BREWING INDUSTRY
CASE STUDY

Reducing Solid Wastes and Water Consumption while Improving Productivity and Product Safety

By Dominik Sedlmayer, Brewmaster
Executive Summary

Water usage, wastewater management, and food safety are topics of increasing importance in the global food industry; and the brewing industry is no exception.

Addressing the demands for greater productivity and reducing the environmental footprint in brewing without impacting product yield and quality can present a significant challenge.

This case study describes how one brewer was able to meet productivity and environmental goals in a sustained manner. In addition, a 31.8% reduction in total filtration and stabilization costs was achieved without compromising beer yield and quality by incorporating a new silica-based stabilizing agent.

Introduction

The brewing industry continues to face new opportunities and challenges. Today, environmental concerns combined with productivity demands are placing even greater pressure on the industry. All major players in the brewing industry have made sustainability commitments to reduce the amount of water used in brewing beer, minimize solid waste, lower CO2 emissions, and reduce their overall environmental footprint.

This case study will present results obtained from an actual brewery and demonstrate how a new stabilizing agent can help to reduce solid waste generated and water used during the filtration CIP cycle while also improving productivity and beer quality.

Since each brewery is unique, results obtained at this particular facility may not be exactly replicated in other breweries. Data and results herein serve as an example that similar breweries can achieve. Results may vary depending on size, amount of diatomaceous earth currently used, filtration techniques, and other variables related to current processes employed at a given brewery.

Solid Waste Reduction Combined with Increased Productivity

Traditional solid waste landfill disposal has become an unsustainable practice and increasingly expensive in recent years [1]. Breweries have discovered that waste reduction and improved waste management can considerably lower operating costs.

Solid wastes can be classified in four main categories: brewing process waste; packaging wastes; food service wastes; and wastes generated during special social and entertainment events. In this case study, we will focus our attention only on the brewing process waste category and in particular on the portion generated as part of the filtration process where diatomaceous earth is used as a filter aid.

Diatomaceous Earth (DE) is the skeletal remains of single-celled plants called diatoms. When diatoms die, their skeletons settle to form a diatomite deposit. It is estimated that the global beer industry uses approximately 180kmt of diatomaceous earth as a filter aid. Spent DE disposal, if not properly controlled or managed can contribute to increased landfill and additional costs to the brewing process.

Unlike Silica Gel (SG) used for beer stabilization, which contains up to 99%+ of amorphous silica; DE contains between 80-93% silica expressed as SiO2, 2% to 4% alumina, and the balance composed of a variety of metal and heavy metal oxides such as: Fe, Ca, etc, that can represent from a few ppm up to a few percentage points of the total DE composition [2]. In recent years, DE has also been scrutinized due to its crystalline silica content which is suspected to be dangerous to human health [3] [4].

Filtration is typically referred to as a mechanical process used to separate undesired impurities from the main liquid stream. In the brewing process, beer is typically mixed with a filter aid, such as DE, that is retained on a filter septum. Clarified beer goes through the DE filter cake that is then removed and usually disposed of as landfill.

Regardless of possible reuse scenarios, the brewing industry has committed to reduce or eliminate the use of DE not only to reduce costs associated with its disposal but also as a matter of health due to food safety risks associated with its use [4].

Today, novel alternative solutions have been made available to breweries striving to reduce or eliminate use of DE as filter aid. These include technologies such as membranes or recyclable/regenerable polymeric materials but there are some caveats when considering these. The risk is to merely...
shift the problem from one point to another in the brewing process given the fact that they may actually require more water and chemicals for their regeneration.

**Case Study Results – Solid Waste Reduction**

In order to respond to the modern brewing industry’s need for solid waste reduction and improvements in productivity and food safety standards, W. R. Grace has developed a novel beer stabilizer called DARACLAR® 9000HP silica.

DARACLAR® 9000HP silica is an innovative beer stabilizer that combines best in class haze-sensitive protein adsorption with fast filtering properties typically only achieved with filter aids such as DE.

To demonstrate the performance of this material, we ran comparative tests during 181 beer filtration cycles at an existing brewery. DARACLAR® 9000HP silica was able to help the customer achieve a total DE reduction of 50% in volume (See Chart 1 – Diatomaceous Earth g/hl used by Month). The use of DARACLAR® 9000HP silica required no process change or capital investment to implement its use.

