Minimization of Environmental Impact of Wachusett Brewing Company Processes

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Abstract

The following project summarizes an environmental assessment of the Wachusett Brewing Company in Westminster, MA, considering wastewater, solid and general wastes, and air emissions. This assessment includes research into all applicable environmental regulations on a national, state, and local level, determination of compliance through qualitative and quantitative process and waste stream analysis, and recommendations to decrease environmental impact.
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<table>
<thead>
<tr>
<th>Section</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Introduction</td>
<td>All</td>
</tr>
<tr>
<td>2.1 History of Beer Brewing</td>
<td>Alicia Bridgewater</td>
</tr>
<tr>
<td>2.2 Beer Brewing</td>
<td>Alicia Bridgewater</td>
</tr>
<tr>
<td>2.3 Wachusett Brewing Company History and Process</td>
<td>Alicia Bridgewater</td>
</tr>
<tr>
<td>2.4 Brewery Wastewater</td>
<td>Michael Slezycki</td>
</tr>
<tr>
<td>2.5 General Waste Regulations</td>
<td>Michael Slezycki</td>
</tr>
<tr>
<td>2.6 Air Emissions in a Brewery</td>
<td>Brian Conner</td>
</tr>
<tr>
<td>3 Methodology</td>
<td>All</td>
</tr>
<tr>
<td>4.1 Brewing Process Observation</td>
<td>Brian Conner</td>
</tr>
<tr>
<td>4.2 Cleaning Process Observation</td>
<td>Brian Conner</td>
</tr>
<tr>
<td>4.3 Wastewater Regulation Compliance</td>
<td>Michael Slezycki</td>
</tr>
<tr>
<td>4.4 General Waste Regulation Compliance</td>
<td>Brian Conner and Michael Slezycki</td>
</tr>
<tr>
<td>4.5 Investigation of Additional Materials of Interest</td>
<td>Brian Conner</td>
</tr>
<tr>
<td>4.6 Wastewater Testing Results</td>
<td>Michael Slezycki</td>
</tr>
<tr>
<td>5 Recommendations</td>
<td>Alicia Bridgewater</td>
</tr>
</tbody>
</table>

All members of the team participated in the editing of the report. Overall the workload of the project was evenly distributed and all team members made significant and comparable contributions.
# Table of Contents

Abstract .......................................................................................................................... ii
Acknowledgements ......................................................................................................... iii
Table of Contents ............................................................................................................ v

1  Introduction .................................................................................................................. 1
2  Background ................................................................................................................... 3
    2.1  History of Beer Brewing ......................................................................................... 3
        2.1.1  Origin of Beer ............................................................................................... 3
        2.1.2  Evolution of Brewing Process ....................................................................... 4
    2.2  Beer Brewing .......................................................................................................... 5
        2.2.1  General Brewing Process ............................................................................. 5
        2.2.2  Beer Types ..................................................................................................... 7
            2.2.2.1  Ales ......................................................................................................... 8
            2.2.2.2  Stouts ..................................................................................................... 8
            2.2.2.3  Lagers ..................................................................................................... 8
            2.2.2.4  Light Beer .............................................................................................. 8
            2.2.2.5  Draft Beers ............................................................................................ 9
    2.3  Wachusett Brewing Company History and Process .............................................. 9
2.4  Brewery Wastewater .................................................................................................. 11
    2.4.1  Wastewater Characteristics ............................................................................. 11
        2.4.1.1  Biochemical Oxygen Demand .................................................................. 11
        2.4.1.2  Chemical Oxygen Demand ..................................................................... 12
        2.4.1.3  Total Suspended Solids .......................................................................... 12
        2.4.1.4  pH and Temperature ................................................................................ 12
    2.4.2  Clean Water Act ................................................................................................ 12
        2.4.2.1  National Pollutant Discharge Elimination System (NPDES) ................. 13
        2.4.2.2  National Pretreatment Program and Applicable Regulations ............... 14
            2.4.2.2.1  National Standards ............................................................................ 14
                2.4.2.2.1.1  40 CFR 403 – General Pretreatment Regulations for Existing and New Sources of Pollution ................................................................. 14
                2.4.2.2.1.1  National Pretreatment Standards – Prohibited Discharges .... 15
                2.4.2.2.1.2  National Pretreatment Standards - Categorical Standards .... 16
            2.4.2.2.2  Local Standards .................................................................................. 16
                2.4.2.2.2.1  314 CMR 12.00 - Operation and Maintenance and Pretreatment Standards for Wastewater Treatment Works and Indirect Discharges .......... 17
                2.4.2.2.2.1.1  Prohibitions and Standards for Discharges to POTWs 17
                2.4.2.2.2.2  314 CMR 7.00 – Sewer System Extension and Connection Permit Program ................................................................. 17
                2.4.2.2.2.1.1  Activities Requiring a Permit .................................................... 18
2.4.2.2.2.1.2 Activities Not Requiring a Permit................................. 18
2.4.2.2.2.1.3 Summary ..................................................................... 18
2.5 General Waste Regulations.......................................................... 19
  2.5.1 Emergency Planning and Community Right-to-Know Act............ 19
    2.5.1.1 Hazardous Chemical Inventory and Toxic Chemical Reporting .... 19
  2.5.2 Resource Conservation and Recovery Act .................................... 20
  2.5.3 Massachusetts Toxic Use Reduction Act (TURA)....................... 20
    2.5.3.1 TURA Applicability ........................................................ 21
    2.5.3.2 Rules for Determining the Amount of Toxic Substances Manufactured, Processed, or Otherwise Used................................................................. 22
2.6 Air Emissions in a Brewery ............................................................ 23
  2.6.1 Carbon Dioxide .................................................................... 23
  2.6.2 Noise and Odor ..................................................................... 25
  2.6.3 Dust ..................................................................................... 26
  2.6.4 Volatile Organic Compounds ................................................... 26
3 Methodology .................................................................................. 28
  3.1 Background Research of Applicable Regulations ......................... 28
  3.2 Material Balance ........................................................................ 28
    3.2.1 Brewing Process Observation .............................................. 29
    3.2.2 Cleaning Process Observation .............................................. 29
    3.2.3 Identification of Materials of Interest .................................... 29
  3.3 Wastewater Sampling and Testing .............................................. 30
    3.3.1 Sampling Procedure ............................................................ 30
    3.3.2 Testing Procedure .............................................................. 31
      3.3.2.1 pH Analysis ................................................................. 32
        3.3.2.1.1 pH Dilution Calculations ........................................ 32
      3.3.2.2 COD .......................................................................... 32
      3.3.2.3 TSS .......................................................................... 33
  3.4 Wastewater Regulation Compliance .......................................... 33
    3.4.1 Clean Water Act ................................................................ 33
  3.5 General Waste Regulation Compliance .................................... 34
    3.5.1 EPCRA ............................................................................ 34
    3.5.2 RCRA ............................................................................. 34
    3.5.3 TURA ............................................................................. 35
  3.6 Air Emission Regulation Compliance ....................................... 35
    3.6.1 Clean Air Act ................................................................. 35
4 Results and Discussion .................................................................. 36
  4.1 Brewing Process Observation .................................................... 36
    4.1.1 Mash Tun ........................................................................ 36
    4.1.2 Brew Kettle ................................................................. 37
    4.1.3 Whirlpool/Heat Exchanger ............................................... 37
    4.1.4 Fermentation Vessel ....................................................... 38
    4.1.5 Diatomaceous Earth Filtration .......................................... 39
    4.1.6 Bright Tank .................................................................... 39
    4.1.7 Bottle and Keg Pack Out ................................................. 39
  4.2 Cleaning Process Observation ................................................... 40
4.2.1 Mash Tun ................................................................. 40
4.2.2 Brew Kettle ............................................................... 40
4.2.3 Whirlpool/Heat Exchanger ........................................... 40
4.2.4 Fermentation Vessel ................................................... 41
4.2.5 Diatomaceous Earth Filter .......................................... 41
4.2.6 Bright Tank ............................................................. 41
4.2.7 Keg Washer Operation ............................................... 42
4.2.8 Bottle Pack Out ........................................................ 42
4.3 Wastewater Regulation Compliance .................................. 43
4.4 General Waste Regulation Compliance .............................. 44
4.4.1 EPCRA ................................................................ 44
4.4.2 RCRA ................................................................ 44
4.4.3 TURA ................................................................ 45
4.5 Investigation of Additional Materials of Interest ................. 47
4.5.1 Trub ................................................................. 47
4.5.2 Diatomaceous Earth Filter Media ................................. 47
4.6 Wastewater Testing Results ............................................. 47
4.6.1 pH ................................................................. 48
4.6.2 pH Dilution Calculations ............................................ 48
4.6.3 COD and TSS ............................................................... 48
5 Recommendations .................................................................. 49
5.1 Trub Collection ............................................................. 49
5.2 DE Filter Media Proper Storage and Disposal .................. 49
5.3 Recommendations Related to TURA Compliance ............ 50
5.4 Wastewater pH Monitoring System ................................. 50
References ................................................................................. 52
Appendix I ................................................................................. 54
COD Testing Procedure ......................................................... 54
Appendix II ................................................................................. 55
COD Graphic Calibration Curves ............................................. 55
Appendix III ................................................................................. 56
TSS Testing Procedure .......................................................... 56
Appendix IV ................................................................................ 57
Brewing Process Material Balance ......................................... 57
Appendix V ................................................................................ 58
Cleaning Process Material Balance .......................................... 58
Appendix VI ................................................................................ 59
Daily Water Discharge .......................................................... 59
Appendix VII ............................................................................... 60
Sodium Hydroxide Caustic Material Safety Data Sheet ............ 60
Appendix VIII ............................................................................. 69
Acid Cleaner Material Safety Data Sheet ................................. 69
Appendix IX ................................................................................ 79
Full Laboratory Data Sheet and Testing Results ....................... 79
Appendix X ................................................................................ 81
pH Calculations ........................................................................... 81
1 Introduction

Wachusett Brewing Company (WBC), a microbrewery in Westminster, MA is a popular producer of several types of ales distributed through Massachusetts and New York. WBC has employed the same method for management of waste streams, as was approved through verbal agreement, by the local water treatment facility, since they were first operational in 1993. However, as demand and sales have increased, production has increased, as has the likelihood of continued growth in the future. Related to this increase in production, WBC has requested an analysis of all wastes leaving the brewery in order to determine regulatory compliance and how to minimize the environmental impact of the brewery on the surrounding community and local water treatment facility, Fitchburg East POTW.

In the determination of what wastes are of the greatest concern, the WPI MQP team has completed background research in; the general brewery processes including all operations with waste being discharged to the environment, all applicable wastewater legal regulations as well as restrictions related to biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), pH, and temperature concerns based on the local treatment facility, all possible permits needed in conjunction with wastewater, and regulations and concerns associated with air emissions.

In completion of the above goal of decreasing environmental impact, the team completed a general material balance on all brewing processes and cleaning processes, determined where each material entered and exited, in what form it was released, how it was managed on-site, how it was treated off-site, if at all, and what is required to ensure that each waste stream is being properly managed and treated. Based on material balance findings, further research into the applicable federal, state and local environmental regulations and required permits, and possible recycling opportunities was also completed.

In addition to general material balance study and research, wastewater stream samples were collected at several locations and tested for pH, chemical oxygen demand (COD), and total suspended solids (TSS) to determine current compliance with environmental regulations.
A concern of WBC is that with continuing growth in production, there may also be an increase in by-product generation and the current method of management and subsequent treatment and disposal may be outgrown, either currently or in the future. Based on the findings of the process examination and sample testing, recommendations were made regarding process modifications to decrease environmental impact as well as areas for further research and investigation.
2 Background

In determination of the full scope of the environmental impact of Wachusett Brewing Company (WBC), background research on general brewing practices and environmental concerns associated with breweries was completed. In addition, applicable regulations and possible permit requirements were also researched; summaries and determination of applicability to WBC processes are also included in the following.

2.1 History of Beer Brewing

There are many opinions on the exact origin of beer as there is evidence of its beginnings in many different locations and cultures worldwide. There is analytical chemical evidence of beer discovered in pottery as far back as 7,000 years ago in the Middle East, ancient Sumerian tablet paintings and poems referencing beer, as well as written evidence of the brewing of beer in Armenia as far back as the fifth century B.C. (Bamforth). Once discovered the process of brewing beer spread throughout the world and evolved differently across different cultures resulting in the common practices and products used and consumed today.

2.1.1 Origin of Beer

It is agreed that most historical references consider Babylon the origin of beer. These first batches of this now popular beverage were brewed quite differently than what is consumed today. Through intense chemical analysis, an estimate of the first brewing process and recipe was developed. The main ingredients used by the Egyptians were malted barley and emmer, a primitive type of wheat that is no longer used. The exact history of how the brewing process was initially discovered remains a mystery, however it is speculated that stored grain somehow became wet and began to germinate. Once dried, the germination would have stopped resulting in a better tasting and more nutritional malt; the sprouted grains, for all their benefits, would have appealed to the Egyptians and been used in place of other grains in the baking of bread. This dough could have spontaneously fermented due to the available yeast and the brewers could have
thinned the dough with water and strained it adding different plants to improve flavor (Bamforth).

The techniques of brewing beer were shared with the Romans and Greeks and grew in popularity among the common folk, since the choice beverage of the aristocracy was still wine in these areas (Bamforth). Beer brewing continued to spread onwards through to the rest of Europe, the English bringing beer to America. Each culture’s beer history and techniques varying from one to another reflecting the differences in preferences in types of beer that exist around the world, even to this day.

2.1.2 Evolution of Brewing Process

Beer brewing evolved differently throughout the world, ingredients and recipes changed, with the addition of hops becoming common practice, and different types of beers began to emerge. Although by the seventeenth century there was but one book on the brewing process and with a lot of the science behind the process still unknown, consistency and quality were still difficult to attain.

The first breakthrough in the explanation of the science behind brewing process came when Antoine van Leeuwenhoek examined a drop of fermenting beer under a microscope and identified the yeast. Although at this time and for the next 150 years, the functionality of the yeast remained unknown. At this time German scientist Theodor Schwann and French scientist Charles Cagniard Latour both claimed yeast was an organism that could bud whereas two other German scientists Friedrich Wohler and Justus von Liebig argued that yeast were eggs that hatched into organisms that consumed grain and excreted alcohol and carbonic acid. It was not until the research of French scientist Louis Pasteur that the science behind fermentation was explained with any sort of accuracy. As the study of brewing science continued there were contributions to the explanation of the process by many other scientists as well. Some notable contributions include that of Carl Balling, James Muspratt, and Heinrich Bottinger all recognizing the living nature of yeast and its importance; Emil Christian Hansen who coined the phrase “wild yeasts” as yeast cells present that differ from those intended by the brewer and explained the problems associated with such cells; as well as many other scientists whose
research on yeast and other parts of the brewing process have developed the common knowledge and practices used in the brewing industry today (Bamforth).

### 2.2 Beer Brewing

With the advances and improvements made throughout the history of beer brewing, the general techniques for all brewers are relatively the same with each brewer adding their own differences through different recipes, ingredients, and process techniques. However, all beer is brewed using ingredients from the same four categories, malted barley, other grains such as wheat and rice, hops, yeast, and water. Any type of beer can be brewed from these ingredients; it is merely a matter of the recipe and brewing technique, and often the “craft” of the brew master that determines the differences in beer (Bamforth).

#### 2.2.1 General Brewing Process

All beer is brewed using the same general process with different variations on techniques and recipes. Each part of the brewing process is important and must be carried out correctly and effectively to ensure the desired final product. The first step in the process is milling. The malted grain, which could be barley, rye or wheat, is crushed to increase the surface area and separate the husks and is then added to the mash tun along with hot water and so mashing occurs. Mashing occurs for one to two hours and depending on the grain being used and the desired result, has different waiting periods where the mixture is held at a certain temperature, called rests, to allow the enzymes in the malt to breakdown the malt into the fermentable sugars. Different temperatures activate certain enzymes resulting in a variety of products. Once mashing is complete the remaining malt may be raised to a temperature of 75° C to deactivate any remaining live enzymes, a process called mashout (Nice).

Following is a process called lautering, which occurs in a vessel called a lauter tun, in which the liquid from mashing is separated from the remaining grain and transferred to the kettle. This liquid is known as the wort. The remaining grain may be again sprinkled with water to rinse through any remaining sugars, a process known as sparging. The mash tun and lauter tun can be combined into one vessel, followed by a
vessel to collect the hot wort and hold it during sparging. It is important for the wort to be as clear and concentrated as possible. In the kettle, the wort is boiled and additional ingredients such as hops, or other sugars or flavoring may be added. Hops add the aroma and bitterness to the beer. Hops may also be added in the last few minutes of boiling, late hopping, to create a stronger hop taste, or even later in the process, dry hopping. The boiling of the wort serves several purposes such as the inactivation of any enzymes that may have survived mashout, sterilization of the beer, boiling off unwanted flavors, and creating more or less concentrated wort depending on the type of beer being made. Additionally, while boiling, the wort precipitates out what is called trub, a solid complex containing all of the remaining proteins that will cause haziness and sediments in the beer if not removed.

