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TECHNICAL FEASIBILITY RISK FACTORS FOR THE APPLICATION OF:

High Rate Anaerobic Treatment of Brewery Wastewater

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ABSTRACT

A brewery can incur a significant operating cost from fees associated with wastewater discharge. Financial or regulatory pressures can encourage brewery management to seek capital investment in the wastewater treatment area to reduce annual operating costs. The upflow anaerobic sludge blanket (UASB) process, including the expanded granular sludge bed (EGSB) technology is one such method used in the beverage industry worldwide, with more than 230 installations. The number of UASB installations, including the newer high rate EGSB system, has grown tremendously during the 90's. Because this technology is becoming widespread, there is an urgent need for onsite reviews and evaluations of operational problems and associated costs.

In today's highly competitive business environment, brewery management can't afford to commit to projects without consultation with competent and knowledgeable vendors and consultants to explain the risks that they face. While a project may look like a sure money-maker on paper, it may have hidden problems that can affect the return on investment (ROI) calculations, and jeopardize its economic feasibility.

Project risks come from a number of sources: regulatory changes, team turnover, or unreliable time and cost estimates. This paper identifies and discusses some potential technical risks associated with a UASB installation that brewery staffs need to consider and address-early in the equipment selection stage before a contract is signed to improve ultimate project success. Topics include temperature control, toxicity potential, macro- and micronutrient requirements, odor management, and pH/alkalinity effects on anaerobic systems performance.

Keywords: anaerobic systems, wastewater, brewery, design

SINTÉSIS

Un costo de operacion significativo para una cerveceria puede resultar de las tarifas asociadas a la descarga de aguas servidas. Presiones financieras o regulatorias pueden forzar a la administracion de una cerveceria a buscar una inversion de capital para el tratamiento de aguas servidas para reducir los costos de operacion. La tecnologia de Camas Granulares Expanidads de lodos es popular en mas de 230 instalaciones del cause alto de la capa anerobica de lodos (UASB) en procesos en la industria de bebidas a nivel mundial. El numero de instalaciones UASB, incluyendo los sitemas mas nuevos de alto flujo, ha incrementado tremendamente durante la decada de los 90. Esta tecnologia es relativamente nueva, y hay una gran urgencia para revisiones en lugar y evaluaciones de problemas operativos y costos asociados.

En el medio de negocios altamente competitivo de hoy dia, administracion de una cerveceria no puede darse el lujo de entrar a ciegas en proyectos sin cabalmente entender los riesgos que enfrentan. Un proyecto se puede ver como un ganador seguro en papel pero puede tener problemas escondidos que pueden afectar los calculos de retorno sobre la inversion, y hacer peligrar la fisibilidad economica.

Los riesgos de un proyectos provienen de varias fuentes; cambio de equipos, o estimados desconfiables de estimados de tiempo y costos. Este trabajo identificara y discutira riesgos tecnicos potenciales asociados con la instalacion UASB que el personal de una cerveceria necesita considerar y tratar en la seleccion de equipos en las primeras fases del proyecto antes de que se firme un contrato, para mejorar el exito final del proyecto. Topicos discutidos incluyen el control de temperatura, potencial de toxticidad, requerimientos micro y macro de nutricion, manejo de olores, y efectos de pH/alkalinidad en el rendimiento de sistemas anaerobicos.

RISK MANAGEMENT

Risk management includes identifying, analyzing, and responding to project risk, as well as maximizing the results of positive aspects and minimizing the consequences of adverse events.

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Today's project professionals must be able to identify and quantify risk and implement mitigating strategies. The rationale behind risk analysis is simple — knowledge is power. The more you know about what could happen, the better equipped you are to make decisions about what to do. Risk assessment starts during the early project selection process before a contract for equipment and work has been prepared and executed. Common risks come from fairly standard sources,[1] such as 1) technically rooted risks, 2) incompetent consultative staff, 3) poor time and cost estimates, 4) regulatory changes, and 5) a change in players. Technical risk is the risk that the project team will not be able to achieve the project objectives, that they won't have the know-how, skills, technology, or information to produce the final "deliverable" in accordance with the customer's acceptance criteria.[2]

Closer management attention will be required as the number of the following factors increases:

- Interaction across multiple divisions of a company
- Interactions outside a company, especially with new consul tants and vendors
- Development of technology that is new to the company, or to a particular brewery site
- Application of a new method of project delivery, such as design- build rather than traditional design-review-bid-build.
- Introduction of technologies outside of a brewery's core business of brewing and packaging beer.