**Process Description and Methodology**

All data refers to a brewery processing 2Mhl/year of various beer types. Beer coming from the brew house was sent after fermentation to the filtration and stabilization unit comprised of a plate and frame filter and a PVPP filter. In the brewery’s initial process, beer was metered with 30-35g/hl of a standard xerogel (XG) silica pre-mixed with chilled water in a buffer tank and then added in-line to the beer stream prior to filtration.

Filtration had been achieved with a mix of two different DE grades, one having average permeability of 200mDa and the other, a faster filtering grade with typical filterability of 1Da. Once filtered and silica stabilized, the beer might also go through an additional stabilization step carried out with PVPP before going to bright beer tanks (BBT) and bottling. All beer was filtered at high gravity (≥17°P).

In the new process, standard XG silica gel stabilizer was replaced with DARACLAR® 9000HP silica at the same dosage. The goal was to leverage the superior performance of the new material, minimize the need for DE, and also...
debottleneck the filtration step which had been identified as one of the major limiting factors in achieving higher productivity in their brewing process.

The above charts represent results from the 181 filtration and stabilization cycles across 9 months of production at this brewery.

As shown in Chart 1, the first 36 filtration and stabilization cycles were performed with an average DE consumption of 117g/hl and an average filtration throughput of 3054hl. Starting from cycle 37 and up to cycle 120, (four months of production), standard XG silica was replaced with an equivalent quantity of the new DARACLAR® 9000HP silica. Four months after switching to DARACLAR® 9000HP silica, the average DE consumption was reduced from the initial 117g/hl down to 45g/hl and the average filtration process was debottlenecked from a previous 3054hl/cycle up to the current +/-5000hl/cycle, achieving outstanding results especially when considering that this particular brewery had no centrifuge available.

In order to confirm that the DE reduction achieved was due to the replacement of standard XG silica with DARACLAR® 9000HP during this four month period, we switched back to the former standard XG silica stabilizer. In Chart 1 between filtration cycles 55-80, the average DE consumption went immediately back up to an average value of 100g/hl. This demonstrates that at least 55g/hl of DE savings was directly attributable to DARACLAR® 9000HP silica with the balance attributed to naturally occurring variations in beer quality and raw materials used throughout the season.

From cycle 120 to 145, DARACLAR® 9000HP was mixed with the standard XG in a 50:50 ratio before switching back to 100% DARACLAR® 9000HP silica. By the end of cycle 181, the average DE consumption was reduced to 43.6 g/hl or down -62.7% with an average and sustained improvement in filtration throughput up to 7305hl or increased +139%. Faster filtering DE was reduced from 68g/hl down to 18g/hl.

The table below summarizes the benefits achieved by replacing a standard XG silica stabilizer with new GRACE® DARACLAR® 9000HP silica:

<table>
<thead>
<tr>
<th>Filtration Cycle (hl/cycle)</th>
<th>with standard XG silica</th>
<th>After implementing DARACLAR® 9000HP Silica</th>
<th>Delta Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>3050 hl/cycle</td>
<td>7305 hl/cycle</td>
<td>+139.5%</td>
<td></td>
</tr>
<tr>
<td>Total (DE+SG)/hl</td>
<td>147 g/hl</td>
<td>75 g/hl</td>
<td>-48.9%</td>
</tr>
<tr>
<td>Total filtration time(*)</td>
<td>5245.9 h</td>
<td>2190.3 h</td>
<td>-58.2%</td>
</tr>
</tbody>
</table>

(*) assuming each filtration cycle=8h
With 58.2% reduction in total filtration time, theoretically a 58.2% additional filtration unit capacity could ultimately be achieved with further investment in process improvements. However, with no investment at all, the customer was able to add an additional 10% capacity or +200khl.

Capacity gains beyond 10% could be achieved with investment in the PVPP unit and BBT tank farm. Any such investment would be more than offset by additional profit generated from capacity gains.

**Water Usage**

Water is the most important raw material used in the brewing process and also one of the scarcest natural resources that must be conserved especially in certain drought stricken or water constrained geographies where sanctions or water use restrictions are often imposed. [5] [6].

On average, water makes up about 92% of beer, with ethanol and extract from other raw materials composing the remaining 8%.

Despite the fact that the brewing industry has made tremendous strides over the last 20 years, water consumption and wastewater management remain environmental and economic challenges that directly affect all brewer-ies and the brewing process.

The Worldwide Brewery Industry Water and Energy Benchmarking Survey reports that breweries have reduced their water usage by over 17% 2008-2012 [7].