Following the kettle processing, the wort is transferred to a whirlpool vessel where the aforementioned trub is removed by allowing the beer to swirl for around an hour creating centrifugal forces that cause the solids to drop out and collect in the cone shaped bottom of the tank. The resultant wort is now ready to be fermented, however; the temperature of the liquid is still too high for living yeast. To prepare the wort for the addition of yeast, it is passed through a heat exchanger, counter-currently, with cooling water. The fermentation temperature may be as low as 6°C for a lager style beer or as high as 15-20°C for ales. In addition to cooling the wort, a small amount of pure oxygen is bubbled into the stream, as it passes from the heat exchanger into the fermentation vessel, in preparation for the yeast. Although fermentation is an anaerobic process, the yeast requires a small amount of oxygen to be effective.

Once the wort is ready, the yeast is added, or pitched, as it is called in the brewing process. There are two main types of yeast, top-fermenting yeast generally used for ale brewing and bottom-fermenting yeast generally used for lager brewing. However, the common use of cylindro-conical tanks as fermentation vessels makes the distinction between the two types visually unclear. Fermentation is the process where the sugars are converted to alcohol by the yeast; the rate at which this occurs is affected by both the temperature and the amount of yeast pitched into the wort. The time required for fermentation also depends on the type of yeast being used and the desired type of beer
being produced. Once the yeast are spent they drop to the bottom of the tank into the conical portion and are removed off the bottom.

Once fermentation is complete, there are different methods for processing the beer. Many types of beers are cooled either by lagering, slowly decreasing the temperature from 5 to 0°C over a period of months, or just by chilling the beer as low as -1°C for a few days. The cooling is designed to increase stability in the beer and causes any remaining reduced-temperature, precipitating proteins to drop out of the liquid. There are other methods of clarifying used for different types of beer as well. After any of the above processes are completed, the beer needs to be clarified further through filtration. The most common method of filtering in use today is passing the beer through diatomaceous earth, a mined substance containing skeletons of small primitive diatom organisms.

Once filtering is complete, other stabilizing or anti-oxidant ingredients, such as gypsum salts, may be added to the beer to extend the shelf life of the beer. The beer is then transferred to the bright tanks where it is stored until packaging. Before packaging, the right amount of Carbon Dioxide (CO₂) is added or removed for the desired amount of carbonation. The beer is then either packaged in cans, glass bottles, or kegs. The packaging process must be performed such that no oxygen is introduced into the beer, as this would cause the beer ingredients to oxidize and quickly become stale. To ensure that no oxygen escapes into the bottles, a drop of liquid nitrogen is placed at the bottom of the bottle prior to filling to displace any oxygen. All packaged beer must meet specific regulations depending on where it is to be marketed (Bamforth, Nice).

### 2.2.2 Beer Types

Alterations made to the ingredients and techniques described above result in the many different characteristics and styles of beer produced. Traditionally, beers can be grouped into three main categories. Beer can be grouped into are ales, stouts, and lagers; characterized by the types of yeast used, top-fermenting for ales and stouts, and bottom-fermenting for lagers. Generically, the term “beer” often may be used to describe any one or all three of these main categories. However, the advancement of brewing techniques through time has created an even wider variety of categories based, for example, on the
process used, visual or taste characteristics, or other distinguishing features such as light or non-alcoholic beers (Bamforth).

2.2.2.1 Ales

There are many different types of beer within the main category of ales, such as pale ale, dark ale, brown ale, Belgium ale, German ale, cream ale, India pale ale, Irish red ale, and others. Ales are brewed using malted barley, top fermenting yeasts \((Saccharomyces cerevisiae)\), relatively higher fermentation temperatures and relatively fast fermentation periods resulting in full-bodied, somewhat sweet beers, frequently with fruity flavors. Most ales use hops in the brewing process along with many different, often proprietary, types of herbs and spices (Bamforth).

2.2.2.2 Stouts

Stouts are similar to ales, as they also are processed with top-fermenting yeast; the major distinction is the grains used in stouts are roasted barley or roasted malts resulting in a generally darker color and stronger flavor. As with ales, there are many different types of stouts including porter, dry stout, imperial stout, oatmeal stout, chocolate stouts, and others. Stouts also generally have higher alcohol content than ales (Bamforth).

2.2.2.3 Lagers

Lagers differ from both ales and stouts in that they use bottom-fermenting yeasts that ferment slowly and at lower temperatures and result in a pale to golden colored product with a dry, clean, and crisp flavor due to the acidity. The main ingredients distinguishing lagers are the pilsner malts and noble hops (Bamforth).

2.2.2.4 Light Beer

Light beer makes up the biggest and most popular market for beer in the United States. Any remaining carbohydrates are removed from the beer post fermentation resulting in lower calorie beer. Light beer also frequently has less alcohol as well, as alcohol is a calorie source in itself (Bamforth).
2.2.2.5 Draft Beers

Draft beer generally refers to the way in which the beer is sold and dispensed. Beer can be packaged in cans, glass bottles, or kegs. Beer dispensed from kegs via pipes and pumps in a public house or bar is referred to as draft beer. Draft beer is also used to describe beer sold in small packs that has been sterilized but not pasteurized, therefore not heat-treated and theoretically retaining more of its original characteristics (Bamforth).

2.3 Wachusett Brewing Company History and Process

Wachusett Brewing Company (WBC), a microbrewery located in Westminster, MA, was founded in 1993 by three entrepreneurial-minded graduates of Worcester Polytechnic Institute, Kevin Buckler, Ned LaFortune, and Peter Quinn. They brew several types of ales, the most popular of which is their blueberry beer, which makes up over 50% of their sales.

The WBC process generally follows the process previously described along with their unique recipes and techniques. The process begins with the selected amounts of the various malts that WBC utilizes, with the exact recipe dependent on the type of beer being produced. The most common malt used in the WBC process is 2-rowbarley malt although each type of beer uses different combinations of different malts. The malt is first milled through a gravity-fed roller mill and is collected in the grist case where it is held before being transferred to the mash tun. Milling is a very important and delicate process as the endosperm of the malted barley is exposed important for the cultivation of yeast later on, however, it is necessary to not over process the grain as this could cause a degradation of the husk, possibly causing a stuck mash in the mash tun. WBC goes through approximately 60,000 pounds of grain in just one week of production (Groth, Croteau).

The milled grain is fed to the mash/lauter tun where it is sprayed with hot water allowing the malted grain to be converted to fermentable sugars. Care is taken to make sure none of the grain is left dry and that they are held at the correct temperature, 150 °F, to ensure maximum conversion to fermentable sugars by the alpha enzymes, breaking the sugar chains in half, and the beta enzymes, breaking the chains several more times. The
grains remain in the mash tun for approximately one hour before the liquid is drained off. The remaining grains are sparged and all of the liquid is transferred to the brew kettle.

In the brew kettle, the hops are added and the wort is boiled for around 90 minutes. Depending on the style of beer, more hops may be added in the last 10 minutes of the boil. The boiling sterilizes the beer and boils of the volatile sulfur and other chemicals that could become sulfur. The sulfur comes from chemicals in the grain that change during the brewing process. A loss of nearly 6 percent of the liquid is expected in this part of the process (Howard).

The sterilized wort is then fed tangentially into the whirlpool vessel followed by the heat exchanger which uses cooling water to cool the wort to a temperature low enough to allow the yeast to thrive, approximately 68 °F. Upon exiting the heat exchanger and before entering the fermentation tank, 8 to 14 parts per billion of oxygen is added to the wort in the line as it exits the heat exchanger, to activate and facilitate the life of the yeast. In the fermentation tank, WBC adds their specific strain of yeast. The yeast is recovered from the bottom of the tank at the end of the fermentation and viable yeast is re-used several times before being discarded so the yeast pitched could range from new to several generations old. The fermentation process initiated by the yeast is exothermic requiring WBC to provide cooling to the tank through a jacket using ethylene glycol heat transfer fluid. Fermentation occurs for four to eight days depending on the type of beer. Once fermentation is complete, the beer is cooled from 68 °F to 52°F causing all of the viable yeast to settle out in the conical bottom of the fermentation tank. The beer is further cooled to 32 °F causing any remaining yeast to settle out. This part of the process also creates a protein “chill haze” that allows the rest of the solids to be filtered out in the later steps.

From the fermentation vessel, the beer is filtered through diatomaceous earth. Any particle larger than one micron is removed. The beer is then stored in a bright tank where it is conditioned and additional CO₂ is added. The beer is further processed by being passed through a dual-stage cartridge membrane system to remove any particles larger than 0.45 microns and to remove any leftover proteins that can cause cloudiness, haze, or an off-taste. The beer is then packaged in glass bottles or kegs and distributed to retailers by distributors.
2.4 Brewery Wastewater

Water is the largest raw material used in the brewing process which requires an estimated seven barrels of raw water to produce just one barrel of beer. Generally, roughly 65% of the total water used in the brewery ends up as wastewater while a small portion of the water is boiled off during the kettle boil or captured in the spent grain (Ockert 139). Brewery wastewater is produced through several brewing processes including fermentation vessel bottoms, vessel and keg washes, as well as other wash water used in the brewery. With such a large volume of wastewater being produced in the brewing process, it is important to have a thorough understanding of wastewater properties and characteristics and the applicable national, state and local regulations regarding wastewater treatment and disposal.

2.4.1 Wastewater Characteristics

In order to determine the proper treatment and disposal of wastewater, the type and level of pollutants in the wastewater must be characterized. Water treatment facilities set specific standards on the types and levels of pollutants in wastewater which are acceptable to treat. There are several ways to measure the principal pollutants in wastewater, and a description of the methods utilized follows.

2.4.1.1 Biochemical Oxygen Demand

In wastewater and wastewater treatment, a variety of aerobic organisms oxidize various organic matter contained in wastewater. The amount of oxygen consumed in this oxidation process is known as the biochemical oxygen demand (BOD). The BOD for a wastewater stream can be determined by incubating a bacterial culture in the wastewater at 20 degrees Celsius for a period five days. The difference between the final and initial dissolved oxygen content is determined to be the BOD of the wastewater. BOD is a qualitative method to determine the initial quality and levels of organic matter in wastewater and BOD is considered a conventional pollutant and Publicly Owned Treatment Works (POTWs) often set effluent limitations on the levels of BOD that are acceptable for wastewater generators to discharge.
2.4.1.2 Chemical Oxygen Demand

The chemical oxygen demand (COD) is the amount of oxygen required to completely oxidize all of the organic matter contained in wastewater to form carbon dioxide, ammonia and water. The COD test is performed under acidic conditions using a strong oxidizing agent and it can be completed in around 2 hours. The COD is another quantitative method for determining the levels of organic matter in wastewater and effluent limitations are again established by POTWs for the levels of acceptable COD in wastewater discharges from POTW users.

2.4.1.3 Total Suspended Solids

Total suspended solids (TSS) is the level of solids suspended in wastewater which are usually removed by filtration. TSS can be measured by running a sample of wastewater through a specified filter and determining the weight of solids retained by the filter. TSS is considered a conventional pollutant and once again effluent limitations are established by POTWs for the acceptable level of TSS in wastewater discharges.

2.4.1.4 pH and Temperature

Effluent limitations are also established for acceptable ranges of wastewater pH. Acidic wastewater with pH levels below 6 can interfere with the bacteria used at the POTW to treat wastewater. Highly basic wastewater with pH levels above 10 can damage the piping used in the sewer system as well as interfere with the POTW operations. Wastewater streams of high temperature are also of concern. Temperatures above 140 degrees Fahrenheit can interfere as well as pose as a safety risk with POTW operations and operators.

2.4.2 Clean Water Act

The Clean Water Act (CWA) was enacted by congress in 1972 and further amended in 1977 with the purpose of maintaining water quality in the nation’s waters. A level of cleanliness and a degree of required POTW wastewater treatment is accomplished by prohibiting the discharge of any polluting wastewater into navigable waters without a permit that specifies allowable pollutant discharge limitations. The
CWA enabled the Environmental Protection Agency (EPA) to establish and enforce nationwide effluent standards on an industry by industry basis for 21 major industry categories and set limitations for over 65 toxic pollutants for each of the 21 categories. The CWA also established guidelines for new source performance standards and pretreatment standards for conventional pollutants such as Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), fecal coliform, oil and grease, pH, and temperature.

The overall objective of the CWA is to “restore and maintain the chemical, physical, and biological integrity of the nations waters” by eliminating the discharge of pollutants into surface waters while establishing and enforcing water quality of standards for the nations waterways. Such water quality standards are to be achieved by a permitting system to control the types and amounts of pollutants discharged into such waterways. Such permitted discharges are regulated and enforced at both federal and state levels controlled by the National Pollutant Discharge Elimination System, or NPDES (Cheremisinoff 76-78).

The CWA also establishes systems and procedures for providing partial funding for the construction of water treatment works as well as setting national pretreatment standards to protect the workers and operations of the water treatment works.

2.4.2.1 National Pollutant Discharge Elimination System (NPDES)

The National Pollutant Discharge Elimination System (NPDES) is a permit program implemented by the CWA to meet the water quality standards established by the CWA. NPDES requires a permit for all point source discharges into the waters of the United States. A point source discharge is defined as “any discernable, confined and discrete conveyance….from which pollutants are or may be discharged”. Conveyances are simply defined as any pipes, ditches or other means by which pollutants can be discharged into waterways. Pollutants are defined as any dredged soil, solid wastes, sewage, garbage, chemical wastes, heat, and radioactive wastes that might be contained in such discharged water (Gallagher 9-10). The permits give the permittee the right to discharge specified levels of pollutants and the permits are issued by the EPA and/or by states authorized by the EPA. Examples of discharges that require NPDES permits are
industrial process water and non-contact cooling water and collected, point source, storm water runoff. Other non-point sources of storm water runoff such as sheet runoff do not require a discharge permit by NPDES (Sullivan 114). Wastewater that is not discharged directly into national waterways is not subject to the NPDES, but is addressed in other areas of the CWA including the national pretreatment program. Discharges to both the ground and surface water also require permits under the NPDES system.

2.4.2.2 National Pretreatment Program and Applicable Regulations

Wastewater that is not discharged into the nation’s waterways and rather discharged into a public sanitary sewer system is determined as non-point sources and is not subject to the National Pollutant Discharge Elimination System. Instead, non-point sources that discharge into POTWs are subject to and regulated by National Pretreatment Program which is again established by the CWA. The National Pretreatment Program establishes limitations on discharges into public sanitary sewers systems and functions to establish the regulatory backbone for the proper treatment and disposal of wastewater on the federal, state and local levels (Gallagher 105-106). First, discharges are subject to national general limitations on prohibited discharges including national categorical industry standards. Secondly, discharges are subject to state prohibited discharges and finally they are subject to limitations established by the receiving POTW. Most discharges are regulated by appropriate permits that are issued by the receiving POTW which must be in agreement with both state and federal regulations (Sullivan 136).

2.4.2.2.1 National Standards

In order to fully understand the national pretreatment program, one needs to have an understanding of the applicable standards and regulations on both the national and state levels. National pretreatment regulations can be found in 40 CFR 403 which is summarized as follows. It is important to note that the following is a summary of the applicable regulations and dischargers must consult the complete regulations for a more comprehensive understanding in order to be in compliance.

2.4.2.2.1.1 40 CFR 403 – General Pretreatment Regulations for Existing and New Sources of Pollution
The purpose of 40 CFR 403 is to “establish responsibilities of Federal, State and local government, industry and the public to implement national pretreatment standards to control pollutants which pass through or interfere with the treatment process in POTWs or which may contaminate sewage sludge.” (403.1). This regulation is applicable to industries which directly discharge into a POTW and was established to fulfill water quality standards established in the Clean Water Act and its National Pollutant Discharge Elimination System. The objective of such established responsibilities is to prevent the introduction of pollutants into POTWs, which interfere and disrupt the treatment process, which may result in pollutants passing through the POTW as well as contaminate the sludge produced by the POTW or cause harm to POTW operators. Such restriction on the types and levels of pollutants also encourages industries to recycle, reclaim, eliminate or pre-treat pollutants that would otherwise be discharged into the POTW.

2.4.2.2.1.1.1 National Pretreatment Standards – Prohibited Discharges

40 CFR Part 403 Section 403.5 prohibits discharges of pollutants that interfere or pass through any POTW and sets up specific prohibitions on pollutants that must not be introduced into a POTW.

(1) Pollutants which create a fire or explosion hazard or have a flashpoint of less than 140 degrees Fahrenheit.

(2) Pollutants which will cause corrosive structural damage to the POTW and in no case discharges with a pH lower than 5.0 unless otherwise specified by the POTW.

(3) Solid or viscous pollutants in amounts that cause obstructions in flow and operation of the POTW.

(4) Any pollutant with oxygen demands (BOD & COD) that may interfere with the operation of the POTW.

(5) Heat in amounts that the temperature at the POTW exceeds 104 degrees Fahrenheit which would interfere with the operation of the POTW.
(6) Petroleum oil, non-biodegradable oil and any other oil that would interfere with the operation of the POTW.

(7) Pollutants which result in the production of toxic gases, vapors, and fumes which would endanger POTW worker health and safety.

