<table>
<thead>
<tr>
<th>Chapter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Overview of Craft Brewing Industry</td>
</tr>
<tr>
<td>2. Brewing Process and Issues in WW Management</td>
</tr>
<tr>
<td>3. GLBC’s Approach to WW Management</td>
</tr>
<tr>
<td>4. Tales from the Industry</td>
</tr>
</tbody>
</table>
Growth of Craft Breweries

Astronomical growth – 549 new openings in 2015 (14.9% growth)

Brewpubs
>25% of sales on-site

Microbreweries – packaging breweries
<15,000 barrels annual output

Regional craft breweries – packaging breweries
>15,000 barrels annual output
“Very long tail of craft brewing”
95% of craft brewers produce only 20% of the beer

**Craft Brewery Production**

Brewpubs –
Avg. 775 barrels/year

Microbreweries –
Avg. 1,600 barrels/year

Regional craft breweries -
Avg. 107,000 barrels/year

GLBC -
150,000 bbls in 2016

**Historical Craft Brewery Production by Category**

- Brewpubs – Avg. 775 barrels/year
- Microbreweries – Avg. 1,600 barrels/year
- Regional craft breweries - Avg. 107,000 barrels/year
- GLBC - 150,000 bbls in 2016
Craft Brewery Wastewater Production

Very few breweries are significant producers of wastewater. Here are the estimated wastewater production values for different types of craft breweries:

**Brewpubs**
- Average: 850 gpd WW
- Max: Perhaps 2,000 gpd

**Microbreweries**
- Average: 1,000 gpd WW
- Max: Perhaps 7,500 gpd

**Regional craft breweries**
- Average: 50,000 gpd WW
- Max: Perhaps 500,000 gpd

**GLBC**
- 67,500 gpd WW
Growth of Industry

Growth in production:
- Industry growing at double-digit pace
- Aggressive expansion (20-30% per year)
- Astronomical expansion (40%+ per year)
- 20% of overall beer market is craft

Rapid growth - collision course with municipal sewer authorities
Brewing Process

**High strength wastes (red):**
- last runnings
- trub
- Spent yeast
- Returned beer

**Extreme pH (orange):**
- CIP acid and caustic solutions
### High Strength Wastes

#### Main Areas Of Wastewater Generation

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>OPERATION</th>
<th>CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mash Tun</td>
<td>Rinsing</td>
<td>Cellulose, sugars, amino acids. ~3,000 ppm BOD</td>
</tr>
<tr>
<td>Lauter Tun</td>
<td>Rinsing</td>
<td>Cellulose, sugars, spent grain. SS ~3,000 ppm, BOD ~10,000 ppm</td>
</tr>
<tr>
<td>Spent Grain</td>
<td>Last running and washing</td>
<td>Cellulose, nitrogenous material. Very high in SS (~30,000 ppm). Up to 100,000 ppm</td>
</tr>
<tr>
<td>Boil Kettle</td>
<td>Dewatering</td>
<td>Nitrogenous residue. BOD ~2,000 ppm</td>
</tr>
<tr>
<td>Whirlpool</td>
<td>Rinsing spent hops and hot trub</td>
<td>Proteins, sludge and wort. High in SS (~35,000 ppm). BOD ~85,000 ppm</td>
</tr>
<tr>
<td>Fermenters</td>
<td>Rinsing</td>
<td>Yeast SS ~6,000 ppm, BOD up to 100,000 ppm</td>
</tr>
<tr>
<td>Storage tanks</td>
<td>Rinsing</td>
<td>Beer, yeast, protein. High SS (~4,000 ppm). BOD ~80,000 ppm</td>
</tr>
<tr>
<td>Filtration</td>
<td>Cleaning, start up, end of filtration, leaks during filtration</td>
<td>Excessive SS (up to 60,000 ppm). Beer, yeast, proteins. BOD up to 135,000 ppm</td>
</tr>
<tr>
<td>Beer spills</td>
<td>Waste, flushing etc</td>
<td>1,000 ppm BOD</td>
</tr>
<tr>
<td>Bottle washer</td>
<td>Discharges from bottle washer operation</td>
<td>High pH due to chemical used. Also high SS and BOD, especially thru load of paper pulp.</td>
</tr>
<tr>
<td>Keg washer</td>
<td>Discharges from keg washing operations</td>
<td>Low in SS (~400 ppm). Higher BOD.</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Discharged cleaning and sanitation materials, floor washing, flushing water, boiler blow-down etc.</td>
<td>Relatively low on SS and BOD. Problem is pH due to chemicals being used.</td>
</tr>
</tbody>
</table>

