester - This will help not only to treat the spent wash by the activity of methanogenic bacteria to reduce the BOD and COD values by 90 and 65% respectively, but will also produce biogas with a calorific value of 5,500 kcal/m³ that can be used the major fuel in the boiler with bagasse as the supporting fuel. This system helps to treat the spent wash in an economical way with less energy consumption and saving the cost of additional fuel.

Fig. 3. Spent wash treatment alternatives.
Reduction of effluent quantity – To reduce the quantity of effluent for easier handling and to require less land for disposal, the processes of reverse osmosis or multiple effect evaporators are installed to reduce the quantity of effluent by up to 60% and concentrate the effluent to 20-25 °Brix. This technology requires energy and consumes steam and its sole role is to reduce the volume of effluent.

Bio-composting – The concentrated effluent can be mixed with another waste product of the sugar industry, the press mud, and mixed with an effective consortium of bacteria to decompose the organic matter present in concentrated spent wash and the press mud in a thermophilic process. After 60 days, a nutrient-rich biocompost is produced, which is recycled back to cane fields to replenish the soil nutrients. The sugarcane field loses its nutrients in different ways (Fig. 5), so they are not replenished from by-product sources, then annual application of synthetic fertilizers will be needed to meet the demand for nutrients.

In such case the best economic route of effluent treatment plant is given in Figure 4.

![Sugar Factory
Press Mud
Spent Wash
Digester
Biogas to Boiler
RO Plant
MEE Plant
Bio Composting
Ferti-Irrigation
To Soil
To Soil](image)

*Fig. 4.* Case 1: suggested treatment of spent wash and press mud.

![Fig. 5. Loss of sugarcane nutrients (Dept Water Resouce, Roorkee)](image)
Ferti-Irrigation of treated effluent – This is another method to utilize the distillery effluent by application to cane fields. This helps recycle the soil nutrients directly to field at a very low cost, especially for areas close to the industry. The only threat of this system is to control ground water pollution in the area, so piezometers should be installed at different places to regularly check the ground water quality. Based on surrounding land availability and farmers’ association rules, a percentage of the effluent may be treated utilizing this route.

The advantages and disadvantages of Case 1 are summarized in Table 1.

**Table 1.** Merits and drawbacks of Case 1.

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant CAPEX is less</td>
<td>Plant can not run in rainy season</td>
</tr>
<tr>
<td>Less energy consumption</td>
<td>Huge land area requirement for bio-composting</td>
</tr>
<tr>
<td>Less operational cost</td>
<td>Land area and farmer association for ferti-irrigation</td>
</tr>
<tr>
<td>Energy production</td>
<td>Bio-compost acceptability to farmers</td>
</tr>
<tr>
<td>Nutrient recycling back to field</td>
<td>Government support needed to allow recycling of nutrients</td>
</tr>
</tbody>
</table>

**Case 2 – Distillery of larger capacity, more than 100 kL/d, attached to a sugar mill**

Due to higher capacity of the distillery, a combination of technologies are required to be more effective and economic. As the effluent quantity is higher, land availability and raw material for composting will be constraints. In this case the adopted route may be as in Figure 6.

![Fig. 6](image-url)
Multiple effect evaporator – This reduces the quantity of effluent quantity and increases the effluent concentration up to 60°Brix using steam and power. This is an energy and steam consuming process to reduce the quantity of effluent for easy handling and to match the sizing of the incineration boiler.

Incineration boiler – This requires a specifically designed incineration boiler for burning concentrated effluent (slop) along with other fuel such as biogas, bagasse, coal, rice husk, etc. The calorific value of slop is 1,500-1,600 kcal/kg. Slop incineration boiler ash is rich in potash, up to 18%, so the potash can be returned to fields to replenish potash levels.

Biogas generation from press mud and the slurry used for composting – Press mud generated from a sugar mill may be used for production of biogas, which may then be used as a supporting fuel in the incineration boiler. The slurry generated after biogas production will be used for composting and then used as a fertilizer for soil-nutrient recycling.

The advantages and disadvantages of Case 2 are summarized in Table 2.

**Table 2.** Advantages and disadvantages of Case 2.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>More energy generation</td>
<td>Very high CAPEX</td>
</tr>
<tr>
<td>Full year working possibility</td>
<td>High operational and maintenance cost</td>
</tr>
<tr>
<td>Sugar factory press mud could also give energy as well as nutrients in form of compost</td>
<td>Due to high salt concentration the scaling in boiler is a big problem so frequent cleaning is required</td>
</tr>
<tr>
<td>Higher energy and steam consumption in the system</td>
<td>Acceptability by farmers of potash-rich ash</td>
</tr>
<tr>
<td>Nutrient recycling back to fields</td>
<td>In the future, dioxin problem in air pollution</td>
</tr>
<tr>
<td>Potash rich ash</td>
<td></td>
</tr>
</tbody>
</table>

**Case 3 - Stand-alone distillery**

For stand-alone distillery the only possible route is MEE and an incineration boiler to achieve zero discharge (Figure 7). The availability of press mud availability from a sugar mill is not a viable or cost-effective solution.