Section 403.5 also enables each local POTW to require dischargers to develop an individual pretreatment program to implement the specific limitations above as well as any other limitations to prevent pollutant pass through and disruption of the POTW operation.

2.4.2.2.1.1.2 National Pretreatment Standards - Categorical Standards

40 CFR Part 403 Section 403.6 establishes industry based categorical pretreatment standards for pollutants and pollutant properties that may be discharged by industrial users, based on the industry type. Written request must be completed to determine if the industrial user qualifies for a particular category. Industries that are included in such categorical standards are usually subject to stricter effluent limitations due to the greater volumes, known industry type pollutants and pollutant levels in the wastewater that they discharge. In addition, any added processes or process modifications must receive certification prior to implementation (40 CFR 403).

2.4.2.2.2 Local Standards

Federal regulations apply to the federal level and provide general guidelines on the limitations associated with wastewater discharges. Regulations are also established on the state and local levels and are applicable to the wastewater issues and concerns found locally. Local pretreatment standards and regulations can be found in the Massachusetts Department of Environmental Pollution (DEP) 314 CMR 12.00 and sewer system extensions and connections regulations can be found in 314 CMR 7.00, both of which are summarized as follows. Again, it is important to note the following is a summary of the applicable regulations and complete compliance would require consultation of the complete regulations for a more comprehensive understanding.
2.4.2.2.1  314 CMR 12.00 - Operation and Maintenance and Pretreatment Standards for Wastewater Treatment Works and Indirect Discharges

The purpose of 314 CMR 12.00 is to insure the proper operation and maintenance of POTWs within the Commonwealth of Massachusetts. This is achieved by compliance with established operational standards and procedures for POTWs as well as establishing prohibited discharges and pretreatment standards for the state of Massachusetts.

2.4.2.2.1.1.1 Prohibitions and Standards for Discharges to POTWs

It is important as an industrial discharger to follow all state regulations regarding prohibited discharges that are additional to federally established prohibited discharges. In Massachusetts, 314 CRM 12.08 establishes such prohibitions and standards for wastewater discharges to POTWs. As with the national general prohibitions established in 40 CRF 403, no person shall discharge materials or pollutants that cause harm, disrupt, or pass through the POTW. Specific prohibitions are similar to those established in 40 CFR 403 with the lower pH discharge limit set to 5.5 rather than 5.0 and the upper pH limit set to 10.0. In addition, section 12.08(3) states that any discharger must also comply with the local sewer use rules and regulations established by the receiving POTW (314 CMR 12.00).

2.4.2.2.2  314 CMR 7.00 – Sewer System Extension and Connection Permit Program

314 CMR 7.00 establishes a program in which sewer system extensions and connections are regulated by permits to insure the proper operation of wastewater treatment facilities. It is the permitting process established in this CMR that enforces the effluent limitations that are established in 314 CRM 12.00.
2.4.2.2.2.1.1 Activities Requiring a Permit

Section three of this CMR states that no person shall construct, effect, maintain, modify or use any sewer system extension or connection without a currently valid permit from the Massachusetts Department of Environmental Protection unless such activity meets all the applicable conditions stated in 314 CMR 7.05. It also states that the Mass DEP may require any person to provide information to determine whether that person is subject to any regulation of this CMR.

2.4.2.2.2.1.2 Activities Not Requiring a Permit

There are some activities that are determined to not require a permit; they include but are not limited to the following conditions.

(a) Existing sanitary sewer connections constructed prior to May 10, 1979 do not require a permit as long as they have not been physically altered since construction.

(b) Sanitary sewer connections that have been previously permitted by the Mass DEP which are maintained according to the permit do not require any additional permits.

(c) New sanitary and industrial sewer connections of less than 15,000 gallons per day do not require a permit as long as the facility Standard Industrial Classification (SIC) code is listed in 314 CMR 7.17(2)c. Breweries have a SIC code of 2028-Malt Beverages which is listed in this section under 2000-3999 Manufacturing. Industrial users listed under 314 CMR 7.17(2)c with a new or existing sewer connection that discharge greater than 50,000 gallons per day to POTWs with Industrial Pretreatment Programs (IPP-POTWs) require a sewer connection permit (314 CMR 7.00).

2.4.2.2.2.1.3 Summary

This CMR sets up guidelines for which processes need to acquire permits and which do not. For the industrial discharger, the level of Mass DEP approval depends on the volume of discharge and the availability of a pre-treatment program in the wastewater treatment plant that receives the discharge. A “Permit by Rule” approval is required for a
facility that discharges less than 50,000 gallons per day into a POTW that operates an Industrial Pretreatment Program. Permit by Rule does not require the discharger to file any paperwork with the Mass DEP as long as they meet all applicable local and federal requirements established in 314 CMR 12.00 and 40 CFR 403.

2.5 General Waste Regulations

2.5.1 Emergency Planning and Community Right-to-Know Act

In response to the industrial accidents such as the 1984 Union Carbide disaster in Bhopal, India, where over 3,500 people were killed by facility escaping methyl isocyanate gas, Congress passed the Emergency Planning and Community Right-to-Know Act (EPCRA), also known as the Superfund Amendment Reauthorization Act (SARA), which is covered in 40 CFR 355.30. This act is intended to inform community and local agencies of the quantity and types of hazardous materials being used and discharged by local industries as well as the hazards associated with them. The governor of each state is responsible for creating a State Emergency Response Commission (SERC), which will appoint, supervise, and coordinate Local Emergency Planning Committees (LEPC’s) compromised of appropriate local government and public service officials. A facility falls under the act when it uses or stores one or more extremely hazardous substance (EHS) at or above the threshold planning quantity (TPQ). If a facility is using an extremely hazardous substance it is responsible for notifying the LEPC within 60 days of falling within the requirements of the title and must include an inventory of all EHS manufactured, imported, or released at the facility.

2.5.1.1 Hazardous Chemical Inventory and Toxic Chemical Reporting

Hazardous Chemical Inventory and Toxic Chemical Reporting was established to collect information to inform the public and the communities surrounding a facility about the hazards associated with chemical storage and possible releases from that facility. Hazardous chemical inventory reporting is covered in 40 CRF 370 and requires facilities to file annual Tier II reports for EHS materials that exceed thresholds and those materials that require a Material Safety Data Sheet (MSDS) and are inventoried on site at levels greater than 10,000 pounds. It also requires the facility to submit copies of their Material
safety data Sheets (MSDS) to their local emergency planning committee and fire
departments

Toxic chemical reporting is covered in 40 CFR 372.00 and not all facilities are
subject to chemical reporting. Facilities with 10 or more full time employees and a SIC
code between 20 and 39 which produce, process or use an EHS greater than the TPQ
must follow chemical reporting regulations. Common threshold planning quantities are
defined as manufacturing or processing 25,000 pounds or otherwise using greater than
10,000 pounds of the EHS of the chemical per calendar year. Reporting requirements are
covered in 40 CFR 372.30 and requires the facility to file an EPA Form R in accordance
with instructions covered in the CFR (Bregman 217-222).

2.5.2 Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) were enacted in 1976 as an
expansion of the Solid Waste Disposal Act of 1965. It regulates the generation,
management, transportation, treatment, storage, and disposal of hazardous waste. This
regulation includes a predetermined list of substances deemed hazardous waste by virtue
of the substance’s known hazards. In addition to the list of substances applicable under
this act, waste byproducts, spills, and cleanup materials that have a pH less than 2.0 or
greater than 12.5 must be managed and handled as RCRA, and Mass. DEP hazardous
waste.

2.5.3 Massachusetts Toxic Use Reduction Act (TURA)

The Toxic Use Reduction Act (TURA) was established in 1989 by the
Massachusetts Department of Environmental Protection to promote reduction in the
usage of hazardous and toxic substances in companies as well as promote a reduction of
the amount of required permitting subject to those companies. The act requires
companies that use large quantities of specific toxic materials to investigate toxic usage
and pollution prevention opportunities and report their findings on a yearly basis with a
TURA report. TURA-listed chemicals include any toxic substances listed in section 313
of Emergency Planning and Community Right to Know Act (EPCRA) as well as those
listed in the Comprehensive Environmental Response, Compensation, and Liability Act
(CERCLA). The complete documentation of TURA can be found in the regulation 310 CMR 50.

There are several benefits that result from toxic use reduction that are advantageous to companies. Use reduction can result in process modification, recycling in the process, and substitution with less hazardous chemicals all of which can reduce operating costs as well as minimize waste and byproduct production.

### 2.5.3.1 TURA Applicability

The Toxic Use Reduction Act applies to companies that meet at least one of the following three criteria:

1. Manufacture, process, or otherwise use a TURA-listed chemical at or above any one of the following reporting thresholds for an annual basis:
   i. 25,000 pounds for a chemical that was manufactured or processed;
   ii. 10,000 pounds for a chemical that was otherwise used;
   iii. 1,000 pounds for a higher hazard chemical that was manufactured, processed, or otherwise used.
   iv. For designated Persistent Bioaccumulative Toxics, 100 pounds, 10 pounds, or 0.1 gram, depending on the specific chemical.

2. Employ the equivalent of ten or more full-time workers.

3. Fall within at least one of the following Standard Industrial Classification codes
   i. 10 through 14 – Mining
   ii. 20 through 39 – Manufacturing
   iii. 40, 44 through 49 – Transportation
   iv. 50 and 51 – Wholesale
   v. 72, 73, 75 and 76 – Certain Services

If a company meets any of the paragraph 1 criteria mentioned above, they are classified as a Large Quantity Toxics User (LQUTU) and are required by TURA to complete the following responsibilities.

1. Submit a Toxics Use Reduction report to the Mass DEP every year.
2. Develop an initial toxics use reduction plan the first even-numbered year after filing, as well as update the plan every even-numbered year thereafter, and a summary of the plan and updates must be submitted to the Mass DEP.
3. Once the toxics use reduction plan has gone through two updates, a resource conservation plan including energy, water, or materials can be prepared.
4. Pay an annual toxics use fee ranging from $1,850 to $9,250, depending on the number of employees at the facility, and $1,100 for each chemical that is reported.

If a company doesn’t qualify as a large quantity toxics user, they are called a small quantity toxic user and are not subject to TURA reporting. Information regarding the development of a toxics use reduction plan, annual reporting, and specific toxics use fees can be found through the Mass DEP website. If a company fails to meet the requirements established in TURA, the Mass DEP may take enforcement action as well as financial penalties.

2.5.3.2 Rules for Determining the Amount of Toxic Substances Manufactured, Processed, or Otherwise Used

In order to determine if a company is a Large Quantity Toxic User and if TURA is applicable, the amount of a toxic substance manufactured, processed, or otherwise used must be determined. If a company manufactures, processes or otherwise uses a toxic substance that is contained as part of a combined product as is the case at WBC, the amount of that toxic substance that is used must be determined. There are several guidelines for determining the amount of such toxic substances and a complete listing can be found in 310 CMR 50.20, a listing of those applicable to WBC are as follows;

1. When a facility manufactures, processes, or otherwise uses more than one member of a TURA toxic chemical category, the individual members will be added together in order to determine the amount of toxic substance manufactured, processed, or otherwise used.
2. If a facility uses a recycle/reuse operation with a TURA toxic chemical, the user shall count the amount of the toxic substance added to the recycle/reuse operation during a calendar year.
3. If a toxic substance is present as a component of a mixture or a trade name product, the user shall consider the quantity of the toxic substance. If the user knows the specific chemical identity of the toxic substance and the specific concentration at which it is present in the mixture or trade name product, the toxics users shall determine the weight of the toxic substance manufactured, processed, or otherwise used. Concentration determination guidelines are provided in the TURA regulation.

2.6 Air Emissions in a Brewery

Air emissions of a brewery, especially of a local brewery, are of less concern than the wastewater produced. There are far greater potential hazards leaving the brew house in its wastewater including high pH, high organic content, and high temperature. Even the solid waste generated from a brewery, such as the spent grain and spent diatomaceous earth filter media, are more of a concern than air emissions. Though this may be the case, a brewery must take into account any gaseous waste streams that may be deemed hazardous in order to be in compliance with all environmental standards. Furthermore, even if a brewery is not discharging in violation of any Clean Air Act law, its owners may wish to reduce certain air emissions if for nothing more than establishing “green” best management practices. In some cases, it may not be economical to reduce or recycle waste gas streams. This situation yields to the environmental laws provided by the states.

2.6.1 Carbon Dioxide

There are several waste gas streams produced by breweries that can be and studied to develop a plan for emission reduction. The first and foremost air emission comes in the form of carbon dioxide. Carbon dioxide is a greenhouse gas that is produced during the fermentation process and possibly as a result of energy production.

Fermentation is the process of consuming sugars by yeast to produce sugars under anaerobic conditions (CO₂ Chemistry). One by product of this is carbon dioxide. This process is of high importance and necessity to a brewery. Without it, the brew process would be without alcohol or the bottled carbonation and beer would be a whole different beverage. Unfortunately, carbon dioxide is not a good material to release into the
atmosphere in large quantities due to it being recognized as a known greenhouse gas. Unfortunately, it is a very costly emission for a brewery to reduce or capture. Carbon dioxide is known to be bubbling through hoses in the water seals of all the fermentation vessels during the entire fermentation cycle. Often this carbon dioxide is released from the bubbling water seal directly into the atmosphere. This makes it very difficult for a brewery to capture these outputs before they escape into the environment.

Furthermore, the equipment needed to recycle the carbon dioxide in the system is very expensive (Witteman). This makes it very hard to justify the capital cost especially when a brewery may be in compliance with all other regulations. This is not the only problem with capturing the carbon dioxide. Even if it was captured for recycle, most of it would still be released during the next batch. This is due to the fact that a surplus of carbon dioxide is produced with each batch of beer. Only a small fraction is reintroduced into the system for some minor control of carbonation. Far more is produced than needed for this control (Ockert). Furthermore, for the small amount of carbon dioxide that is needed to control carbonation, it is cheaper to purchase gas bottled carbon dioxide rather than implement a carbon dioxide recovery system. The problem is that there is nowhere for the other carbon dioxide to go except into the atmosphere. This makes it far cheaper to purchase the small amount of carbon dioxide rather than attempt to recycle the lower concentration carbon dioxide the process already generates.

The alternative to reusing the collected carbon dioxide is to collect and liquefy the carbon dioxide. Then it can be sold as a raw material for another consumer who can use this quality of raw material for their process rather than let escape into the air (Witteman). However, a small brewery does not produce enough carbon dioxide to make this a worthwhile endeavor. Some large scale breweries do institute recycle streams and collection vessels to resell their waste carbon dioxide as they are producing vast quantities of carbon dioxide which off sets the capital cost of new equipment.

In addition to the fermentation process, carbon dioxide waste can result through the use of energy used during many steps in the brewing process. If the required heat is being produced by the combustion of hydrocarbons, carbon dioxide emissions will clearly increase. Once again, it is rare that this emission of carbon dioxide from any brewery process is of any significance when thinking about the entire scope of
environmental concerns for a brewery. However, being that a greenhouse gas has been determined as a source of global warming, these fugitive emissions are not beneficial to the environment. However, the emission is small in relation to other sources of carbon dioxide emission, such as power plants, automobiles or numerous other industrial processes.

No matter the situation, carbon dioxide is harmful to the environment and should be minimized wherever possible. Many variables must be weighed when justifying the initial investment over the long term gain. For a small brewery, it has not proved to be economical for carbon dioxide recycle or recovery and natural gas combustion is also the current most economical energy source for the brewery. This may change in the future as technology advances; however, until then, a small brewery fermentation process is more than likely going to release minor amounts of this greenhouse gas into the environment.

2.6.2 Noise and Odor

Residential communities and industrial grounds have been living side by side ever since the industrial revolution well over a century ago. As factories of all types are built, living communities spring up alongside in order to provide labor. Often large sections of towns are districted as industrial with the housing in the surrounding areas. Nobody wants to live beside a noisy factory with trucks and trains always driving by. Each branch of industry poses different concerns for the surrounding community. A power plant could cause of fire. A quarry may have lots of loud equipment always running. A waste water treatment plant may have a horrific odor. In these cases housing communities are rarely found nearby. However there are certain situations where an industrial process may be located near homes. In the case of a brewery, the hazards and annoyances are minimal to the surrounding community. One of the biggest concerns is the odors emitted from the wort boiling (Ockert). To some the odor may be pleasant; to others it may go unnoticed. Regardless it must be addressed by the brewery to the specific surrounding neighborhood. As in the case with the carbon dioxide emissions, large scale breweries are not in the same category as microbreweries or specialty breweries. Large scale breweries tend to be located farther away from residential communities. The large scale brewery will probably own a sizeable land area surrounding
their plant. This is necessary due to the larger affect of odor and trailer truck traffic. A small brewery may have homes located nearby, but the odors will be far more subtle. Once again a balance must be reached between the brew company and its neighbors. The odors from the brewery can be minimized by condensing the vapors from the wort boiling. Once again, a costly piece of equipment must be installed in order to reduce the smell. In most cases, the smell emanating from a brewery is going to be of little importance or concern.

2.6.3 Dust

Another air quality concern can be sourced from dust billowing from the mash as it is ground from whole kernels. This also may not be an environmental concern due to the locality of the dust and the nature of the waste. However, dust can be a nuisance for the employees or visitors and should be evaluated.