Yeast is the highest strength waste, about 100,000 ppm BOD, though only about 0.2% of total wastewater flow.
## Typical Brewery Effluent Characteristics

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Water: Beer</td>
<td>6.94</td>
<td>&lt;1,000 bbls</td>
<td>13.1</td>
</tr>
<tr>
<td>Wastewater: Beer</td>
<td>5.39</td>
<td>1,000-10k bbls</td>
<td>7.3</td>
</tr>
<tr>
<td>BOD</td>
<td>10,563 mg/L</td>
<td>10k-100k bbls</td>
<td>5.9</td>
</tr>
<tr>
<td>TSS</td>
<td>2,330 mg/L</td>
<td>&gt;100k bbls</td>
<td>4.5</td>
</tr>
</tbody>
</table>

BOD and TSS concentrations affected by water use ratio and removal of high-strength wastes.
Main Issues in Brewery WW Management

1. Compliance with discharge regulations
   - primarily pH
   - other parameters (e.g. temperature)

2. Cost of treatment

3. Daily maximum discharge limits
   - lbs of BOD, TSS
   - ppm of BOD, TSS
   - Other parameters (phosphorus, nitrogen)
Company Profile

- Company incorporated in 1987, opened in 1988
  - first craft brewery in the State of Ohio
  - only brewery in Cleveland
- Packaging brewery opened in 1998
- 100,000 guests annually

- Distribution in 13 states
- 5 year-round beers, 9 seasonal products
- Commitment to three pillars of sustainability:
  - social,
  - environmental, and
  - economic sustainability

- 1,000 barrels produced in 1988
- 150,000 barrels produced in 2016
Our Sustainability Story

• One of early adopters in Cleveland

• Many, diverse initiatives –
  • energy management,
  • renewable energy,
  • water management,
  • local foods and farming,
  • green building,
  • philanthropy, and advocacy

• High touch with consumers – story telling aspect

• High employee involvement

Wastewater management has not been a major focus of sustainability program
Inversion of significance of base rate and surcharge.

Wastewater costs increasing from 1% of sales to over 2% of sales.

<table>
<thead>
<tr>
<th>% of 2016</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base rate</td>
<td>100%</td>
<td>106%</td>
<td>113%</td>
<td>121%</td>
<td>128%</td>
<td>136%</td>
</tr>
<tr>
<td>Surcharge</td>
<td>100%</td>
<td>162%</td>
<td>225%</td>
<td>292%</td>
<td>363%</td>
<td>440%</td>
</tr>
<tr>
<td>Total rate</td>
<td>100%</td>
<td>124%</td>
<td>148%</td>
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<td>Surcharge</td>
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</table>
## Wastewater Rate Benchmarks

<table>
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<tr>
<th>Industry Rates</th>
<th>Min</th>
<th>Average</th>
<th>Max</th>
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<tr>
<td>Flow ($/1000 gal)</td>
<td>$0.25</td>
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<td>BOD Surcharge ($/lb)</td>
<td>$0.11</td>
<td>$0.34</td>
<td>$0.69</td>
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<td>TSS Surcharge ($/lb)</td>
<td>$0.11</td>
<td>$0.16</td>
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<th>GLBC Rates</th>
<th>2016 rate</th>
<th>2021 rate</th>
</tr>
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<tbody>
<tr>
<td>Flow ($/1000 gal)</td>
<td>$10.43</td>
<td>$14.24</td>
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<tr>
<td>BOD Surcharge ($/lb)</td>
<td>$0.10</td>
<td>$0.43</td>
</tr>
<tr>
<td>TSS Surcharge ($/lb)</td>
<td>$0.09</td>
<td>$0.41</td>
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Flow rates – above average and near max of benchmark
Surcharges – near minimum and tending above average
Water Management

• Achieving avg. reduction of 5.0% per year for the last 5 years

• Water usage ratio of 6.4:1 in 2016

• 19,760,000 gallons drawn in 2009
• 29,670,000 gallons drawn in 2014

• 50% growth in total water usage vs. 91% growth in production
Water Saving Projects - Process