Fundamentals of Anaerobic Digestion

A review of published literature indicates that anaerobic processes are suitable for brewery wastewater treatment.[3] Furthermore, using the high-rate UASB as the reactor for the final conversion of organic matter into methane and carbon dioxide has been proven to be reliable.[4] However, the task for the brewery engineer is threefold: 1) to put subjective vendor claims into objective criteria for management evaluation; 2) to accurately estimate the capital investment for a reliable operation; and 3) to quantify the annual operational costs to meet the objective criteria.

The latest UASB process maintains a high active solids mass. The terminology for the reactors varies from 'expanded granular sludge beds' to 'high rate.' The term "bugs" is frequently used for the sludge granules. The UASB process works best on wastewaters—such as those from a brewery—with a high percentage of chemical oxygen demand (COD) in the solubilized form. With EGSB reactors, the volumetric loading rates are reported to achieve levels in excess of 30 Kg-TCOD/day per cubic meter of reactor volume. The EGSB reactor can achieve higher performance than the conventional UASB due to specific system design parameters which include the proper reactor height to diameter ratio; effective 3 phase separation of bio-gas, wastewater, and granules; and effective distribution, dilution, and mixing of both influent and recirculated wastewater. The higher loading rates are accomplished using the same type of sludge typical of a UASB, seeding it into the high rate reactor, and allowing the sludge to develop a biomass granulation that can achieve up to twice the sludge activity level ($Kg\text{-}COD_{bio\text{-}degraded}$ /day per Kg of biomass in the reactor). The EGSB can handle significantly higher upflow velocities and gas production rates without washing out the sludge.[5] With regard to high rate reactors, the equipment vendor guarantees the development of a granular biomass that achieves a specified rate of COD reduction and a specified quantity and quality of biogas.

Available literature suggests that anaerobic digestion is a complex multi-step biological process that undergoes the following stages:

- **Stage 1, Hydrolysis** - Non-soluble organic compounds such as carbohydrates, protein, and lipids are hydrolyzed to yield monomer compounds such as amino acids, sugars, and fatty acids. Fermenting bacteria carry out this step using extracellular enzymes.

- **Stage 2, Acidogenesis** - The monomer compounds are fermented by intracellular enzymes into Volatile Fatty Acids (VFAs) such as acetic, propionic, and butyric acids. Hydrogen, carbon dioxide, and ethanol are by-products of this reaction.

- **Stage 3, Acetogenesis** - Organic acids with more than three carbons per molecule are converted to acetic acid. Hydrogen and carbon dioxide are also by-products of this reaction.

- **Stage 4, Methanogenesis** - This is the only step in which actual COD reduction occurs. Acetic acid, hydrogen, and carbon dioxide are converted to methane by methanogenic bacteria. Methane gas is highly insoluble, and its departure from solution represents actual waste stabilization. Figure 1 shows the various stages of anaerobic digestion.