Whole kernels of a variety of different grains are crushed and ground into powder in order to properly release the maximum amount of sugars for fermenting in the beer (Nice). This fine matter can be thrown air borne during this mashing process. Though this is of almost no environmental concern, it may be a concern to the employee’s safety. No one wants to work in a dusty environment and breathe in crushed grains. There are a variety of simple things that can be instituted to reduce the amount of dust in the air. The grinder should be covered at all times and any exhaust air should be fitted with filters. Upon completion, the mash should be allowed to settle before transferring it to the next step. If the mash is pumped over to the next step, the hose should be tightly fitted to avoid fugitive dust. Lastly, employees should have access to dust masks in order to protect them from any dust that may be in the air. Though dust may not be deemed hazardous to the environment, it still should be controlled to prevent respiratory particle exposure to the workers.

2.6.4 Volatile Organic Compounds

One final air emissions hazard in the beer making process is volatile organic compounds (VOCs). These may be the hardest of all the wastes air streams to control in the brew process due to the breadth of substances available. VOC’s have the ability to be emitted from a variety of the steps in the brew process ranging from the mash tun to the
brew kettle to the fermentation tank (Rapoport). To completely remove all VOC emissions, each step would require a scrubber to remove the organics. The best way to deal with VOC’s is to focus on the emission of most harmful concern. Often a brewery will not emit nearly enough VOC’s to be in violation of any laws or regulations. However, studies have been done to see where the worst emissions occur. Once again, large breweries and small breweries have different problems. Large breweries naturally yield the most organics, but smaller breweries yield more organics per liter of beer (Rapoport). The fermentation room of a small brewery, on average, discharges most of the VOC’s. In a large brewery, the majority comes from the brew kettle. This can be contributed to the fact that large breweries can afford activated carbon in their vent stacks, which absorbs many of the organics before being emitted to the environment. Collection and treatment equipment such as scrubbers can be costly, especially for a small brewery not in violation of any emission standard. Either way, VOC emissions should be reduced wherever possible.

Regardless of the situation, it should be each brewery’s goal to seek zero emissions to the environment. This situation with current technology is not likely possible. However it is imperative that all breweries view their air emissions as potential problems and if possible reduce the quantity of emissions in every step of the brew process.
3 Methodology

The main objectives of the project are; determine and research all environmental regulations, with primary focus on wastewater, applicable to Wachusett Brewing Company, study the brewing process and identify all waste streams through a complete material balance, examine purchase and inventory records to determine yearly usage of identified materials of concern, sample and test wastewater streams at various points for pH, COD, and TSS, determine environmental compliance, and finally to research and recommend possible brewing and cleaning process modifications to ensure current and future compliance. This will be accomplished through several steps outlined below.

3.1 Background Research of Applicable Regulations

In preparation for the process observation, sampling, and testing portions of the project, background research was completed including all national, state, and local environmental regulations to determine which are applicable to WBC processes. A summarization of all applicable regulations and how they relate to WBC is included above under brewery wastewater and general brewery waste.

3.2 Material Balance

In order to get a better understanding of where problem areas may arise regarding waste discharge at WBC, an overall material balance was conducted on both the brewing and cleaning processes. The purpose of this was to be able to follow certain raw materials through the process and identify where the problematic waste is discharged. This was completed both through communication with WBC staff and process observation. Each step in the process, both brewing and cleaning, was thoroughly studied by one or more members of the team over the course of a week. As the steps completed may vary throughout the day and day to day over the course of a week, the team ensured that all steps were covered by observing on several different days at several different times. In addition, communication with WBC staff was conducted to determine which days of the week followed the same schedules to make certain that no steps were missed. Once all
entering and exiting materials were identified and traced, the materials of interest for further consideration were identified.

### 3.2.1 Brewing Process Observation

Observation of the brewing process alone was carried out first. This was done as a group beginning with a walk through following the path of one batch of beer with WBC staff. Following these observations, an initial material balance was completed including flow of all materials in and out of each vessel and generally in and out of the entire system. The material balance was revised several times after further communication with WBC staff to ensure complete accuracy. This preliminary material balance included all materials used even those that are conserved or are not of environmental concern.

### 3.2.2 Cleaning Process Observation

The most significant source of environmental concern in Wachusett Brewing Company’s wastewater comes from the cleaning processes for their equipment. A strong caustic, comprised of 30% Sodium Hydroxide, and acid comprised of less than 38% Nitric acid and less than 12% Phosphoric acid, are used in order to ensure the cleanliness of each vessel as sterilization of all equipment coming in contact with the beer is an important factor in the quality of the final product. All wash water is sent directly down the drain to the local POTW, Fitchburg East, without any treatment or monitoring system to verify the pH is within acceptable ranges for discharge to the local POTW. To determine exactly what is being discharged and in what amounts, the cleaning processes of each pieces of equipment were carried out. This included a qualitative and quantitative description of the cleaning processes including the amounts of caustic or other chemicals used, the amount of water used in the wash and diagrams of the major pieces of equipment using the highest amount of caustic. Each piece of equipment in the process has a different protocol for cleaning so each needed to be observed and recorded separately.

### 3.2.3 Identification of Materials of Interest

Based on the observations of the brewing and cleaning processes at WBC, the team considered all materials and determined which of those needed to be investigated further
in relation to general environmental impact reduction and applicable regulation compliance. Many of the materials used by Wachusett Brewing Company have little to no environmental impact or lead to no concern regarding disposal. Also, many raw materials are necessary to the brewing process and cannot be replaced or reduced without a significant harmful effect to the final product. However, during the study, five materials of interest were determined in area where improvement may be possible; caustic, acid, water, trub, and diatomaceous earth filter media. Each one posed a unique concern to the minimization of environmental impact and applicable regulatory compliance. Caustic and acid usage are dangerous and are regulated regarding how much can be used without exceeding a reporting threshold. Water discharge over certain limits can increase permitting requirements and may cause certain fees to be applicable; therefore, usage should be minimized. Trub as a material is not regulated; however the disposal of it in the wash water may increase COD levels which should be minimized. Finally, the DE filter media under certain conditions can be hazardous to employees working with it or to anyone exposed to it over a long period of time. Each of the aforementioned materials was investigated further within the following parts of the methodology.

3.3 Wastewater Sampling and Testing

In addition to identifying all waste streams and their paths, wastewater samples will also be taken at several locations and tested accordingly. This will allow identification of the areas in the process that may be problematic in raising levels of controlled quantities in wastewater. The following describes the sampling and testing procedures to be used.

3.3.1 Sampling Procedure

Wastewater samples were collected from various points in the cleaning processes as outlined in Table 1. All wastewater created is a result of a vessel cleaning process using either caustic or acid and thus appropriate safety precautions were taken by wearing gloves and safety glasses. Each sample container was triple rinsed with the sample stream to remove any existing contaminants before collecting the sample for testing. The samples were not likely to change in any way between collection and testing and were
not kept on ice. A formal chain of command was deemed unnecessary for this level of testing; however, the person whom collected and tested each sample was recorded and can be found in Appendix IV with the initial lab data.

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Sample Description (Location, Equipment, Processes Details, etc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mash tun rise (no caustic) after solids shoveled out, sample of waste stream going down the drain</td>
</tr>
<tr>
<td>2</td>
<td>Kettle bottoms (trub), collected from the first ten gallons as sample will have the highest amount of trub and subsequently highest solids and COD</td>
</tr>
<tr>
<td>3</td>
<td>Kettle wash sample (caustic) after trub was drained, sample of waste stream going down the drain</td>
</tr>
<tr>
<td>4</td>
<td>Whirlpool bottoms, mostly trub, collected from first 50 gallons emptied to get highest amount of trub and subsequently highest solids and COD</td>
</tr>
<tr>
<td>5</td>
<td>Whirlpool stream that went through exchanger, then to fermentor, collected sample with residual hops from whirlpool</td>
</tr>
<tr>
<td>6</td>
<td>Whirlpool caustic wash, sample of waste stream going down drain</td>
</tr>
<tr>
<td>7</td>
<td>Yeast drained off of the bottom of the fermentor, sample of stream going down the drain</td>
</tr>
<tr>
<td>8</td>
<td>Fermentor hot water prewash including residual yeast, sample of what is going down the drain</td>
</tr>
<tr>
<td>9</td>
<td>Fermentor caustic wash followed by water rise, sample of what is going directly down drain</td>
</tr>
<tr>
<td>10</td>
<td>Fermentor iodine water solution, last step to seal tank, sample of what is going directly down the drain</td>
</tr>
<tr>
<td>11</td>
<td>Bright tank caustic wash, sample of what is going down drain</td>
</tr>
<tr>
<td>12</td>
<td>DE filter caustic wash, sample of what is going down drain, collected during once weekly cleaning</td>
</tr>
<tr>
<td>13</td>
<td>Keg Washer waste water, sample of what is going down drain, collected during operation</td>
</tr>
<tr>
<td>14</td>
<td>Bottle packout caustic wash, sample of what is going down drain, collected during operation</td>
</tr>
<tr>
<td>15</td>
<td>Run off from grain truck collection bin</td>
</tr>
</tbody>
</table>

Table 1 Wastewater Sample Locations and Descriptions

**3.3.2 Testing Procedure**

There were three tests performed on the wastewater samples collected, pH, chemical oxygen demand (COD), and total suspended solids (TSS). Samples from each vessel were tested with one or more of the below tests. The chosen sample streams,
rationale and testing procedures are as follows. Further background information on the significance of these tests and the results is included in the background section.

### 3.3.2.1 pH Analysis

Brewery wastewater was sampled during the caustic washes of the mash tun, brew kettle, whirlpool, heat exchanger, fermentation vessels, DE filter, and bright tanks as well as during the operations of the keg and bottle washers. The pH of the wastewater samples for each process was determined by the use of litmus paper and an Orion 420A Simple pH/mV/ORP/Temperature Benchtop Meter. The pH meter reads to an accuracy of 0.001 and the margin of error is +/- 0.005. The pH meter was calibrated with pH buffers of 4, 7, and 10 and calibration was performed at the beginning of each reading to better ensure that an accurate reading was made.

#### 3.3.2.1.1 pH Dilution Calculations

An alternative method was considered for determining the pH of brewery wastewater to validate the results of our wastewater sampling. This method involved calculating the pH of the wastewater using the following equation given the amount of caustic and water used.

\[
pH = \log \left( \frac{lbs \ of \ caustic}{gallons \ of \ water} \times \frac{1}{3.33 \times 10^{-15}} \right)
\]

This method was also applied to investigate the pH of the combined caustic wash and rinse water involved in the caustic wash processes assuming that ideal mixing occurred by the time of street level discharge. These calculations were performed to prove that pH of the street level discharge is possibly lower than the sampled results of the caustic wash processes.

### 3.3.2.2 COD

Brewery wastewater was sampled and analyzed for chemical oxygen demand (COD) during periods of anticipated high organic matter content. Samples were
collected during washes of the mash tun, brew kettle, whirlpool, and the fermentation vessels as there is an expected high organic matter wastewater content resulting from trub, yeast, and spent hops and grains during these washes. Analysis was performed in Kaven Hall in the Wastewater Treatment Lab at Worcester Polytechnic Institute. A step-by-step procedure of the analysis completed is included in Appendix I.

3.3.2.3 TSS

Brewery wastewater was sampled and analyzed for total suspended solids (TSS) during periods of anticipated high organic matter and other solid content. Samples were collected during washes of the mash tun, brew kettle, whirlpool, and the fermentation vessels as there is an expected high organic matter and other solid wastewater content resulting from trub, yeast, and spent hops and grains during these washes. Analysis was performed in Goddard Hall in the Unit Operations Lab at Worcester Polytechnic Institute. A step-by-step procedure of the analysis completed is included in Appendix III.

3.4 Wastewater Regulation Compliance

Following the research and sampling portions of the project, the level of compliance within the applicable wastewater regulations was determined. This was done both by considering all quantitative information collected and calculated as well as qualitative observations made by the team.

3.4.1 Clean Water Act

In order to determine the applicability of the Clean Water Act to WBC, the wastewater characteristics of all wastewater produced at WBC were sampled and determined if it was within the limits and pretreatment standards established by the Federal Clean Water Act and any additional local standards. As mentioned in the background section, such limits and pretreatment standards state that wastewater pH must fall within a range of 5.5-10, must not contain an excessive amount of solid content, and must not contain excessively high levels of oxygen demand. Using the results from our wastewater sampling and testing, the applicability of the Clean Water Act was determined. In addition, the applicability of any projected local discharge permits were determined. Water usage records were researched and analyzed to determine the daily
level of wastewater discharge which was used to determine the type of local discharge permit applicable to WBC.

### 3.5 General Waste Regulation Compliance

Following the research and sampling portions of the project, the level of compliance within the applicable general waste regulations was determined. This was done both by considering all quantitative information collected and calculated as well as qualitative observations made by the team.

#### 3.5.1 EPCRA

The applicability of the Emergency Planning and Community Right to Know Act (EPCRA), also known as the SARA act, was determined by first identifying the type and amount all of the raw materials used and stored at the WBC facility. Once identified, it was determined if any of the raw materials were considered an extremely hazardous substance and whether or not it was used or stored at or above the threshold planning quantity. These usage and storage amounts were determined by investigating purchase and inventory records of applicable materials. With this information the applicability of the EPCRA to WBC was determined.

#### 3.5.2 RCRA

The applicability of the Resource Conservation and Recovery Act (RCRA) was determined by identifying any possible sources of hazardous materials potentially located at the WBC facility. This includes but is not limited to raw materials, products, byproducts, waste streams of any phase, and secondary materials used throughout the brewing process. Any material found to be hazardous was then studied further to understand its role at WBC. A material safety data sheet (MSDS) was acquired in order to understand the precautions necessary for handling the material, including storage and disposal. Using the obtained information the applicability of RCRA to WBC was determined.
3.5.3 TURA

The applicability of the Toxic Use Reduction Act to WBC was determined by first identifying all the substances manufactured, processed or otherwise used at WBC and then it was determined if any of these substances contained any of the TURA listed chemicals. If any of these substances contained any TURA listed chemicals, the amount of each TURA listed chemical manufactured, processed or otherwise used on an annual basis was then determined. These numbers were determined by investigating purchase and inventory records of applicable materials. Using this information the applicability of the TURA was determined.

3.6 Air Emission Regulation Compliance

Following the research and sampling portions of the project, the level of compliance within the applicable air emission regulations was determined. This was done both by considering qualitative observations made by the team as no quantitative data was collected or available in association with air emissions.

3.6.1 Clean Air Act

In determination of compliance within the clean air act, all sources of carbon dioxide released into the atmosphere were considered. As carbon dioxide only comes from the combustion of gas to heat the kettle and the by-product of the alcohol producing yeasts, the total amount released is very minimal and WBC needn’t be concerned further with air emissions or the Clean Air Act.
4 Results and Discussion

In completion of the above methodology, the team gathered many qualitative and quantitative results in relation to the environmental impact of WBC considering both regulation compliance and general affect on their surrounding environment. Following is a summarization and discussion of the most significant results.

4.1 Brewing Process Observation

The main result of the brewing process observation portion of the project was a general material balance including all materials entering and exiting the each vessel in the process. Through several days of process observation by each team member and personal communication with brewery staff the team created a general material balance in Appendix IV and more in depth qualitative descriptions of each piece of equipment as follows.

4.1.1 Mash Tun

The mash tun is the first step in the brewing process; the two materials entering the mash tun are the milled grain and water. The grain is added first and hot water is rained over the mashed grain in order to release the fermentable sugars that will eventually be digested by the yeast to produce alcohol and thus, beer. This process creates two exiting material streams, a sugar and water mixture, called wort, which is passed on to the brew kettle for further processing and the solid spent grain left in the mash tun. Fortunately, this grain is still very high in protein and can be used as feed for local farm animals and to minimize their solid waste. WBC shovels all of this spent grain down a chute and into a truck, which is then sold to a local farm as feed. By adding this step, not only do they minimize their waste, but they also gain back some of the raw material cost of the grain. The residual spent grain is washed down the drain when the vessel is sprayed with water; however, nearly all of the grain goes out with the animal feed helping to decrease environmental impact.
4.1.2 Brew Kettle

The second step to consider in the material balance is the brew kettle. The brew kettle is used to boil the wort for two main reasons; to destroy any unwanted chemicals, such as the precursors of sulfur that may be present from the spent grain and to stabilize the composition of the wort, ensuring an unwavering fermentation step. Essentially it sterilizes the wort and makes it possible to control the fermentation as only the specific sugars that can withstand the boiling remain. This allows the same ale to be made over and over again, minimizing imperfections and achieving the highest quality. The materials entering the brew kettle include the wort from the mash tun, hops in different quantities at different times depending on the brew, and PVB a flocculent chemical used to help remove the trub during the boiling process. There are three exiting material streams prior to the cleaning process; the majority of the liquid goes to the next step, the whirlpool, although about 6% of this liquid evaporates during the process into the atmosphere, and finally there is residual trub that is drained from the brew kettle with additional water that is added upon the exit of the boiled wort.