• Optimizing wort heat exchanger (est. 1.2 million gpy)
• Installing rinse timers for initial rinse of tank (est. 400,000 gpy)
• Collecting water from initial bottle rinse for vacuum pump cooling water (est. 200,000 gpy)
• Integration of final bottle rinse with packaging line (est. 200,000 gpy)

Annual Savings of $46,000
Water Saving Projects – Employee Led

- Leak identification program (est. 250,000 gpy)
- Solicitation of ideas at annual meeting
- Employee incentives – one of six company goals

Annual Savings of $46,000
Current Compliance Project

- pH of discharges from our CIP systems out of acceptable range
- Currently engineering a solution to capture CIP discharges and neutralize
- Tanks sized to accept 150 gal flows
- Tanks to be sited in 3 locations—
  - fermentation cellar,
  - packaging line, and
  - brewhouse
- Neutralization either via:
  - dosed caustic and acid, or
  - by combining acid and caustic wastewaters
Other Initiatives Considered

1) Sidestreaming of High Strength Wastes
   • Users of yeast exist
   • Space for storage tank limited
   • No economic driver
   • No regulatory driver

2) High Rate Anaerobic Digestion
   • No space
   • No regulatory driver
   • Historically low treatment cost
   • Low energy costs

Absence of regulatory drivers or cost signals.
## GLBC Wastewater Costs

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Revisit sidestreaming and pretreatment conversations.
Initiatives in the Industry

Manuals on Water and Wastewater Management

Benchmarking Project – Utility Usages and Costs

www.brewersassociation.org
BA Advice on Wastewater Management

1. Read and track utility bills.

2. Determine which discharges contribute to loading
   - BOD concentration
   - volumes

3. Understand ordinance restrictions.


5. Look for continuous improvement opportunities.
6. Evaluate feasibility and economics of side streaming.

7. Evaluate feasibility and economics of simple pretreatment.

8. Evaluate feasibility and economics of full scale pretreatment.
Wide variation leads to a wide variety of approaches to wastewater management.

### Wastewater Rate Benchmarks

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Case Study – Upland Brewing Company

- Bloomington, IN (pop. 80,000)
- 16,000 barrels/year
- 6,000-8,000 gpd wastewater
- Didn’t give much consideration to wastewater when they began operations
- Paid about $150/month for wastewater surcharge
- Surcharge of roughly $0.50/lb BOD levied with no lead time or warning
- Began receiving surcharges on average $4,000/month
- Additionally daily limit for phosphorus

Tenuous relationship between brewery and municipality.
Case Study – Upland Brewing Company

- Sidestreamed yeast and trub
- Installed storage tanks for equalization, solids settling
- Alum treatment for phosphorus reduction
- Has invested about $80,000 in pretreatment equipment
- Investigating small-scale pretreatment equipment, able to handle <15,000 gpd
- In intermediate range, unable to justify six-figure cost of full scale pretreatment

Small-scale pretreatment systems being designed, targeted for small-scale brewers - some vendor uncertainty remains
Brewers ready to take action within reason to work with municipal sewer districts

- Predictability
- Reasonable notice of pending changes (pricing or discharge limits)
- Reasonable scope of improvements imposed on brewers
- Reasonable pricing
- Pricing increases imposed over time
- Reasonable flexibility
Case Study – Cincinnati Area Brewers

- Collection of 15-20 microbrewers in Cincinnati
- Most have less than 10,000 barrel production
- Notice of intent to levy a surcharge on high strength wastes, when previously none had been imposed
- Surcharge to be imposed for BOD, TSS, NOD
- Proposed surcharge rates higher than upper limit of BA’s Benchmark

Very little notice given; very high proposed rates; unusual structure (NOD)
Rate structures in Cleveland and Cinci

<table>
<thead>
<tr>
<th>Surcharge Fees</th>
<th>NEORSD (2015)</th>
<th>Cincinnati MSD proposed rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD (per ccf * mg/L)</td>
<td>$0.000579</td>
<td>$0.004989</td>
</tr>
<tr>
<td>NOD (per ccf * mg/L)</td>
<td>-</td>
<td>$0.004369</td>
</tr>
<tr>
<td>TSS (per ccf * mg/L)</td>
<td>$0.00059</td>
<td>$0.002921</td>
</tr>
</tbody>
</table>

Major difference in proposed surcharges... almost a factor of 10
Our spend/year in Cleveland v. Cinci