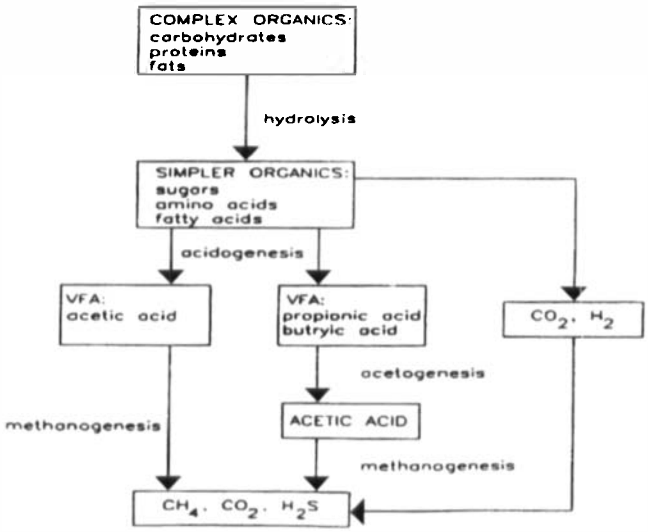

FIGURE 1
Anaerobic Digestion Process

System Design Considerations

Vendors are given a set of wastewater characteristics for use during reactor design. These parameters will consist of a typical range of organic loading, solids loading, pH, temperature, and flow variations. Either the reactor must be robust enough to handle the wastewater within these variations or the peripheral equipment must be designed to consistently provide the organic substrate to the reactor under adequate environmental conditions. General design considerations that are common to all anaerobic systems include:[6]

- the need for heating/cooling of the wastewater
- nutrient (micro and/or macro) addition requirements
- pH and/or alkalinity adjustment
- hydrogen sulfide management (odors, corrosion, biogas treatment)
- anaerobic sludge (source for seeding and excess disposal)
- biogas handling (flaring and/or compression and beneficial use)
- a level of process control consistent with the brewery's staffing and operational capabilities
- toxic characteristics of influent wastewater

Design considerations that are specific to brewery wastewater and the UASB include:

- flow/load equalization
- preconditioning (hydrolysis) of the wastewater
- limitation of influent total suspended solids (TSS) to approximately 20 per cent of the influent total chemical oxygen demand (TCOD)
- single or multiple reactors
- removal of sanitary components from process wastewater
- removal of coarse solids
- removal of diatomaceous earth

The peripheral equipment must be adequately designed so that properly trained technicians can operate the anaerobic system to achieve process stability through the following three basic requirements:

- Maintain a viable and active sludge granule population by providing a wastewater influent stream that is within the proper operating range of key parameters.
(Keep the bugs happy.)
- Ensure the growth of the proper type of granules and prevent cell washout or degradation.
(Keep the bugs in the reactor.)
- Provide chemicals and nutrients at optimal rates.
(Operating experience will show whether these rates meet initial expectations provided by consultants and vendors.)

Figure 2 shows an example of components for an anaerobic system.

This paper addresses the various factors involved in determining the technical feasibility of applying high-rate UASB technology to treat brewery wastewater. Case study examples will be presented and discussed.

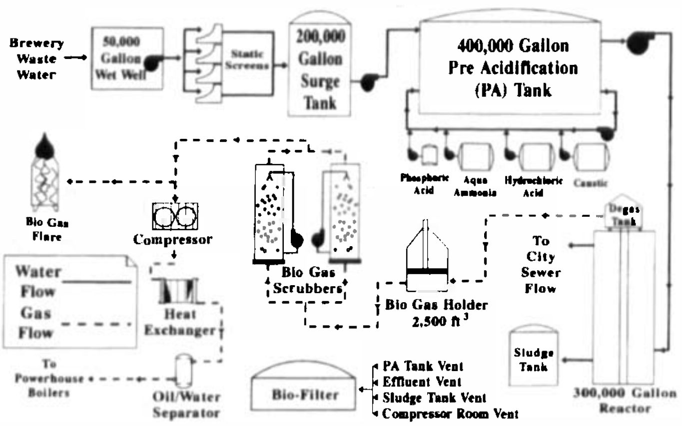

FIGURE 2
Example Layout for Anaerobic System

MATERIALS AND METHODS

The project under consideration is an operational, full-scale, expanded granular sludge bed reactor designed for a daily flow of 1.7 million gallons (1200 gpm) treating brewery wastewater at 5,800 ppm of TCOD. The following methods were used to monitor system performance.

Total Suspended Solids Analysis

Each morning, 24 hour composite wastewater samples are taken from the influent to the pre-acidification (PA) tank and from the reactor effluent. TSS (mg/l) is determined by using AWWA Standard Method 2540 D.[7]

COD Analysis

Twenty-four-hour composite wastewater samples from the influent to the PA tank and from the reactor effluent are analyzed for total and soluble COD using the U.S. EPA-approved Hach spectrophotometric method.