4.1.3 Whirlpool/Heat Exchanger

The third step in the process is the whirlpool, used to separate any residual solids from the wort before it is sent to the fermentation vessel and transformed into beer. Hot wort is brought in at about 200 °F and rapidly eddied in order to force any solids to the outside which can then settle down in the conical bottom of the whirlpool. The wort is then sent through a heat exchanger, the fourth step, in order to cool it to 50 °F before being sent to the fermentation vessel. The entering materials in the whirlpool step are the wort directly from the kettle and additional water added after the wort is transferred through the heat exchanger to the fermentation vessel. After the wort is transferred, there is still a substantial amount of material left in the whirlpool in the form of solids left behind. The two exiting streams from the whirlpool are the wort transferred to the heat exchanger and the trub water mixture sent down the drain which ultimately continues to the local POTW without any further treatment or separation. Although collecting trub can be difficult, it is high in protein and food grade leaving several possibilities for decreasing the amount of trub going down the drain as it is high in both TSS and COD.
This step in the process can definitely be improved upon and options for doing so will be discussed later. The heat exchanger following the whirlpool has two entering materials, the wort and a small amount of oxygen bubbled in to later be used to activate the yeast, its only exiting stream is the wort being sent to the fermentation vessel.

### 4.1.4 Fermentation Vessel

The fifth step is the fermentation vessel and it is in the step that the wort is converted to a drinkable beer. This step is very timely and depending on the style of ale can take up to several weeks. The entering materials in this step are the wort, yeast, hops, and other unique ingredients, such as blueberry flavoring, are added depending on the type of beer being brewed. This step is also very temperature sensitive in order to optimize the flavor and quality of product. The yeast consumes the fermentable sugars and after digestion emits alcohols. The fermentation step is known to be complete once a desired specific gravity is reached. There are two exiting streams in this process; the fermented beer product is sent through a DE filter media to clarify the beer and allowed to sit in a bright tank before bottling, and the solids collected in the conical bottom of the vessel are removed and discharged. The materials in the bottom consist of spent hops, residual trub and mainly spent yeast some of which is conserved for another process and some of which is sent directly down the drain which continues to the local POTW without any further treatment. This solid material is high in COD and TSS and can essentially be broken up into three layers. First, at the very bottom, is the dead yeast that settled out of the fermentation process first. Since ale is top fermenting, any living yeast will stay at the top to digest the fermentable sugars. As those sugars are eaten up, the yeast will settle out of the beer. The bottom third of the bottoms are discarded and also contains residual trub. It is sent directly down the drain. The middle section of the bottoms is considered as the most active and healthy yeast. It is saved and reused in the next batch of beer. Once enough yeast has been saved for the next batch, the top layer of bottoms is discarded down the drain also. Although this may not be the best thing to do, it would be quite difficult to filter out any solids before they go down the drain. Since there are no toxic substances in the discharge, it was deemed acceptable to discharge this material.
4.1.5 Diatomaceous Earth Filtration

The sixth step is the diatomaceous earth filtration system is used to filter out any solids left in the fermentation vessel before being sent to the bright tank. The entering materials include the fermented beer and the DE filter media. The two exiting streams include the clarified beer sent to the bright tank and spent DE filter media containing residual solids consisting of yeast, hops, trub, etc. not removed in the previous steps. Here it is not the solids passing through the system that are of concern, since none of the discharge goes out as wastewater. The filter media itself is considered a waste once it becomes soiled. The filter media can be used several times but needs to be replaced with fresh media periodically in order to maintain the quality of filtration. Currently, the filter bed is bagged and thrown away as municipal waste. Although the material itself is not considered hazardous waste, the way in which it is handled after leaving the WBC dumpster must be considered and will be discussed later on.

4.1.6 Bright Tank

Once the beer is filtered, it is moved along to the seventh step, the bright tank for storage. This is the last step of fine tuning the final product before packaging and sale. The ale is stored and aged under pressure to add a little extra carbonation to the beer. It is also stored cold in order to stop any secondary fermentation to begin. Before packaging, each batch is tested for color, taste, and specific gravity. Once the batch passes, it is moved along to bottling. The bright tank served as the bottling supply.

4.1.7 Bottle and Keg Pack Out

The bottle and keg pack out is the final process in the brewing process. The entering materials in the process include the beer itself, filter media, and the bottles or kegs. The beer is filtered once more and filter media handled as with the previously discussed DE filter. The two exiting streams in this step is the final bottled or kegged beer and the spent filter media.
4.2 Cleaning Process Observation

The main result of the cleaning process observation portion of the project was a general material balance including all materials entering and exiting the each vessel as a part of the vessel wash operations. Through several days of process observation by each team member and personal communication with brewery staff the team created a general material balance of these processes in Appendix V and more in depth qualitative descriptions, including cleaning frequency, of each piece of equipment as follows.

4.2.1 Mash Tun

After each batch the mash tun has solids shoveled out and is rinsed with water sending residual solids down the drain which continues to the local POTW without any further treatment. It is cleaned with caustic three or four times per year, so high pH discharge is not a concern for this piece of equipment on a frequent basis. The cleaning frequency is determined as needed by the brewing team. It is washed with a mixture of 100 oz of 30% sodium hydroxide caustic solution and 100 gal of water and rinsed with 300 gallons of water. All waste streams from the wash operation are sent down the drain which continues to the POTW without any further treatment.

4.2.2 Brew Kettle

After each batch water is rinsed through the brew kettle to remove any residual trub and sent down the drain. The brew kettle is caustic washed nightly on brewing days by in order to have it ready for the following morning. One gallon of 30% sodium hydroxide caustic solution is added to 80 gallons of water and allowed to circulate through the vessel for 15-20 minutes. That wash water is discharged. Then 100 gallons fresh water is added and allowed to rinse the tank of any caustic and is also discharged directly down the drain.

4.2.3 Whirlpool/Heat Exchanger

These two pieces of equipment are caustic cleaned simultaneously early each morning on brewing days. One gallon of 30% sodium hydroxide caustic solution is added to 100 gallons of water and allowed to eddy through both the whirlpool and heat
exchanger at the same time in a closed loop fashion. Each valve is opened and closed to ensure caustic is able to reach all of the piping in the system and everything is thoroughly cleaned. After discharge, 100 gallons of fresh water is added to rinse all pieces of the equipment. This water is also sent directly down the drain.

4.2.4 Fermentation Vessel

The fermentation vessel is one of the most tedious vessels to clean to ensure that absolutely nothing in the tank is there unwarranted which could upset a whole batch of beer, as this is one of the most delicate processes. After the beer is sent to the bright tank, the residual yeast, hops, and trub are still present at the bottom of the tank. As mentioned before, these solids are discharged down the drain except for the live yeast that will be used in the next batch. Second, a hot water prewash is sent through the tank in order to loosen and remove any solids that may have become caked to the sides of the tank. Once this is allowed to settle it is discharged down the drain. Next, 72 ounces of 30% sodium hydroxide caustic solution is added to 80 gallons of water and allowed to circulate through the system for 20 minutes. While this is happening all of the removable clamps and seals to the tanks are removed and allowed to soak in a caustic and water solution. Finally, Iodoform (an iodine solution), is cycled through the tank with water in order to fully sanitize the tank for the next batch. All streams apart from the reusable yeast are sent directly down the drain.

4.2.5 Diatomaceous Earth Filter

The wheeled piece of equipment that serves as the DE filter is also cleaned with caustic, but only once per week on Monday’s in the morning. Ten ounces of 30& sodium hydroxide caustic solution mixed with 100 gallons of water are pumped through the filter and subsequently through all of the piping for 10 minutes followed by 100 gallons of fresh water. Any removable pieces are soaked in highly concentrated caustic during the 10 minute cycle and rinsed.

4.2.6 Bright Tank

The bright tank also has a fairly in depth cleaning process due to the importance of the tank being absolutely pristine when it comes to storing the beer before it gets
bottled or kegged. Any impurities in the tank could alter the flavor of the entire batch. Each bright tank is cleaned on Sunday for the upcoming week by adding one gallon of caustic with 80 gallons of water. This is circulated through the tank for twenty minutes. Once again, any removable pieces are soaked in caustic. After this is drained, one gallon of Iodoform is cycled through the tank with water in order to ensure cleanliness. All waste streams are sent directly down the drain.

**4.2.7 Keg Washer Operation**

WBC operates an automatic keg washer to clean and sanitize kegs prior to filling. The keg washer is capable of washing three kegs at a time and it operates in three cycles; prewash, wash, and rinse. The first cycle is a prewash in which roughly 15 gallons of the previous run’s rinse water is cycled through the keg to remove excess solid materials. At the end of the prewash, the 15 gallons of prewash water exits the keg washer as wastewater. The second is the wash cycle in which roughly 125 gallons of a water caustic mixture is cycled to clean and sanitize the kegs. The exact composition of this mixture is unknown as it is reused several times in the process. At the end of the cycle the wash water is collected in a reservoir and recycled for use in the next wash. The level of the reservoir is maintained at a constant level by a small addition of water and caustic each wash. The last cycle is the rinse cycle in which the kegs are rinsed with roughly 15 gallons of fresh water. At the end of the rinse cycle the rinse water is collected in a separate reservoir for use in the next prewash cycle. Overall the only wastewater stream from the keg washer operation is the 15 gallons of prewash that is sent down the drain to the POTW for each cycle. A single mash results in 48 kegs, or 744 gallons, of finished product which requires 16 runs of the keg washer per mash and generates roughly 365 gallons of waste water.

**4.2.8 Bottle Pack Out**

The bottle pack-out is a fully automated process in which bottles are filled, capped, labeled, and boxed. A single mash results in 325 cases or 7,800 bottles, or 978 gallons, of finished product. Prior to use the bottle pack out is washed and sanitized using a caustic solution. First, 300 gallons of hot water are circulated through the system to raise its temperature for cleaning. Next a mixture of 120 gallons of water and 80oz of caustic
are circulated through the system for cleaning and sanitization purposes. The caustic wash is followed by a rinse of 300 gallons of water.

### 4.3 Wastewater Regulation Compliance

After reviewing federal, state, and local regulations regarding wastewater discharges it was identified which regulations are applicable to the brewing industry and Wachusett Brewing Company (WBC). First, the National Pollutant Discharge Elimination System (NPDES) does not apply since WBC does not have any point source discharges into national waterways. On the other hand, since WBC discharges wastewater into the local sewer system, and regulations regarding non point source discharges and pretreatment standards are applicable.

On the federal level, all national pretreatment standards must be met. Since WBC does not discharge any wastewater with explosion potential, high temperature, or oil content, such prohibited discharges are not of concern. Prohibited discharges of concern include wastewater with solid content, high or low pH levels, and high oxygen demands which may result from several brewing processes. Wastewater solid contents of potential concern include trub, spent hops, spent yeast, and proteins that are produced through the brewing process. It is important to note that these same constituents also include potentially high oxygen demands which are also of concern. In addition high or low wastewater pH levels might potentially result from caustic and acid washes of process vessels. The wastewater produced during operations at WBC was investigated to determine the level of solids, oxygen demand and pH to identify if any prohibited discharges existed. In addition, it was investigated as to whether or not WBC qualifies as any of the federal industry categories to ensure that all categorical standards are met.

On the state and local level, all additional pretreatment standards must be met and the appropriate discharge permits obtained unless determined otherwise. On the state level, additional pretreatment standards include a stricter wastewater pH limit between 5.5 and 10.0. Additionally, wastewater effluent limitations of the receiving POTW were indentified and do not contain any restrictions on total suspended solids or chemical oxygen demand, on the other hand they do require that a pH discharge limit between 5.5 and 10.0.
Once it is assured that all pretreatment standards and prohibited discharges are met, appropriate state and local discharge permits must be obtained unless it can be proven that no such permits are required. Since the building containing WBC was constructed in 1989, after the cut-off date of May 10, 1979 and since the brewery has not been previously permitted by Mass DEP, they do not qualify as an activity that does not require a permit per 314 CMR 7.05. Similarly, since WBC has an SIC code of 2082 they do not qualify as an activity not requiring a permit. On the other hand, since WBC discharges to a POTW with an industrial pretreatment program, and their daily flow wastewater was proven to be below 50,000 gallons per day, ranging from 4,000 to 11,000 gallons per day average, and indicated in Appendix VI they qualify for a “permit by rule” case in which they do not have to file any paperwork with the Mass DEP but must meet all federal and state pretreatment standards as well as effluent limitations established by the receiving POTW.

4.4 General Waste Regulation Compliance

4.4.1 EPCRA

In regards to the regulations associated with EPCRA, two chemicals with the potential applicability to chemical reporting were considered and investigated, Lerapur 238, a 30% sodium hydroxide caustic wash and Leracid K-MS 10 an acid wash comprised of less than 38% nitric acid and less than 12% phosphoric acid. Neither the sodium hydroxide nor phosphoric acid is listed as extremely hazardous substances. Nitric Acid is listed as an EHS but the threshold planning quantity for this substance is 1,000 lbs of pure nitric acid, or 2800 lbs of the acid solution, and WBC does not store more than this level of the acid wash at any given time. Therefore, WBC should not be concerned with the regulations associated with Title III of the EPCRA.

4.4.2 RCRA

Currently, WBC does not produce any waste substances that are classified as hazardous waste. The only material of concern within the scope of RCRA is the spent DE produced from the filtering process. Spent diatomaceous earth (DE) is not classified as a hazardous substance, and can be disposed of as WBC has been doing so in the
regular dumpster and sent to a landfill. However, DE is a proposed carcinogen in its dry, solid form, unlike the form it is in when it is disposed of. Therefore, in regards to disposing the spent media, it is very important to know where it ultimately ends up. Though it is not dangerous to dispose of it in the dumpster, it should be assured that the disposal of that waste goes to landfill and not an incinerator to avoid making it dry and airborne. In addition, it should be of WBC greatest concern to handle this material with care when received in its dry form. When in storage, the bin should be closed tightly and put in an area with high ventilation. When an employee handles the media, respirators should be worn to minimize inhalation.

An additional area of concern within the regulations of RCRA relates to the sodium hydroxide caustic cleaning agent used by WBC. This substance does not qualify as a hazardous waste; however, spills of any liquid with a pH over 12.5 must be considered RCRA and Mass. DEP hazardous waste and must be cleaned up and disposed of appropriately. Therefore, it must be managed accordingly if such a spill should ever occur as outlined on the MSDS, included in Appendix VII and VIII for the caustic and acid respectively.

4.4.3 TURA

During brewing operations, Wachusett Brewery Company uses two trade products that contain TURA-listed chemicals. The first trade product is Lerapur – 283, which is a heavy duty caustic clean-in-place (CIP) cleaner which is used to clean vessels, kegs, and other process equipment. The Lerapur-283 contains 30% sodium hydroxide and 1% nitric acid, both of which are TURA-listed chemicals. A Material Safety Data Sheet for this chemical is attached in Appendix VII. The second trade product is the Leracid K-MS-10, which is an acid cleaner which is also used to clean vessels and other process equipment. The Leracid K-MS-10 contains 38% nitric acid and 12% phosphoric acid, which again are both TURA-listed chemicals. A Material Safety Data Sheet for this chemical is attached in Appendix VIII.

The Toxic Use Reduction Act is applicable to WBC as long as it qualifies as a Large Quantity Toxics User by meeting the criteria mentioned above. Since WBC currently employs 10 or more full time employees it meets the LQTU criteria #2, and
since breweries fall under the SIC code of “2082 malt beverages”, WBC meets LQTU criteria #3. In order for WBC to not qualify as a LQTU criteria #1 must not be met. WBC will not qualify as a LQTU and be subject to TURA reporting if the brewery uses less than 10,000 lbs per year of the TURA-listed chemicals contained in the Lerapur-283 and Leracid K-MS-10.

In order to determine if the Toxic Use Reduction Act is applicable to WBC, the amount of TURA listed chemicals used on an annual basis was determined. As stated earlier, WBC uses two trade products that contain TURA listed chemicals. The first is Lerapur – 283, which contains the following TURA listed chemicals of 30% sodium hydroxide and 1% nitric acid. The second trade product is the Leracid K-MS-10 which contains the following TURA listed chemicals of 38% nitric acid and 12% phosphoric acid. Using purchase records of the two trade products the annual usage of the two chemicals was determined and using the compositions from the MSDS for each product. The 2007 purchase records indicated a total annual usage of 44 drums of Lerapur-283. Using the Lerapur – 283 product density of 11.25 lbs/gal, the total mass of a 55 gallon drum was determined to be 618.75 lbs. The total usage of 44 drums per year results in a total product usage of 27225 lbs/year. Since Lerapur – 283 is 30% sodium hydroxide by weight, the annual usage of sodium hydroxide was determined to be 8,167.5 lbs to year, which is less than the TURA annual threshold of 10,000 lbs/year. Such calculations can be performed for the annual usage of nitric acid which was determined to be 272.25 lbs/year, which is also less than the TURA annual threshold value of 10,000 lbs/year. Both annual usage amounts for sodium hydroxide and nitric acid indicate that WBC does not qualify as a Large Quantity Toxics User per the TURA regulations and thus does not need to submit a toxic use report and a toxic use reduction plan to the Mass DEP. The annual usage of the Leracid K-MS-10 was determined to be 6, 55 gallon drums resulting in a total usage of 3,795 lbs, therefore the annual usage of nitric acid is 1,442 lbs, far below a level of concern with respect to the regulations of TURA.
4.5 Investigation of Additional Materials of Interest

4.5.1 Trub

Trub is the biggest contributor to high TSS and COD discharges from a brewery. Currently that is sent down the drain and left for the wastewater treatment facility to deal with. Just like the spent grain, trub is high in protein and can be used for feed for local farm animals (WorldBook). The problem is that WBC is not set up for collection of this material at this time. The spent grain can be shoveled out of the mash tun, but this is not an option for trub. It is a suspended solid liquid and there is no entrance into the whirlpool. The trub would have to be filtered through a media to allow the wasted wort to be disposed of down the drain, retaining the solid trub back for sale to a farmer (Priest). There were several options for this collection, including sock filters or using the spent grain as a filter bed, but this will be discussed in detail later on.