<table>
<thead>
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<th>Fee</th>
<th>Cleveland / NEORSD</th>
<th>Cincinnati MSD proposed rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (45,000 ccf)</td>
<td>$147,150</td>
<td>$106,650</td>
</tr>
<tr>
<td>Base sewage (37,500 ccf)</td>
<td>$308,250</td>
<td>$176,958</td>
</tr>
<tr>
<td>BOD (7,500 mg/L)</td>
<td>$162,844</td>
<td>$1,358,255</td>
</tr>
<tr>
<td>NOD (375 mg/L)</td>
<td>-</td>
<td>$57,343</td>
</tr>
<tr>
<td>TSS (1,100 mg/L)</td>
<td>$24,337</td>
<td>$87,630</td>
</tr>
<tr>
<td>Total</td>
<td>$642,581</td>
<td>$1,786,836</td>
</tr>
<tr>
<td>Total / barrel packaged</td>
<td>$4.00</td>
<td>$11.12</td>
</tr>
</tbody>
</table>

Proposed Cincinnati rates are 3-4% of sales
Case Study – Cincinnati Area Brewers

• Brewers raised a fuss in media and in public comment meetings
• City of Cincinnati imposed moratorium on Hamilton County’s proposed rates June 2015
• No surcharges have been imposed
• Brewers beginning to install simple pretreatment (eg. settling tanks)
• Beginning to experiment with small-scale treatment systems
• New rates to be imposed with brewer input and representation
Case Study – Goose Island Brewery

- Near West Side of Chicago, founded 1988
- Wastewater rates determined in retrospect via quarterly sampling
- No daily maximum discharge limits
- Slightly below average wastewater rates of $0.25/lb BOD and $0.17/lb TSS
- No significant driver other than frustration with regulatory scheme and active sustainability program
Case Study – Goose Island Brewery

• Identified yeast as primary contributor to loading
• Identified potential recipients of waste stream
• Fermentation vessel repurposed as yeast storage tank (lower production)
• Since 2013, sending to Indiana-based corn ethanol producer
• Ethanol producer paid for tanker truck and charged no fees
• Residual alcohol content of 5-6% was needed for ethanol producer
In absence of regulatory driver, sidestreaming is cost-benefit consideration. Relationships with recipients of sidestreamed materials are not always lasting.

- $40,000 of annual savings,
  - 40 tons of BOD reduced
  - 30 tons of TSS reduced
  - 100,000 gallons of spent yeast diverted
- Since 2016, incentives for ethanol producer fell apart
- Cost of $15,000/y incurred to send yeast to digester in Chicago suburbs
Case Study – Shorts Brewing

• Located in Bellaire, MI at North end of Lower Peninsula
• About 30,000 barrels of production
• Received notice that Village’s wastewater treatment plant was having issues
• Village surveyed 3 industrial users and found that brewery was the culprit
• Brewery given 30 days to reduce loading to the system
Case Study – Shorts Brewing

- Immediate need to find high strength wastes and remove them from the system
- Removal of yeast from waste stream
  - 70% reduction in TSS
  - 40% reduction in BOD
- Removal of other high strength wastes
  - 90% reduction in TSS
  - 70% reduction in BOD
- Satisfying agreement with municipality
- However, operational costs of sidestreaming were high

Short's Brewing Company Wastewater Case Study

<table>
<thead>
<tr>
<th>Effluent Notes</th>
<th>TSS (mg/L)</th>
<th>BOD (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>5130</td>
<td>10830</td>
</tr>
<tr>
<td>No Yeast</td>
<td>1430</td>
<td>6420</td>
</tr>
<tr>
<td>No Yeast, Trub, or Weak Wort</td>
<td>540</td>
<td>4900</td>
</tr>
<tr>
<td>No Yeast, Sugars, or Cellar</td>
<td>280</td>
<td>3550</td>
</tr>
</tbody>
</table>
Case Study – Shorts Brewing

- Because of high operational costs, Shorts ended up installing their own pretreatment system
- $1.6 million capital cost
- Operational costs avoided
- Additional labor avoided
- Ability to increase capacity by 3-4x
- Primarily aerobic system
- Relationship between brewery and municipality was initially shaky
- Now high mutual respect

Main driver was need for reliable BOD reductions with low operational cost
Case Study – New Glarus Brewing