Methanogenic Activity Test

This test determines the maximum rate at which anaerobic sludge can produce methane from a readily bio-degradable substrate. It can also assess or evaluate the current quality of the anaerobic sludge or establish a reference point for toxicity testing at a specific brewery. The methanogenic activity test normally is not done at the brewery since the sludge must be sent to a properly equipped laboratory for testing.

The basis of the test is that a specific amount of substrate (usually acetic acid) is added to a known amount of sludge under ideal conditions. Temperature and pH are controlled, and sufficient nutrients and trace elements are supplied. Methane production is then determined over time and a maximum methane production rate is established. Approximately 80 percent of the acetic acid substrate is utilized after seven days. A second feeding of the same amount of acetic acid is then added. In most cases, the measured activity is greater after the second feeding because the granular sludge has adapted to the substrate. The COD equivalence of 0.395 m^3 of methane produced per kilogram of degradable COD at 95°F is used to calculate the methanogenic activity.
The methanogenic activity level determined by this test is based on using acetic acid as a substrate for the biomass. When interpreting the results, the temperature difference between the lab tests (95°F) and the actual reactor must be considered.

Alkalinity and VFA Determination

Alkalinity and VFAs are determined by centrifuging (or filtering) a grab sample and titrating it with 0.1 N HCl to a pH of 3.0 to convert the VFAs from the ionized to un-ionized form (A ml). Next, the sample is boiled to remove the CO_2 and cooled. The sample is then titrated with 0.1 N NaOH to a pH of 6.5 (B ml).[8] The titrant volumes are designated A and B in the following calculations:

$$\text{Alkalinity} = (A-B) \text{ milli-equivalents/liter}$$
$$\text{VFAs} = (B*101) - (A + 100) /101 \text{ meq/l}$$

Temperature

Temperature is measured by a sensing element installed in the side of the reactor.

Biomass Inventory

To estimate the total amount of sludge present in the reactor, sludge samples are taken from sample ports mounted on the reactor wall. The total amount of sludge present in the reactor is calculated by multiplying the solids concentration determined at a sample port by the reactor volume for which the sample port represents and adding these numbers. An assumption is made that the concentration found at port 1 (bottom port) is representative of the total solids (TS) content between the bottom of the reactor and halfway between the first and second ports. The concentration at port 2 represents the concentration of sludge from halfway between ports 1 and 2 to halfway between port 2 and 3, etc. The total sludge inventory equals the sum of each measurement. The organic content from each sample port is used to determine the volatile solids (VS):

% VS = (% Organic) * (% TS) / 100

TS and VS are determined by using AWWA Standard Method 2540 B and 2540 E respectively. In the following equations TS is in kg/m^3 (1% TS = 10 kg/m^3):

Total sludge inventory (Kg-TS) = (Port 1 TS) * (Volume of Port 1) + (Port 2 TS)*(Volume of Port 2) + (Port 3 TS) * (Volume of Port 3) + (Port 4 TS) * (Volume of Port 4) + (Port 5 TS) * (Volume of Port 5).

Total biomass inventory (Kg-VS) = (Port 1 VS) * (Volume of Port 1) + (Port 2 VS) * (Volume of Port 2) + (Port 3 VS) * (Volume of Port 3) + (Port 4 VS) * (Volume of Port 4) + (Port 5 VS) * (Volume of Port 5).

Toxic Agents

In toxicity testing, the methanogenic activity level of a specific sludge sample that is metabolizing an acetic acid (blank) solution is compared to activity levels of that same sludge in contact with a certain concentration of the suspected toxic product to be tested. If the tested product is toxic to the methanogenic bacteria, the sludge activity will be lower. This decrease in activity level is expressed in percent inhibition. Repeated feedings can determine whether and/or how quickly the granular sludge can adapt to a specific wastewater.

If the activity recovers to that of the blank after the toxic solution is replaced with the standard solution, the toxicity is reversible. If the sludge activity does not recover, the resultant toxicity is called irreversible. Further analysis of the effects of certain toxicants can be investigated in the lab (i.e., dilution, pH adjustment, chemical addition, etc.).