4.5.2 Diatomaceous Earth Filter Media

Diatomaceous Earth Filter media (DE) is considered a hazard when stored as a dry material (Diatomaceous). The dust can cause nearby employees with long term exposure a disease called silicosis. DE filter beds have also been found to be a carcinogen with long term inhalation (Baker). There, even though Wachusett Brewing Company is only a small user of DE, it still should be defined as one of the hazardous materials located within the plant and treated with the utmost care. Any employee in contact with it should always wear an appropriate face mask in order to ensure their least exposure.

4.6 Wastewater Testing Results

Wastewater from each brewing and cleaning process were collected and analyzed for pH, chemical oxygen demand, and total suspended solids. A summary of the wastewater testing results can be found in Appendix IX. Using the results from the wastewater testing, areas of high environmental concern were then identified for both the brewing and cleaning processes.
4.6.1 pH

Several steps during the brewery wash operations were identified as having high levels of pH. High levels of pH, with several samples exceeding a pH of 12, were observed during the caustic wash of the fermentation vessel and whirlpool vessels, the cleaning of the DE filter, and during the operation of the keg washer. The reduction of the high wastewater pH should be investigated in order to reduce the environmental impact of the brewery operations as well as meet wastewater regulations.

4.6.2 pH Dilution Calculations

The results of the pH calculations can be found in Appendix X and from analysis of the results several conclusions can be made. It is observable that the sampled wastewater pH results were lower and in some cases varied greatly than those determined by calculation. This difference is possibly due to the fact that the amount of caustic is reduced by reactions with materials in the equipment being cleaned. A more realistic conclusion is that the sample was collected during a period of low caustic concentration as it is difficult to estimate when the majority of the caustic used in the wash leaves the equipment being washed and enters the drain as wastewater.

It is also observable that the combination of the volume caustic wash and rinse water has a small observable difference on the calculated pH. The pH of the original caustic wash and the combined caustic wash and rinse varied at most by 6% and indicates that the assumed ideal mixing of both streams before street level discharge has little to no effect on the pH of the caustic wash wastewater.

4.6.3 COD and TSS

Several steps during the brewing process were identified as producing high levels of total suspended solids as well as chemical oxygen demand. High levels of wastewater TSS and COD were identified during the rinsing of the mash tun, the drainage of whirlpool bottoms, and the discharge spent yeast from the fermentation vessels. Possible sources of TSS and COD reduction should be investigated in order to reduce the environmental impact of the brewing operations.
5 Recommendations

After all of the above research, observations, and testing, the team came up with a set of recommendations for WBC to remain within all applicable environmental regulations and to generally ensure the safety of employees and decrease potential environmental impact. The recommendations fall into the four following categories, trub collection to reduce TSS and COD, proper storage and disposal of DE filter media, recommendations related to TURA compliance, and the installation of a street level pH monitoring system.

5.1 Trub Collection

There is a great deal of trub sent directly down the drain from the whirlpool in the brewing process. As previously discussed, the team has found many sources ensuring that this high protein substance is food grade and completely safe to use as animal feed. Although the team has not found any specific regulations from the local Fitchburg East POTW limiting the level of COD and TSS they can receive, removing this trub could significantly decrease these quantities and therefore decrease the impact WBC has on its surrounding environment.

The team recommends that a system be designed to send the trub stream to the same truck where the spent grain is shoveled. The spent grain in the truck can act as a filter bed and the trub water stream can be sent directly into the truck. The trub will be removed into the grain and residual water will drain off the truck into the collection tray already in place.

Considering the state of the water collection system, this may also need to be improved or replaced. Through discussions with Kevin Buckler the team has gathered that this was already a concern for WBC before the consideration of a trub collection system so wouldn’t necessarily add to the cost of installing such a system.

5.2 DE Filter Media Proper Storage and Disposal

Although the team did not find the spent DE was considered a hazardous waste, in its dry form, as it is received by WBC, it is a suspected possible carcinogen. Therefore great care should be taken in handling the dry media. Protection against any adverse
effects of the dry DE would be very easy and inexpensive to implement. This can be done by making sure there are respirators and any other personal protection equipment available for any employees going near or working with DE and it should be stored in a well ventilated area.

As for the spent DE that is wet and therefore no longer harmful, it can be disposed of through the dumpster and be sent out with regular municipal waste. However, it would be prudent for WBC to endure that the spent media is being sent to a landfill and not an incinerator. If it was sent to an incinerator the media could dry out and become airborne.

5.3 Recommendations Related to TURA Compliance

As previously discussed, WBC is not in violation of the 10,000 lbs limit of usage of their caustic cleaning agent, sodium hydroxide. However, the team found that WBC was relatively close to this limit in the past year and therefore both to decrease environmental impact and to prevent future possibilities of surpassing this limit, WBC should closely monitor the amount of caustic used and investigate alternatives to sodium hydroxide.

One alternative to sodium hydroxide is potassium hydroxide, which WBC has used before. The cleaning agent is generally more expensive but in an effort to ensure that the limit is not surpassed can be employed used. In addition, WBC has considered switching to an acid wash for the bright tank cleaning performed once weekly. This cleaning process uses a great deal of caustic and replacing this caustic with acid could greatly decrease the amount of caustic used on an annual basis and may also be a worthwhile change to ensure future regulation compliance.

5.4 Wastewater pH Monitoring System

In relation to the decrease in caustic usage, the team also thinks WBC should install a system to more closely monitor the pH of the wastewater leaving the brewery. Unfortunately, the team could not get a good picture of the pH levels at the street level and how they change over the course of a brewing day and throughout the week. However, through sampling of waste streams leaving the different vessels at the brewery level, the team found several streams that even with heavy dilution could still be over the pH limit of 10. In order to determine whether or not this is a problem, WBC should
install a real-time pH monitoring and recording system at the street level. The team researched several different options but found that in order to make the best choice for WBC’s needs, an expert in the field should be consulted.
References

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<http://www.mass.gov/dep/service/regulations/310cmr50.pdf>

“314 CMR 07.00” MassDEP. 01 Nov.-Dec. 2007
<http://www.mass.gov/dep/service/regulations/314cmr07.pdf>

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<http://www.epa.gov/npdes/regulations/streamlining_part403.pdf>

< http://www.jtbaker.com/msds/englishhtml/d12.htm>


Cheremisinoff, Nicholas P. _Environmental Health & Safety Management_. New York: William Andrew Inc.

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“Diatomaceous Earth.” 27 Mar 2008
< http://en.wikipedia.org/wiki/Diatomaceous_earth#Safety_considerations>


Groth, Alicia. _Quality Control Improvement Project for Wachusett Brewing Company_. WPI. 2006


Appendix I

COD Testing Procedure

COD analysis will be performed according to the Micro-COD test method (accu-TEST™ High Range (100 – 4500 mg/L COD). The testing procedure for COD is as follows:

1. Preheat a COD heater block (do not use oven) to 150^0 Celsius.

2. Remove the cap from a COD twist-cap vial.

3. Carefully add 0.5 mL of sample down the side of the vial such that it forms a layer on top of the reagents.

4. Replace the twist cap closed.

5. Thoroughly mix the contents of the sealed vial by shaking.

6. Repeat steps 2-5 with process standards and blanks exactly as with the samples.

7. Place the twist-cap vial in a COD heater block capable of maintaining 150^0 +/- 2^0 Celsius for 2 hours.

8. Remove the vial from the heater block and allow to cool.

9. Allow any suspended precipitate to settle and wipe the outside of the vial clean.

10. Set the wavelength of the spectrophotometer to 600 nm, and, using a procedural blank, zero the absorbance reading.

11. Read the absorbance of each standard and sample on the spectrophotometer.

12. Compare sample absorbance to a graphic calibration curve (Appendix II) to determine the COD concentration.
Appendix II

COD Graphic Calibration Curves
Appendix III

TSS Testing Procedure

The testing procedure for TSS is as follows;

1. Pre-weight an evaporating dish to determine its original mass.
2. Stir sample.
3. Pipette 50 mL of sample into the evaporating dish.
4. Dry the sample at 105\(^\circ\) Celsius until evaporated.
5. Cool and weigh the evaporating dish.
6. Calculate the TSS in mg/L using the following equation’

\[
\text{mg of total solids/L} = \frac{(A - B) \times 1000}{mL(sample)}
\]

Where A = Final Weight, B = Initial Weight
Appendix IV

Brewing Process Material Balance

Wachusett Brewery Material Balance – Brewing Operations (1 batch Basis)
Appendix V

Cleaning Process Material Balance

Wachusett Brewery Material Balance – Wash Operations
# Appendix VI

## Daily Water Discharge

<table>
<thead>
<tr>
<th>Period</th>
<th>Days in Period</th>
<th>Period Water Usage in Gallons</th>
<th>Number of Batches</th>
<th>Gallons of product per batch</th>
<th>Gallons of Product in period</th>
<th>Gallons of Discharge in Period</th>
<th>Gallons Discharged Per Day</th>
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<td>175.00</td>
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<td>183.00</td>
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<th>Number of Batches</th>
<th>Gallons of product per batch</th>
<th>Gallons of Product in period</th>
<th>Gallons of Discharge in Period</th>
<th>Gallons Discharged Per Day</th>
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</table>

The maximum possible daily discharge was determined by subtracting the amount of product produced in a period from the amount of water usage during the period and difference was then divided by the number of days in the period.
Appendix VII

Sodium Hydroxide Caustic Material Safety Data Sheet

MATERIAL SAFETY DATA SHEET

PRODUCT NAME: LERAPUR™ 283

SECTION 01 - MATERIAL IDENTIFICATION

PRODUCT NAME: LERAPUR™ 283
CAS CHEMICAL NAME: MIXTURE
SYNONYMS: NONE
INTENDED USAGE: HEAVY DUTY CAUSTIC CIP CLEANER
DATE PREPARED: April 17, 2006
LAST REVISION: October 6, 2003

CHEMICAL EMERGENCY RESPONSE NUMBER:
SPILL, LEAK, FIRE, EXPOSURE, OR ACCIDENT
CALL CHEMTREC (24 hr): 1-800-424-9300

SECTION 02 - HAZARDOUS INGREDIENTS

<table>
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<tr>
<th>CAS NUMBER AND CHEMICAL NAME</th>
<th>%</th>
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<th>ACGIH TWA</th>
<th>ACGIH STEL</th>
<th>ACGIH STEL</th>
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</thead>
<tbody>
<tr>
<td>1310-73-2 Sodium Hydroxide</td>
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<td>C 2</td>
<td>N/E</td>
<td>C 2</td>
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<td>6419-19-8 Phosphoric Acid</td>
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<td>N/E</td>
<td>N/E</td>
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<td>37971-36-1 2-Phosphono-1,2,4-</td>
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<td>N/E</td>
<td>N/E</td>
<td>N/E</td>
<td>N/E</td>
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<tr>
<td>butanetricarboxylic Acid</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

N/E = Not established <> S = Skin <> N/A = Not applicable <> C = Ceiling
MATERIAL SAFETY DATA SHEET

PRODUCT NAME: LERAPUR™ 283

SECTION 03 - HEALTH HAZARDS

EMERGENCY OVERVIEW
HMIS RATING

HEALTH - 3  FLAMMABILITY - 0  REACTIVITY - 1

Personnel Protective Equipment (see Section 13): C

Liquid and mists cause severe burns to all contacted body tissue. Harmful if inhaled. Harmful or fatal when ingested. Corrosive.

ROUTES OF EXPOSURE:
Ingestion
Eyes
Skin Absorption
Inhalation

EXPOSURE STANDARDS:
-OSHA PEL:
  See Section 2

-ACGIH Threshold Limit Value (TLV):
  See Section 2

HEALTH HAZARDS:
Liquid and mists cause severe burns to the skin and eyes with possible destruction of the tissue. Harmful if swallowed or inhaled. Gross overexposure by ingestion may be fatal.

SIGNS AND SYMPTOMS OF EXPOSURE (ACUTE EFFECTS):
Skin contact: Causes severe chemical burns and frequently deep ulceration with subsequent scarring. Symptoms may include pain, stinging, itching, and developing rash. Prolonged contact may destroy the tissue.
Eye contact: Causes severe chemical burns with possible impairment of vision and severe corneal damage. Symptoms may include immediate pain, tearing, and redness.
Inhalation: May cause severe burns and damage to the upper respiratory tract and to the lung tissue, depending upon extent of exposure. Effects can range from mild irritation of mucous membranes, severe pneumonitis, and destruction of lung tissue. Inhalation of high concentrations can result in permanent lung damage.
Ingestion: Causes severe burns to the mouth, esophagus, stomach, and other tissues, which have been contacted. Symptoms may include nausea, vomiting, diarrhea, severe abdominal pain, bleeding, and/or tissue ulceration. Gross overexposure by ingestion may be fatal.
MATERIAL SAFETY DATA SHEET

PRODUCT NAME: LERAPUR™ 283

SIGNs AND SYMPTOMS OF EXPOSURE (LONG TERM EFFECTS):
Prolonged skin exposure may cause destruction of the dermis with impairment of the skin at site of contact to regenerate. Prolonged inhalation exposure may cause impairment of lung function and permanent lung damage. Repeated or prolonged ingestion will cause deep ulceration of all contacted tissue and may be fatal. Repeated eye contact will cause irreversible corneal damage resulting in loss of vision.

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE:
None known.

CARCINOGENICITY:
None of the ingredients are considered a carcinogen by OSHA, NTP, or IARC.

ACUTE TOXICITY EFFECTS DATA:
Inhalation LC50: Not determined
Dermal LD50: Acute corrosive
Oral LD50: 500 mg/kg (rabbit) (based on 100% NaOH)
Acute corrosive to skin, eyes, and mucous membranes.

AQUATIC TOXICITY:
Not determined.

OTHER ACUTE EFFECTS:
No other acute effects known.

SECTION 04 - FIRST AID

EYE CONTACT: Immediately flush eyes with large quantities of running water for at least 15 minutes. Hold the eyelids apart during flushing to ensure rinsing of the entire surface of the eye and lids with water. Do not attempt to neutralize with chemical agents. Get medical attention immediately.

SKIN CONTACT: Immediately flush skin with running water for at least 15 minutes while removing contaminated clothing and shoes under a safety shower. Discard contaminated clothing. Get medical attention if irritation persists.
MATERIAL SAFETY DATA SHEET

PRODUCT NAME: LERAPUR™ 283

INHALATION: Remove victim to fresh air. If breathing is difficult, give oxygen. If breathing has stopped, give artificial respiration. Get medical attention immediately.

INGESTION: DO NOT INDUCE VOMITING! Immediately give large quantities of water or acidic beverages (Tomato or orange juice, carbonated soft drinks), but do not induce vomiting. If vomiting occurs, administer additional water. Do not attempt to give anything by mouth if the victim is unconscious or having convulsions. Get medical attention immediately.

NOTES TO PHYSICIAN: All treatments should be based on observed signs and symptoms of distress in the patient. Consideration should be given to the possibility that overexposure to materials other than this product may have occurred. The principal manifestation of overexposure is corrosion or burns.

SECTION 05 - FIRE AND EXPLOSION DATA

CHARACTERISTICS:
- Flash Point: N/A
- Upper Explosion Limit (UEL): N/A
- Lower Explosion Limit (LEL): N/A
- Autoignition Temperature: N/A
- Flash Point Method(s): N/A
- Fire Hazard Classification (OSHA/NFPA): 0

EXTINGUISHING MEDIA:
If involved in a fire, use water spray.

SPECIAL FIRE FIGHTING PROCEDURES:
Wear self-contained breathing apparatus and full protective gear.

UNUSUAL FIRE AND EXPLOSION HAZARDS:
Contact with some metals, particularly magnesium, aluminum, and zinc (galvanized) can rapidly generate hydrogen, which increases the intensity of fires and may be explosive.
MATERIAL SAFETY DATA SHEET

SECTION 06 - REACTIVITY HAZARD DATA

CHEMICAL STABILITY:
Stable [X]  Unstable [ ]

CONDITIONS TO AVOID (if unstable):
None

INCOMPATIBILITY (Materials to avoid):
Organic materials and concentrated acids, magnesium, aluminum, zinc (galvanized), tin, chromium, brass, bronze, and various food sugars.