**Chart 3 – Brewery Water Reduction 2008-2012**

![Chart 3](image)

On average, the quantity of water used for every filtration CIP cycle is between 150 and 200l including rinsing water (quantity may vary depending upon filter size, etc). It is a common practice in a brewery to operate on fixed filtration cycles of approximately 8h which in our case study corresponded to a 3050hl per cycle volume of filtered beer.

As shown with the implementation of DARACLAR® 9000HP silica, the customer was able to debottleneck this filtration process and bring total throughput up to an average of 7305hl/cycle.

Calculating the impact that 139% filtration throughput increase (summarized in Table 1) has on total water used for filtration CIP, we obtain a net water savings of 58.2% or 0.0334l/hl per hectoliter of filtered beer (see Table 2).
Table 2-Water Reduction using DARACLAR® 9000HP Silica

<table>
<thead>
<tr>
<th></th>
<th>Filtered beer (hl)</th>
<th>Avg. CIP water/cycle (l)</th>
<th>water/hl beer (l/hl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>After DARACLAR® 9000HP</td>
<td>7305</td>
<td>175</td>
<td>0.0239</td>
</tr>
<tr>
<td>With Standard XG Silica</td>
<td>3050</td>
<td>175</td>
<td>0.0573</td>
</tr>
<tr>
<td>Balance</td>
<td>+139%</td>
<td>-</td>
<td>-58.2%</td>
</tr>
</tbody>
</table>

Although this number in absolute terms may appear somewhat small, the implications when applied across the global brewing industry could be substantial. Imagine if by tomorrow the entire brewing industry reduced water consumption by 0.0334 l per hl of beer produced.

Considering that worldwide beer production was ~1973 Mhl in 2013 [9], this would equate to a total savings of 65.9 million liters of water, or the equivalent water needed to fill 26 Olympic swimming pools every production year.

Assuming an average cost of $70 USD per cycle for filtration CIP that includes chemical and water treatment costs, the case study customer saved up to 66850 liters of water and reduced filtration CIP costs by 62%.

**Beer Analysis: Qualitative And Quantitative Results**

In this case study, more than one million hectoliters of beers were produced containing various type and level of malts and adjuncts. All beers were sampled and tested by the brewer. All beer samples treated with DARACLAR® 9000HP were able to meet brewer internal specifications in terms of Haze at 20°C at 25°/90° angle, Forcing test, SASPL Test. Total Polyphenols, sensitive proteins, extract and alcohol content was also tested. Beer samples were also submitted to a panel of experts for a “blind 3 glass tests”; no differences with respect to beer produced with standard process were observed.

**Conclusions**

The chart below shows how the case study brewer was able to achieve a total savings in filtration and stabilization of 31.8% by simply replacing the standard XG silica gel stabilizer with the new DARACLAR® 9000HP silica with no capital investment, extracting as an additional benefit the 10% capacity gain or 200khl.

The new DARACLAR® 9000HP silica beer stabilizer can help make the brewing process more efficient and sustainable by reducing water consumption, creating less solid wastes, all while improving productivity and Food and Health Safety. This benefits not only the brewing industry, but also the consumers they serve and the communities that surround beer manufacturing facilities.
To summarize, the advantages of switching to DARACLAR® 9000HP silica can be grouped in 4 major categories:

1. Environmental
   a. Reduced need for DE hence less solid waste generated
   b. Reduced water demand per hectoliter of produced beer in filtration CIP cycle

2. Productivity
   a. Debottlenecking filtration step
   b. Additional capacity without CAPEX

3. Food & Health Safety
   a. Reducing DE helps minimize health risks associated with free crystalline silica (FCS).
   b. Lower use of DE reduces or dilutes the total amount of leachable beer metals like Ca, Al, Fe naturally present in higher quantities in DE compared to SG.

4. Financial
   a. Reducing DE positively impacts total working capital (less capital in stocks, etc)
   b. Productivity gains reduce overall operating costs

Grace has been innovating beer stabilization technologies for over 40 years. With manufacturing facilities in the United States, Brazil, Europe, and Asia, and a team of beer specialists including brewmasters and TCS staff, customers can depend on expert support to find tailored solutions to address today’s challenges in the brewing industry.

About the Author
Dominik Sedlmayer graduated from Technische Universität München, dipl. Braumeister. He has worked for W. R. Grace since 2003 as a brewmaster and technical customer service manager.

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References