RESULTS AND DISCUSSIONS

The analysis of the risks in attaining consistent, reliable operation of a high-rate UASB project included the following factors: temperature control, toxicity potential, macro-and micronutrients, odor management, pH/alkalinity effects, and technical capability of system vendors. In a situation where the actual system operation does not meet design performance criteria, the cause could be a combination of the possible risk factors.

Temperature Control

Temperature has an important effect on the growth rate and activity of micro-organisms. Brewery wastewater is typically within a mesophilic temperature range of 68-110°F. For the most stable operation, a reactor should be operated at about 95°F.[9] Figure 3 shows an annual wastewater temperature cycle for a brewery in northern Texas.

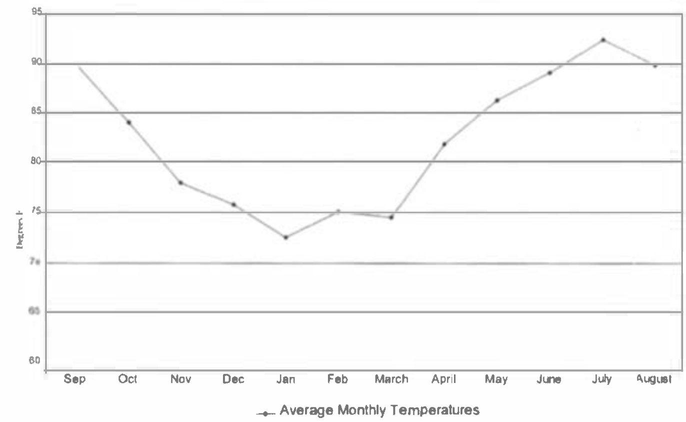

FIGURE 3
Average Monthly Wastewater Temperature

The anaerobic process is more sensitive to temperature variation than its aerobic counterpart. Some equipment vendors use a rule of thumb that sludge activity decreases by a factor of 10 percent for each 1° drop in temperature below 30°C (86°F). Within the reactor, methanogens are more temperature-sensitive than the acidogens. Thus, at lower operating temperatures, higher alkalinity levels may be required to guard against a VFA increase that could in turn lower the pH if the buffer capacity is exceeded. However, factors other than temperature—such as toxicity effects, change in pH, or macro/micronutrient levels—can affect specific biomass performance, and they must be considered in any troubleshooting effort.

If the reactor cannot provide sufficient biomass to compensate for temperature decreases, the project design must consider an alternative method of heating the wastewater. Normally the most cost-effective use of biogas is as supplemental fuel to a process boiler. While diverting the biogas to heat the wastewater will have a significant negative effect on the ROI analysis, it will also improve system performance by providing the sludge with a constant temperature feedstock. Another heat source might consist of excess steam or hot water from an existing process boiler installation.

Between 86°F -104°F, the growth rate and activity level of most methanogenic bacteria are optimized. Sludge activity decreases sharply when the temperature exceeds 104°F, and the effect can be irreversible. Thus, risk assessments must consider the need to both heat and cool the wastewater to maintain stable operation.

Toxicity Potential

Anaerobic equipment vendors can provide a pilot reactor for testing wastewater to determine potential toxic effects. The pilot reactor is seeded with highly active sludge and then continuously exposed to the wastewater stream. A sludge sample is regularly tested with the methanogenic activity test. If the sludge has been exposed to toxins in the wastewater, degradation in performance will be noted. Typically, a three to four month test period is adequate to determine the effects of wastewater on sludge performance.

Wastewater containing chemicals with toxic properties or which can affect granule characteristics must be identified. Competent and knowledgeable vendors and consultants with access to laboratory facilities should evaluate the Material Safety Data Sheets for all chemicals used at the brewery site that could end up in the wastewater. Examples might be water treatment chemicals for cooling towers, evaporative condensers or pasteurizers. The usage of strong disinfectants such as quaternary amines for disinfecting purposes should be quantified and investigated to determine the average and maximum concentrations in the wastewater. Packaging conveyor lubricants are formulated with ingredients that provide not only lubricity but may also have either bio-static or anti-microbial properties that should be investigated. Table 1 shows the toxicity testing results of three packaging conveyor lubricants.