- New Glarus, WI – pop. 2,100
- 150,000 bbls/year exclusively for consumption in WI
- Clear that wastewater production at this level would overwhelm POTW
- No backup plan - needed a system that could treat water consistently
- Additional design criteria – economical to operate, expandable, and aesthetically pleasing

Main driver was need for reliable BOD and TSS reductions
Case Study – New Glarus Brewing

- Treatment consists of flow equalization, screening, dissolved air floatation and ASMC (activated sludge with membrane clarification)
- Reliably achieves BOD and TSS reductions >95%
- Effluent characteristics – 6 mg/L BOD and 10 mg/L TSS
Case Study – Deschutes Brewing

- Bend, Oregon
- Population 35,000 in 1988
- Population around 100,000 today
- Bend becoming tourist destination and highly desirable place to live
- Production of 350,000 barrels
- Bend’s #1 wastewater customer, #2 water customer (after hospital)
- Attempted to install AD system in 1996-8, resulted in failure
Case Study – Deschutes Brewing

- Negotiated discharge limits with POTW for 20 years+
- Company called AgriCycle founded to sidestream and land apply high strength wastewaters for Bend brewers
- 110-140 trucks/month of high strength waste diverted
- 80-90% of load removed
- Loading only 4-6x higher than household
- Daily discharge limits of 3,600 lbs. COD/day
- 130,000 gal on-site storage tanks
- Self-sample and restrict flows to city based on results
Limiting Factors – Deschutes Brewing

- Land availability for application of discharges – open land being converted to residences
- Cost of surcharges increasing 54% a year for 4 years
- Likely sewer bill of over $1 million, not including sidestreaming cost
- Butting up against daily discharge limits

Ability to dispose of wastewater becoming limiting factor
Future Plans – Deschutes Brewing

- Reluctantly becoming WW treatment plant for craft brewers
- Currently in engineering phase for AD plant
- 50% of electricity and 25% of process heat to be generated from biogas
- Adding capacity to process high strength wastes for other brewers
- Missed opportunities to optimize wastewater processing in collaboration with municipality
Lagunitas Started in 1993 in Lagunitas, CA

The town of Lagunitas (pop. ~390)

Our first brewery (‘93)

Original IPA Label 1995
Lagunitas Brewery – Petaluma, CA

Petaluma’s Ellis Creek Facility (built July 2009)

Lagunitas Brewery
Water Costs at Bell's Brewery

<table>
<thead>
<tr>
<th></th>
<th>WW Cost/BBL</th>
<th>H2O Cost/BBL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug-09</td>
<td></td>
<td></td>
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<tr>
<td>Sep-09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct-09</td>
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Average Cost/BBL
Water = $0.24
Wastewater = $2.46
Total = $2.72

Average Costs/BBL
Water = $0.26
Wastewater = $0.39
Total = $0.63
Bell’s Brewing’s Solution to Rising Costs

Anaerobic Digestion Facility

- ~$4.5 million capital cost
- ~$0.4 million annual savings
- 30% tax credit on investment
- ~7 year breakeven, given growth trend
- Wastewater loading to be reduced by 90%
- Value of net electricity and thermal energy about $50k
Bell’s Brewing – Operational Challenges

Difficulty maintaining biogas generation per lb COD reduced
Case Study – Bell’s Brewing

- Removing 75-82% COD
- Removing 6,500-7,000 lbs BOD/day
- Methane generation lower than expected
- Using more caustic than expected
- AD is net energy user
- Surfactants and additives in caustic inhibiting cohabitation of acetogens and methanogens
- Much more solids production than expected – 30 yd rolloff 1x/week
Lessons learned – Bell’s Brewing

• Hire full-time operator, rather than splitting duties between maintenance, lab, and sustainability
• Be sure of characteristics of wastewater when designing facility
• Assume your assumptions are wrong

Will end up as success story
More tales of Anaerobic Digestion

FX Matt, Utica, NY

New Belgium Brewing, Fort Collins, CO

Magic Hat Brewing, Burlington, VT

Sierra Nevada, Asheville, NC

Lots of WWTP being built, with various technologies and variable vendor reliability
Shameless Plug

- Annual Burning River Fest
- August 18-19, 2017
- Raises funds to restore historic Coast Guard Station as center for environmental education and public recreation

Still soliciting sponsors for 2017
Cheers

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