HAZARDOUS DECOMPOSITION PRODUCTS (from burning, heating, or reaction with other materials):
Thermal decomposition may emit phosphoric acid, carbon monoxide, carbon dioxide, oxides of nitrogen, and other unidentified by-products. Phosphines may form after all water has been removed.

HAZARDOUS POLYMERIZATION:
Will not occur.

CONDITIONS TO AVOID (if may occur):
N/A

NFPA REACTIVITY RATING: 1
SECTION 07 - SPILL, LEAK, AND DISPOSAL INFORMATION

CLEAN UP PROCEDURES:

SMALL SPILLS:
Confine spill area. Stop leak if this can be done without danger. Spilled material should be flushed with plenty of water. Neutralize diluted material with diluted acid. Do not flush larger amounts of product into sewer, streams, or waterways. Sewer with excess water.

LARGE SPILLS:
Confine spill area. Stop leak if this can be done without danger. Reclaim spilled material if possible. If not possible, dilute spilled material with large quantities of water and neutralize with diluted acid. Neutralized material can be recovered by vacuum truck for disposal. After all visible traces have been removed, flush area with large quantities of water. Do not flush larger amounts of product into city sewer, streams, or waterways.

OTHER EMERGENCY ADVICE:
Isolate or enclose the area of spill or leak. Only trained personnel equipped with NIOSH/MSHA approved full facepiece combination dust/mist and acid gas respirators should be permitted in this area. Review FIRE AND EXPLOSION HAZARDS and PROTECTIVE MEASURES before proceeding with clean up. All clean up personnel should wear recommended protective equipment during clean up.

WASTE DISPOSALS:
Flushed material should be collected in confined chemical sewer or waste water system. Adjust pH to accepted values before discharging product into city sewer. Methods of disposal may vary upon location. Contact your local agencies to comply with all applicable federal, state, and local laws and regulations. Disposal of neutralized material in an approved hazardous waste management facility is recommended. Care must be taken when using or disposing of chemical materials and/or their containers to prevent environmental contamination. It is the users duty to dispose of the chemical materials and/or their containers in compliance with the Clean Air Act, the Clean Water Act, the Resource Conservation And Recovery Act, as well as any other relevant federal, state, or local laws/regulations regarding disposal.

REPORTABLE QUANTITY (RQ) (40CFR) (CWA/CERCLA):
1,600 lbs (based upon NaOH)
MATERIAL SAFETY DATA SHEET

SECTION 08 - PROTECTIVE MEASURES

EYE PROTECTION:
Wear chemical splash goggles or full-face shield. In addition, wear chemical splash goggles/full-length face shield combination, where the possibility of eye and face contact due to splashing or spraying of material exists. Contact lenses should not be worn when working with this material. Maintain eye wash fountain and quick-drench facilities in work area.

SKIN PROTECTION:
Wear impervious protective clothing, including boots, gloves, lab coat, apron, or coveralls to prevent skin contact.

RESPIRATORY PROTECTION:
A system of local and/or general exhaust is recommended to keep employee exposure below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred because it can control the emission of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document "Industrial Ventilation, A Manual of Recommended Practices", most recent edition for details.

WORKING AND HYGIENIC PRACTICES:
Provide readily accessible showers and eye wash stations. Wash at the end of each working and before eating, smoking, or using the toilet.

SECTION 09 - STORAGE AND HANDLING

STORAGE:
Store product in shipping container and store in a dry, cool, and well-ventilated area. Protect container from physical damage and from direct sunlight. Keep container tightly closed when not in use. KEEP OUT OF REACH OF CHILDREN!

HANDLING:
When handling, wear safety goggles and/or full-face shield, rubber gloves, rubber boots, rubber apron, or coverall to prevent skin or eye contact. Never touch eyes or face with hands or gloves that may be contaminated with product. Hazardous Carbon Monoxide gas may form upon contact with food and beverage products in enclosed vessels and may cause death upon entering the vessel. Follow appropriate tank entry procedures (see ANSI Z177.1-1977). Do not eat, drink, or smoke during handling.

OTHER PRECAUTIONS:
Carefully read all instructions on product label and Technical Data Sheet before handling or using this product. Make sure that all engineering and personal protective equipment is in working order.
MATERIAL SAFETY DATA SHEET

SECTION 10 - PHYSICAL AND CHEMICAL PROPERTIES

FORM, COLOR, AND APPEARANCE:
PHYSICAL FORM: Liquid
COLOR: Clear, colorless to slightly yellow
ODOR: Characteristically

TYPICAL PHYSICAL DATA:
pH (1% solution): ~3.0
VAPOR PRESSURE (mm Hg): N/D
VAPOR DENSITY (Air = 1): N/D
BOILING POINT: ~284° F (140° C)
FREEZING/MELTING POINT: ~3° F (-19° C)
SOLUBILITY IN WATER: Complete
SPECIFIC GRAVITY @ 20° C (g/cm³): ~1.35
DENSITY @ 68° F (lbs/gal): 11.25
EVAPORATION RATE (Butylacetate = 1): < 1

SECTION 11 - TRANSPORTATION INFORMATION

UN No.: 1760
PRIMARY HAZARD CLASS: CORROSIVE (8)
SECONDARY HAZARD CLASS: N/A
PACKAGING GROUP: II
FREIGHT CLASS: 55
DOT SHIPPING NAME: Corrosive liquids, n.o.s. (Sodium Hydroxide)
IMO SHIPPING NAME: ---
IATA SHIPPING NAME: ---

SECTION 12 - FEDERAL REGULATIONS

TOXIC SUBSTANCES CONTROL ACT (TSCA):
Sodium Hydroxide is on the TSCA inventory list under CAS # 1310-73-2

EPA SARA TITLE III SECTION 311/312 (40CFR370) HAZARD CLASSIFICATIONS:

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<th>FIRE</th>
<th>REACTIVITY</th>
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<tr>
<td>X</td>
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<td></td>
<td></td>
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</tr>
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</table>

67
MATERIAL SAFETY DATA SHEET

PRODUCT NAME: LERAPUR™ 283

CERCLA/RCRA REPORTABLE QUANTITY:
This product is listed as a hazardous substance with a reportable quantity of 1,600 lbs. Releases to air, land, or water that exceed the RQ of 1,000 lbs of LERAPUR™ 283 must be reported to the National Response Center (1-800-424-8802) under the proper shipping name and in reference to Sodium Hydroxide.

SECTION 13 - LETTER DESIGNATION OF PERSONAL PROTECTIVE EQUIPMENT

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<tr>
<th>Personal Protective Equipment</th>
<th>Letter Designation</th>
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<td>Safety Glasses</td>
<td>A</td>
</tr>
<tr>
<td>Safety Glasses, Gloves</td>
<td>B</td>
</tr>
<tr>
<td>Safety Glasses, Gloves, Synthetic Apron</td>
<td>C</td>
</tr>
<tr>
<td>Face Shield, Gloves, Synthetic Apron</td>
<td>D</td>
</tr>
<tr>
<td>Safety Glasses, Gloves, Dust Respirator</td>
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<tr>
<td>Safety Glasses, Gloves, Synthetic Apron, Dust Respirator</td>
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</tr>
<tr>
<td>Safety Glasses, Gloves, Vapor Respirator</td>
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<tr>
<td>Splash Goggles, Gloves, Synthetic Apron, Vapor Respirator</td>
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<td>Safety Glasses, Gloves, Combination Dust and Vapor Respirator</td>
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<tr>
<td>Safety Glasses, Gloves, Synthetic Apron, Combination Dust and Vapor Respirator</td>
<td>J</td>
</tr>
<tr>
<td>Airline Hood or Mask, Gloves, Full Protective Suit, Boots</td>
<td>K</td>
</tr>
<tr>
<td>Situations Requiring Specialized Handling</td>
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</table>

The information set forth herein is furnished free of charge and is based on technical data that Loeser Chemical Corp. believes to be reliable. It is intended for use by persons having technical skill and at their own discretion and risk. Since conditions of use are outside our control, Loeser Chemical Corp. makes no warranties, express or implied, and assume no liability in connection with any use of this information. Nothing herein is to be taken as a license to operate under or a recommendation to infringe any patents.
Appendix VIII

Acid Cleaner Material Safety Data Sheet
**PRODUCT NAME:** LERACID™ K-MS 10

**CAS CHEMICAL NAME:** MIXTURE

**SYNONYMS:** NONE

**INTENDED USAGE:** ACID CLEANER

**DATE PREPARED:** April 17, 2008

**LAST REVISION:** September 24, 2003

**CHEMICAL EMERGENCY RESPONSE NUMBER:**

**CALL CHEMTREC (24 hr): 1-800-424-9300**

**SECTION 02 - HAZARDOUS INGREDIENTS**

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<thead>
<tr>
<th>CAS NUMBER AND CHEMICAL NAME</th>
<th>%</th>
<th>ACGIH TWA</th>
<th>ACGIH STEL</th>
<th>ACGIH TWA</th>
<th>ACGIH STEL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PPM</td>
<td>MG/M³</td>
<td>PPM</td>
<td>MG/M³</td>
</tr>
<tr>
<td>7697-37-2 Nitric Acid</td>
<td>&lt;38.0</td>
<td>2</td>
<td>5.2</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>7664-38-2 Phosphoric Acid</td>
<td>&lt;12.0</td>
<td>N/E</td>
<td>1</td>
<td>N/E</td>
<td>3</td>
</tr>
</tbody>
</table>

N/E = Not established  <>  S = Skin  <>  N/A = Not applicable  <>  C = Ceiling
MATERIAL SAFETY DATA SHEET

PRODUCT NAME: LERACID™ K-MS 10

SECTION 03 - HEALTH HAZARDS

EMERGENCY OVERVIEW
HMIS RATING

HEALTH - 3     FLAMMABILITY - 0     REACTIVITY - 1

Personnel Protective Equipment (see Section 13): H

CORROSIVE: Liquid and mist cause severe burns to eyes and skin. Harmful if inhaled. Harmful or fatal when ingested.

ROUTES OF EXPOSURE:
Ingestion
Eyes
Skin Absorption
Inhalation

HEALTH HAZARDS:
Liquid and mist cause severe irritation or chemical burns to the skin and eyes and may destroy the tissue. Inhalation is harmful and may cause lung damage. Harmful or fatal when ingested.

SIGNS AND SYMPTOMS OF EXPOSURE (ACUTE EFFECTS):
Skin contact: Causes severe chemical burns, severe necrosis, and frequently deep ulceration with subsequent scarring. Symptoms may include pain, stinging, itching, and developing rash. Prolonged skin contact destroys the tissue.

Eye contact: Liquid and vapors cause severe chemical burns with possible irreversible corneal damage and may cause irreversible impairment of vision or total loss of vision. Symptoms may include immediate severe pain, tearing, and redness.

Inhalation: May cause severe irritation or chemical burns to the upper respiratory tract and to the lung tissue, depending upon extent of exposure. Effects can range from mild irritation of mucous membranes, breathing difficulties, to severe pneumonitis, and destruction of lung tissue. Inhalation of high concentrations can result in permanent lung damage and may lead to pneumonia and pulmonary edema, which may be fatal.

Ingestion: Causes severe burns to the mouth, throat, esophagus, stomach, and the gastrointestinal tract as well as all other contacted tissue. Symptoms may include nausea, vomiting, diarrhea, severe abdominal pain, bleeding, and/or tissue ulceration. Gross overexposure by ingestion may be fatal.
MATERIAL SAFETY DATA SHEET

PRODUCT NAME: LERACID™ K-MS 10

SIGN AND SYMPTOMS OF EXPOSURE (LONG TERM EFFECTS):
Prolonged skin exposure may cause destruction of the dermis with impairment of the skin at site of contact to regenerate. Prolonged inhalation exposure may cause impairment of lung function and permanent lung damage. Pneumonia or pulmonary edema may occur, which may be fatal. Long-term exposure to high levels of acid fumes may cause erosion of teeth followed by jaw necrosis, bronchial irritation, coughing, and bronchial pneumonia, or gastrointestinal disturbances. Repeated or prolonged ingestion will cause deep ulceration of all contacted tissue and may be fatal. Repeated eye contact will cause irreversible corneal damage resulting in loss of vision.

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE:
Individuals with pre-existing eye, skin, or respiratory diseases may have increased susceptibility to product exposure.

CARCINOGENICITY:
None of the ingredients are considered a carcinogen by OSHA, NTP, or IARC.

ACUTE TOXICITY EFFECTS DATA:
Inhalation LD₅₀: 244 ppm (rat) (NO₂)/30M
Dermal LD₅₀: 2740 mg/kg body weight (rabbit) (H₃PO₄)
Oral LD₅₀: 1530 mg/kg (rat) (H₃PO₄)
Ingestion LD₅₀: As little as 1 ml of concentrated acid has been reported to cause death when ingested (based on H₃PO₄).

AQUATIC TOXICITY:
This product is toxic to aquatic life.

OTHER ACUTE EFFECTS:
No other acute effects known.

SECTION 04 - FIRST AID

EYE CONTACT: Immediately flush eyes with large quantities of running water for at least 15 minutes. Hold the eyelids apart during flushing to ensure rinsing of the entire surface of the eye and lids with water. Do not attempt to neutralize with chemical agents. Get medical attention, referred eye specialist, as soon as possible.

SKIN CONTACT: Immediately flush skin with running water for at least 15 minutes while removing contaminated clothing and shoes under a safety shower. If immediately available, first use a dry cloth and wipe excess material from the skin. Discard contaminated clothing. Get medical attention immediately.
MATERIAL SAFETY DATA SHEET

PRODUCT NAME: LERACID™ K-MS 10

INHALATION: Remove from contaminated atmosphere. If breathing has ceased, clear the victim’s airway and start mouth-to-mouth artificial respiration, which may be supplemented by the use of a bag-mask respirator, or a manually triggered, oxygen supply capable of delivering 1 liter/second or more. If the victim is breathing, oxygen may be administered from a demand-type or continuous-flow inhalator, preferably with a physician’s advice. Get medical attention immediately.

INGESTION: Give victim large quantities of water or milk, but do not induce vomiting. If vomiting occurs, administer additional fluid. Do not attempt induce vomiting or give anything by mouth to an unconscious person. Get immediate medical attention or call the nearest Poison Control Center immediately.

NOTES TO PHYSICIAN: All treatments should be based on observed signs and symptoms of distress in the patient. Consideration should be given to the possibility that overexposure to materials other than this product may have occurred. The principal manifestation of overexposure is corrosion or burns.

SECTION 05 - FIRE AND EXPLOSION DATA

CHARACTERISTICS:
Flash Point: N/A
Upper Explosion Limit (UEL): N/A
Lower Explosion Limit (LEL): N/A
Autoignition Temperature: N/A
Flash Point Method(s): N/A
Fire Hazard Classification: 0
(OSHANFPA)

EXTINGUISHING MEDIA:
Not combustible. Use appropriate extinguishing media for material that is supplying fuel. If water is used, the amount should be large enough to avoid heat and acid build-up.

SPECIAL FIRE FIGHTING PROCEDURES:
Vapors are irritating to the respiratory tract and may cause breathing difficulty and pulmonary edema. Evacuate residents who are downwind of the fire, prevent unauthorized entry to the fire area, close area to prevent runoff and contamination of water resources, have persons who may have been exposed to contaminated smoke examined by a physician and treated appropriately. Use NIOSH/MSHA approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode and full protective clothing if this material is involved in fire.

UNUSUAL FIRE AND EXPLOSION HAZARDS:
Thermal decomposition products may be hazardous. These include phosphorus oxide fumes. Contact with common metals produces flammable and potentially explosive hydrogen gas.
CHEMICAL STABILITY:
Stable [X] Unstable [ ]

CONDITIONS TO AVOID (if unstable):
Protect from moisture.

INCOMPATIBILITY (Materials to avoid):
This product reacts violently with bases, liberating heat and spattering. Contact with common metals produces flammable and potentially explosive hydrogen gas. Product may spatter upon contact with water or water containing chemicals and solvents with evolution of heat. This product also contains a dangerously powerful oxidizing agent and is incompatible with most substances, especially strong bases, metallic powders, carbides, hydrogen sulfide, turpentine, and combustible organics.

HAZARDOUS DECOMPOSITION PRODUCTS (from burning, heating, or reaction with other materials):
Under fire conditions, product may decompose to phosphoric oxide fumes, toxic nitrogen oxide fumes, hydrogen nitrate and acid mist. Contact with common metals produces flammable hydrogen gas.

HAZARDOUS POLYMERIZATION:
Will not occur.