TABLE 1
Comparative toxicity test results of three conveyor lubricants

	FEED #1 (% of Blank)	FEED #2 (% of Blank)	RECOVERY #1 (% of Blank)	RECOVERY #2 (% of Blank)
Lube #1 (115 ppm)	79	78	73	74
Lube #1 (230 ppm)	72	59	NA	40
Lube #2 (115 ppm)	101	99	92	98
Lube #2 (230 ppm)	87	92	93	95
Lube #3 (110 ppm)	96	87	82	81

Conveyor lubricants are in continuous use on the packaging lines with spray water collected in floor drains. In this example, for Lube #1 a concentration of 115 ppm was calculated as the average wastewater concentration, based on total pounds used for one year divided by the total wastewater during that time period. A peak concentration of 230 ppm was selected as the worst case concentration under low wastewater flow conditions, i.e., during weekends or holidays. Lube #1 at 115 ppm reached only 74 percent during recovery test #2. The anaerobic equipment vendor concluded that irreversible damage had occurred to the methanogenic bacteria. Based on these data, Lube #2 appeared to be superior, with no significant drop in activity at 115 ppm and the highest recovery level. The evaluation of this data resulted in a decision to replace Lube #1 with Lube #2.

Macro- and Micronutrients Requirements

Like all organisms, anaerobic bacteria need nutrients for growth. Minimum macronutrient requirements for nitrogen and phosphorus can be calculated from the growth yield and composition (10-12% nitrogen and 2% phosphorus of total solids). Theoretically, for every 350 mg/l of biodegradable COD in the influent, the sludge requires 5 mg/l of nitrogen and 1 mg/l of phosphorus. Thus, for a wastewater stream of 5,800 mg/l of TCOD, the degradable COD would be approximately 80 percent in brewery wastewater, resulting in target concentrations of 66 mg/l of nitrogen and 13 mg/l of phosphorus for the reactor influent. If these concentrations are not in the raw wastewater, the system will normally be designed for nutrient addition.[10]

Table 2 shows recommended micro nutrient levels in the wastewater and the granular sludgemass. The guidelines for nutrient levels in the granules are based on one vendor's experience from documented levels of sludge that performed well across various industrial sectors.

Table 2 lists actual nutrient levels in granular sludge that were detected during an investigation of poor performance suspected to be caused from either toxic chemicals or nutrient deficiency in the wastewater. The table shows the amount of calcium required for balanced cell development. However, calcium is also needed for granule development, which can be affected by operating pH. If problems with granule development are observed in the wastewater, one vendor recommends 100-150 mg/l of calcium be available in the wastewater.

TABLE 2
Vendor Recommendations for Micronutrient Concentrations in Wastewater and Granules

	WASTEWATER		SLUDGE	
	Vendor Guidance on Minimum Micronutrient levels in Wastewater (mg/l)	Actual Levels in Brewery Wastewater (mg/l)	Vendor Guidance on Minimum Levels in Sludge (mg/Kg)	Actual Levels in Reactor Brewery Sludge During Period of Poor System Performance (mg/Kg)
Aluminum	0.0015	0.0760	7,500 - 45,000	128
Calcium	1.45	45	8,800 - 32,000	5,160
Cobalt	0.00044	<.011	7 - 38	1.4
Copper	0.0015	0.0890	83 - 355	286
Iron	0.44	0.98	2,500 - 33,000	9,950
Magnesium	1.45	6.43	1,500 - 3,300	1,100
Manganese	0.0044	0.0230	165 - 1,000	3.3
Molybdenum	0.0004	0.0630	11 - 180	55.5
Nickel	0.0044	<.016	26 - 81	12.8
Potassium	2.3	42.5	2,300 - 9,200	6,980
Sodium	2.3	204.0	1,400 - 7,000	11,600
Zinc	0.015	0.005	570 - 1,650	298