![Spent wash](image)

**Fig. 7.** Case 3: suggested treatment of spent wash.
Case 4 - Stand-alone sugar mill

For a stand-alone sugar mill the possible route is given in Figure 8. Wax can be extracted from the press mud and then energy can be extracted from press mud through anaerobic digestion by producing biogas. The slurry from the digester can be further converted to nutrient-rich bio-compost, which is recycled back to the field. Therefore both energy and nutrients can be derived from the press mud.

![Figure 8. Case 4: suggested treatment of press mud.](image)

Other processes for effluent stream treatment and sludge handling

During the distillery operation, apart from spent wash generation, other process effluents are generated, such as ‘cleared water’ that should be treated separately and recycled back to the process as an alternative to cooling-tower make-up water (Fig. 9). This will help to achieve complete zero discharge and also save the ground water extraction.

Sludge is also generated from the distillery process. The generated sludge is either decomposed in bio-compost or could be used for anaerobic digestion for stabilization.

![Figure 9. Treatment of other distillery effluents.](image)

FUTURE TECHNOLOGIES FOR TREATMENT OF RESIDUES

1) Advancement in incineration boilers to reduce the size and cost of a boiler.
2) Bio-composting in vessels to avoid huge land requirement and operation in open areas.
3) Wet air oxidation – To achieve a COD reduction up to 99 % but at lower CAPEX than it is presently required.
4) Colour removal of spent wash and then proper utilization of treated effluent for irrigation because the colour of spent wash is a big constraint to farmers’ acceptability for use in irrigation, and because melanoidin, which as a complex structure, will remain present in soil for a long periods and will contaminate ground water, If the colour is removed then the farmer acceptability will increase and melanoidin will break down to simpler forms that can be easily degraded by soil bacteria and ground water contamination problem will be minimized.

**CONCLUSIONS**

Different treatment technologies are available to achieve zero discharge conditions, and the selection of the most suitable technology to be adopted depends on considering the size of the distillery, whether the distillery is attached to a sugar mill or not, the land area surrounding the distillery, and always taking into account CAPEX and OPEX for the technical and economic analysis.

**Traitement alternatif pour les effluents de distillerie afin d’atteindre la décharge zéro**

**Résumé.** Toute l’énergie de la canne à sucre doit être utilisée après la production du sucre; chaque produit de la plante a une valeur énergétique. Avec ces sous-produits, la distillerie produit de l’éthanol, qui est une source propre d’énergie. Au cours de ce processus, le déchet liquide généré est appelé vinasse, un produit hautement polluant ayant des valeurs élevées de COD et BOD. La vinasse est une grave menace pour l’environnement si elle est déversée sans traitement. Différentes technologies sont disponibles pour traiter la vinasse et de temps en temps, la technologie a été améliorée. Au début, elle a été traitée par lagunage, méthanisation, digestion aérobique, compostage et fertirrigation; une tendance récente est par évaporation et incinération. Chaque technologie a des avantages et inconvénients et l’objectif devrait être d’adopter la technologie la plus appropriée pour traiter les effluents, tenant compte des aspects techniques et économiques. Ce travail s’applique au système complet de décharge zéro dans différents cas avec leurs avantages et leurs difficultés.

**Mots-clés:** Vinasse, décharge zéro, recyclage, biogaz, effluents de distillerie

**Tecnologías alternativas del tratamiento de efluentes en destilerías para lograr cero descarga contaminante**

**Resumen.** La caña de azúcar es una planta de energía y después de la producción de azúcar cada uno de los subproductos tienen algún valor energético. Fuera de estos subproductos, la destilería es una de las industrias mas valiosas produciendo etanol, que es una fuente de energía ambientalmente amigable. Durante este proceso el líquido de deshecho generado es la llamada vinaza. Esta es altamente contaminante, teniendo altos valores de COD y BOD y es un serio desafío ambiental si las descargas no son tratadas. Existen diferentes tecnologías disponibles para tratar las vinazas y de tanto en tanto la tecnología ha sido mejorada. Inicialmente, fueron tratadas a través de lagunas de tratamiento, digestión anaeróbica, digestión aeróbica, compostaje, y fertirrigación, pero una tendencia reciente es a través de las tecnologías de la evaporación y de la incineración. Cada tecnología tiene su propio mérito e inconvenientes y el objetivo debería ser adoptar la tecnología mas adecuada para tratar el afluentе, considerando los aspectos técnicos y económicos. Este trabajo analiza el sistema completo de cero descarga contaminante en diferentes casos con sus ventajas y desventajas.

**Palabras clave:** Vinaza, cero descarga, reciclado, biogas, efluente de destilería