CONDITIONS TO AVOID (if may occur):
N/A

NFPA REACTIVITY RATING: 1
MATERIAL SAFETY DATA SHEET

PRODUCT NAME: LERACID™ K-MS 10

SECTION 07 - SPILL, LEAK, AND DISPOSAL INFORMATION

CLEAN UP PROCEDURES:

SMALL SPILLS / LARGE SPILLS:
Any leak occurring in pipelines or equipment should be considered an acid leak and treated with extreme caution until the leak is proven not to be an acid leak. All contaminated areas should be immediately zoned off to avoid personnel exposures to the acid spray or stream. Adjust all appropriate valves to isolate the system and stop further leakage. Small spills should be absorbed with non-flammable chemical absorbent or carefully diluted with large amounts of water. The contaminated area should be covered with Sodium Bicarbonate, Soda Ash, or lime taking care to avoid any foaming or spattering that may occur from the neutralization reaction of the acid with these materials. Provide adequate ventilation as Carbon Dioxide may be generated during neutralization. Diking may be advisable to help contain the liquid spill. Make sure, all liquid has been thoroughly contacted and absorbed by the chemical absorbent. Transfer absorbed spill material and any contaminated underlying soil to a suitable chemical waste container. Dispose of container and contents in an environmentally acceptable way (see below). Washing down of spills with water is not recommended, as this tends to spread contamination and increases the possibility of percolation the acid down through the soil, or drains must not come in contact with any acid soluble sulfide wastes (such as sewers) because of the danger of evolving hydrogen gas.

OTHER EMERGENCY ADVICE:
Isolate or enclose the area of spill or leak. Only trained personnel equipped with NIOSH/MSHA approved full facepiece combination dust/mist and acid gas respirators should be permitted in this area. Review FIRE AND EXPLOSION HAZARDS and PROTECTIVE MEASURES before proceeding with clean up.

WASTE DISPOSALS:
Methods of disposal may vary upon location. Contact your local agencies to comply with all applicable federal, state, and local laws and regulations. Disposal of neutralized material in an approved hazardous waste management facility is recommended. Care must be taken when using or disposing of chemical materials and/or their containers to prevent environmental contamination. It is the users’ duty to dispose of the chemical materials and/or their containers in compliance with the Clean Air Act, the Clean Water Act, the Resource Conservation And Recovery Act, as well as any other relevant federal, state, or local laws/regulations regarding disposal.

REPORTABLE QUANTITY (RQ) (49CFR) (CWA/CERCLA):
2,800 lbs
MATERIAL SAFETY DATA SHEET

SECTION 08 - PROTECTIVE MEASURES

EYE PROTECTION:
Wear chemical splash goggles or full face shield. In addition, wear chemical splash goggles/full-length face shield combination, where the possibility of eye and face contact due to splashing or spraying of material exists. Contact lenses should not be worn when working with this material. Maintain eye wash fountain and quick-drench facilities in work area.

SKIN PROTECTION:
Wear impervious protective clothing, including boots, gloves, lab coat, apron, or coveralls to prevent skin contact.

RESPIRATORY PROTECTION:
Where airborne exposures may exceed OSHA/ACGIH permissible air concentrations, the minimum respiratory protection recommended is a negative pressure air purifying respirator with NIOSH/MSHA approved cartridges.

WORKING AND HYGIENIC PRACTICES:
Provide readily accessible showers and eye wash stations. Wash at the end of each working and before eating, smoking, or using the toilet.

SECTION 09 - STORAGE AND HANDLING

STORAGE:
Store product in shipping container in a dry, cool, and well-ventilated area. Isolate product from incompatible substances. Protect from moisture. Protect container from physical damage and from direct sunlight. Keep container tightly closed when not in use. KEEP OUT OF REACH OF CHILDREN!

HANDLING:
When handling, wear safety goggles and/or full face shield, rubber gloves, rubber boots, rubber apron, or coverall to prevent skin or eye contact. Never touch eyes or face with hands or gloves that may be contaminated with product. Wash thoroughly after handling or before eating, drinking, smoking, or using the toilet. Do not eat, drink, or smoke during handling.

OTHER PRECAUTIONS:
Carefully read all instructions on product label and Technical Data Sheet before handling or using this product. Make sure that all engineering and personal protective equipment are in working order.
MATERIAL SAFETY DATA SHEET

SECTION 10 - PHYSICAL AND CHEMICAL PROPERTIES

FORM, COLOR, AND APPEARANCE:

PHYSICAL FORM: Liquid
COLOR: Clear, colorless to yellow
ODOR: Pungent

TYPICAL PHYSICAL DATA:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (1% solution):</td>
<td>~1.8</td>
</tr>
<tr>
<td>VAPOR PRESSURE (mm Hg):</td>
<td>N/D</td>
</tr>
<tr>
<td>VAPOR DENSITY (Air = 1):</td>
<td>N/D</td>
</tr>
<tr>
<td>BOILING POINT:</td>
<td>N/D</td>
</tr>
<tr>
<td>FREEZING/MELTING POINT:</td>
<td>~5° F (-15° C)</td>
</tr>
<tr>
<td>SOLUBILITY IN WATER:</td>
<td>Complete</td>
</tr>
<tr>
<td>SPECIFIC GRAVITY (g/cm³):</td>
<td>1.38</td>
</tr>
<tr>
<td>SPECIFIC GRAVITY (lb/gal):</td>
<td>11.50</td>
</tr>
<tr>
<td>EVAPORATION RATE (Butylacetate = 1):</td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>

SECTION 11 - TRANSPORTATION INFORMATION

UN No.: 1760
PRIMARY HAZARD CLASS: CORROSIVE (8)
SECONDARY HAZARD CLASS: N/A
PACKAGING GROUP: II
FREIGHT CLASS: 55
DOT SHIPPING NAME: Corrosive liquids, n.a.s. (Phosphoric Acid, Nitric Acid)
IMO SHIPPING NAME: ---
IATA SHIPPING NAME: ---

SECTION 12 - FEDERAL REGULATIONS

TOXIC SUBSTANCES CONTROL ACT (TSCA):
Yes, listed.

EPA SARA TITLE III SECTION 311/312 (40CFR370) HAZARD CLASSIFICATIONS:

<table>
<thead>
<tr>
<th>Acute</th>
<th>Chronic</th>
<th>Fire</th>
<th>Reactivity</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
CERCLA Section 103:
Comprehensive Environmental Response, Compensation and Liability Act (Superfund). Releases to air, land or water of these hazardous substances which exceed the Reportable Quantity (RQ) of 2,500 lb. must be reported to the National Response Center, 1-800-424-8882; Listed at 40 CFR 302.4. Reportable Quantity: 2,800 lbs.

SARA SECTION 313:
Toxic Substances subject to annual release reporting requirements listed at 40 CFR 372.65.

USDA AUTHORIZATION:
This product is authorized by USDA for use in federally inspected meat and poultry plants.

SECTION 13 - LETTER DESIGNATION OF PERSONAL PROTECTIVE EQUIPMENT

<table>
<thead>
<tr>
<th>Equipment Description</th>
<th>Letter Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety Glasses</td>
<td>A</td>
</tr>
<tr>
<td>Safety Glasses, Gloves</td>
<td>B</td>
</tr>
<tr>
<td>Safety Glasses, Gloves, Synthetic Apron</td>
<td>C</td>
</tr>
<tr>
<td>Face Shield, Gloves, Synthetic Apron</td>
<td>D</td>
</tr>
<tr>
<td>Safety Glasses, Gloves, Dust Respirator</td>
<td>E</td>
</tr>
<tr>
<td>Safety Glasses, Gloves, Synthetic Apron, Dust Respirator</td>
<td>F</td>
</tr>
<tr>
<td>Safety Glasses, Gloves, Vapor Respirator</td>
<td>G</td>
</tr>
<tr>
<td>Splash Goggles, Gloves, Synthetic Apron, Vapor Respirator</td>
<td>H</td>
</tr>
<tr>
<td>Safety Glasses, Gloves, Combination Dust and Vapor Respirator</td>
<td>I</td>
</tr>
<tr>
<td>Safety Glasses, Gloves, Synthetic Apron, Combination Dust and Vapor Respirator</td>
<td>J</td>
</tr>
<tr>
<td>Airline Hood or Mask, Gloves, Full Protective Suit, Boots</td>
<td>K</td>
</tr>
<tr>
<td>Situations Requiring Specialized Handling</td>
<td>X</td>
</tr>
</tbody>
</table>
# Appendix IX

## Full Laboratory Data Sheet and Testing Results

<table>
<thead>
<tr>
<th>Bottle</th>
<th>Sample # (yyyy-mm-dd-##)</th>
<th>Sample Description (Location, Equipment, Processes Details, etc)</th>
<th>Collected By</th>
<th>pH</th>
<th>TSS (mg/L)</th>
<th>COD</th>
<th>Tested By</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2008-02-12-01</td>
<td>Fermentor Caustic Wash to be followed by water rise, this sample going directly down drain</td>
<td>Brian Conner</td>
<td>9 (paper)</td>
<td>8.98</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>2008-02-12-02</td>
<td>Rinsed through fermenter idodine water solution, last step to seal tank</td>
<td>Brian Conner</td>
<td>5 (paper)</td>
<td>N/A</td>
<td>N/A</td>
<td>pH - M. Slezycki</td>
</tr>
<tr>
<td>3</td>
<td>2008-02-12-03</td>
<td>Mash tun rise (no caustic) after solids shoveled out</td>
<td>Brian Conner</td>
<td>4 (paper)</td>
<td>33.6</td>
<td>10519.7</td>
<td>pH - M. Slezycki</td>
</tr>
<tr>
<td>4</td>
<td>2008-02-12-04</td>
<td>Yeast drained off of the bottom of the fermentor (step 1 of fermentor cleaning)</td>
<td>Brian Conner</td>
<td>6 (paper)</td>
<td>66.4</td>
<td>13244.7</td>
<td>pH - M. Slezycki</td>
</tr>
<tr>
<td>5</td>
<td>2008-02-13-01</td>
<td>Whirlpool through echanger, then to fermenter, cooled from 200 to 50 degrees F, residual hops from whirlpool were collected</td>
<td>Alicia Bridgewater</td>
<td>6 (paper)</td>
<td>130.8</td>
<td>13015.7</td>
<td>pH - M. Slezycki</td>
</tr>
<tr>
<td>6</td>
<td>2008-02-13-02</td>
<td>Pre clean Fermentation vessel: A hot water prewash is used to rinse out residual yeast, no caustic used, just a precursor to the caustic wash</td>
<td>Alicia Bridgewater</td>
<td>6 (paper)</td>
<td>N/A</td>
<td>115.4</td>
<td>pH - M. Slezycki</td>
</tr>
<tr>
<td>7</td>
<td>2008-02-13-03</td>
<td>Fermenter caustic wash followed by water rinse, (Initial discharge down the drain)</td>
<td>Alicia Bridgewater</td>
<td>10 (paper)</td>
<td>9.95</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>8</td>
<td>2008-02-14-01</td>
<td>Caustic wash from whirlpool, 100 gal of H20 to 1 gal of caustic</td>
<td>Michael Slezycki</td>
<td>13 (paper)</td>
<td>12.23</td>
<td>6</td>
<td>N/A</td>
</tr>
<tr>
<td>9</td>
<td>2008-02-14-02</td>
<td>Wash water from mash tun, not much water ends up in the drain, roughly 10 gallons at most</td>
<td>Michael Slezycki</td>
<td>6 (paper)</td>
<td>12.8</td>
<td>5303.6</td>
<td>pH - M. Slezycki</td>
</tr>
<tr>
<td>10</td>
<td>2008-02-14-03</td>
<td>Kettle bottoms, trub from kettle, roughly 10 gallons of trub followed by 10 gallons of H20 wash</td>
<td>Michael Slezycki</td>
<td>6 (paper)</td>
<td>39.8</td>
<td>12607.7</td>
<td>pH - M. Slezycki</td>
</tr>
<tr>
<td></td>
<td>Date</td>
<td>Description</td>
<td>Author</td>
<td>Date</td>
<td>pH</td>
<td>Sample Used</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-----------------</td>
<td>---------</td>
<td>-----</td>
<td>--------------</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>2008-02-14-04</td>
<td>Whirlpool bottoms, trub after whirlpool, roughly 50 gallons of trub followed by 90 gallons of H2O</td>
<td>Michael Slezycki</td>
<td>6 (paper)</td>
<td>138.6</td>
<td>13451</td>
<td>pH - M. Slezycki TSS - A. Bridgewater COD - M. Slezycki</td>
</tr>
<tr>
<td>12</td>
<td>2008-02-14-05</td>
<td>Wastewater sample collected from the Keg Washer during operation.</td>
<td>Michael Slezycki</td>
<td>12 (paper)</td>
<td>N/A</td>
<td>N/A</td>
<td>pH - M. Slezycki</td>
</tr>
<tr>
<td>13</td>
<td>2008-02-18-01</td>
<td>Bright tank wash: 1 gal caustic to 87.5 gal water. Recycled through the tank for 30 minutes, drained, and rinsed. (Sample from dripping door)</td>
<td>Brian Conners</td>
<td>10 (paper)</td>
<td>N/A</td>
<td>N/A</td>
<td>pH - M. Slezycki</td>
</tr>
<tr>
<td>14</td>
<td>2008-02-18-02</td>
<td>Same as 13 except the sample was take from the pump recycling the solution through.</td>
<td>Brian Conners</td>
<td>10 (paper)</td>
<td>N/A</td>
<td>N/A</td>
<td>pH - M. Slezycki</td>
</tr>
<tr>
<td>15</td>
<td>2008-02-19-01</td>
<td>Cleaning process for the DE filter: Cleaned weekly on filtering day for sanitation purposes. 100 oz caustic to 100 gal water.</td>
<td>Brian Conners</td>
<td>12.00 (meter)</td>
<td>N/A</td>
<td>N/A</td>
<td>pH - M. Slezycki</td>
</tr>
<tr>
<td>16</td>
<td>2008-02-28-01</td>
<td>Run off from grain truck collection bin</td>
<td>Michael Slezycki</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>pH - M. Slezycki</td>
</tr>
<tr>
<td>17</td>
<td>2008-02-28-02</td>
<td>Sample from bottle packout caustic wash</td>
<td>Michael Slezycki</td>
<td>7.60 (meter)</td>
<td>N/A</td>
<td>N/A</td>
<td>pH - M. Slezycki</td>
</tr>
<tr>
<td>18</td>
<td>2008-02-28-03</td>
<td>Another grain truck run off sample</td>
<td>Michael Slezycki</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A - Sample not used</td>
</tr>
<tr>
<td>19</td>
<td>2008-02-28-04</td>
<td>Wastewater sample collected from Kettle Wash</td>
<td>Michael Slezycki</td>
<td>12.56 (meter)</td>
<td>N/A</td>
<td>N/A</td>
<td>pH - M. Slezycki</td>
</tr>
</tbody>
</table>
# Appendix X

## pH Calculations

\[
pH = \log \left( \frac{\text{lbs of caustic}}{\text{gallons of water}} \right)
\]

<table>
<thead>
<tr>
<th>Caustic Wash Processes</th>
<th>Volume of Caustic Used (gal)</th>
<th>Weight of Caustic Used (lbs)</th>
<th>Volume of Water in Caustic Wash (gal)</th>
<th>Volume of Water Used in Rinse (gal)</th>
<th>Combined Volume of Wash and Rinse (gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mash Tun</td>
<td>0.78</td>
<td>2.64</td>
<td>100</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>Kettle Wash</td>
<td>1.00</td>
<td>3.38</td>
<td>100</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Whirlpool / Heat Exchanger</td>
<td>1.00</td>
<td>3.38</td>
<td>100</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Fermentation Vessel</td>
<td>0.94</td>
<td>3.16</td>
<td>75</td>
<td>100</td>
<td>175</td>
</tr>
<tr>
<td>Bright Tank</td>
<td>0.94</td>
<td>3.16</td>
<td>75</td>
<td>100</td>
<td>175</td>
</tr>
<tr>
<td>DE Filter</td>
<td>0.78</td>
<td>2.64</td>
<td>100</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Bottle Packout</td>
<td>0.63</td>
<td>2.11</td>
<td>120</td>
<td>600</td>
<td>720</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Caustic Wash Processes</th>
<th>Caustic Wash Concentration (lbs caustic)/(gal H2O)</th>
<th>Caustic Wash and Rinse Combined Concentration (lbs caustic)/(gal H2O)</th>
<th>pH of Caustic Wash</th>
<th>pH of Caustic Wash and Rinse Combined</th>
<th>Sampled pH Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mash Tun</td>
<td>2.64E-02</td>
<td>6.59E-03</td>
<td>12.90</td>
<td>12.30</td>
<td>Not Sampled</td>
</tr>
<tr>
<td>Kettle Wash</td>
<td>3.38E-02</td>
<td>1.69E-02</td>
<td>13.01</td>
<td>12.70</td>
<td>12.56</td>
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<tr>
<td>Whirlpool / Heat Exchanger</td>
<td>3.38E-02</td>
<td>1.69E-02</td>
<td>13.01</td>
<td>12.70</td>
<td>12.23</td>
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<tr>
<td>Fermentation Vessel</td>
<td>4.22E-02</td>
<td>1.81E-02</td>
<td>13.10</td>
<td>12.73</td>
<td>9.95</td>
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<tr>
<td>Bright Tank</td>
<td>4.22E-02</td>
<td>1.81E-02</td>
<td>13.10</td>
<td>12.73</td>
<td>9.03</td>
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<tr>
<td>DE Filter</td>
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<td>1.32E-02</td>
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<td>12.60</td>
<td>12.00</td>
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<td>Bottle Packout</td>
<td>1.76E-02</td>
<td>2.93E-03</td>
<td>12.72</td>
<td>11.94</td>
<td>7.30</td>
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