Odor Management

The anaerobic process reduces sulfates in the wastewater to sulfides. These sulfides will partition between the gas and water phases in the reactor. Hydrogen sulfide in the biogas can be stripped with a caustic scrubber (see Figure 2). A common method to control bulk liquid sulfides is ferric or ferrous chloride addition. Adding iron to the influent to the reactor has the dual benefits of adding a nutrient as well as reducing gas and liquid phase sulfides.[11]

Since hydrogen sulfides can be smelled at low concentrations (<100 ppb), displacement air in the headspace of wastewater storage tanks and lines must be ventilated and any odors removed. Alternate ways to treat the ventilated odors include chemical scrubbing, compost, or soil biofilters.[12] Biofilters offer a way to reduce operating costs by using either a soil or a compost medium to biologically reduce odors as air is passed through a bed. Soil biofilters operate longer than compost media before replacement is required. Both types operate in moist conditions; however, water control is more critical with compost filters, because once dried, they are hydrophobic and difficult to rewet.[13]

Design criteria should be determined for acceptable effluent sulfide concentrations. Sulfides in the wastewater can encounter turbulence in downstream sewers, come out of solution, and cause nuisance odor conditions. Local ordinances should be reviewed. Sulfide limitations are also important to municipalities because the sulfides can be biologically oxidized to sulfuric acid above the waterline in sewers and could cause corrosion problems.[14] Post-treatment of the reactor effluent can be accomplished with biological oxidation of dissolved sulfides to sulfates in aerated tanks.

pH/Alkalinity Effects

The pH in a normally functioning reactor is controlled by an alkalinity system composed of bicarbonates and countered by VFAs. Since carbonic acid often exceeds other weak acids in the wastewater, sufficient bicarbonate alkalinity must be present to neutralize it. Because acidogens grow considerably faster than methanogens, fluctuations in the organic loading rate or other operational conditions may cause variations to VFA concentrations. To maintain a constant pH, sufficient buffering capacity is needed. Figure 4 shows the distribution curves for carbonic acid and bicarbonate ion as a function of pH. Ka is the acid ionization constant. At $pH = pKa_1 = 6.38$, the concentration of H_2CO_3 equals the concentration of HCO_3^-, and a good buffer system exists. Because H_2CO_3 is diprotic, there are actually two different buffer systems that function over different pH regions. Superimposed on the distribution curve is a curve (dashed line) that shows the relative activity of methanogens as a function of pH.[15] The figure shows that methane formation proceeds between pH 6.0 and 8.5, with the optimum methanogenic activity in the 6.5 to 7.5 range. Note the rapid drop in activity outside this range.

Reactor upset can be caused by an organic overload of the reactor. Early signs of a reactor overload can be a drop in pH of the effluent from the reactor, or an abnormal increase in biogas generation within the reactor. Biogas is normally generated at a rate of 0.31 cubic meters per Kg of COD removed with a 70-80% methane content. The biogas generation rate will vary depending on the current volumetric loading rate

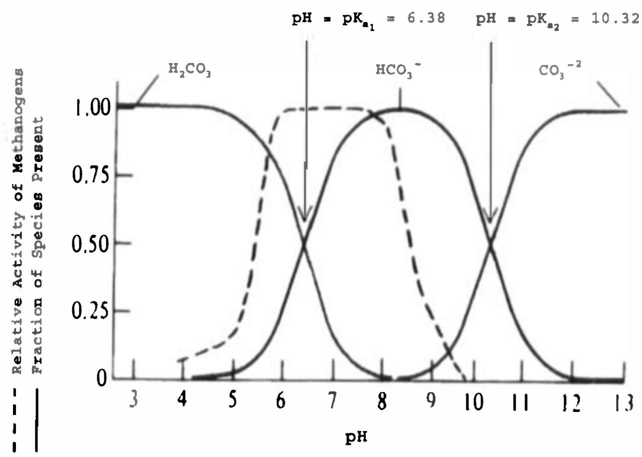

FIGURE 4
Methanogenic Activity Superimposed on pH Distribution Curves for Carbonic Acid and Bicarbonate Ion

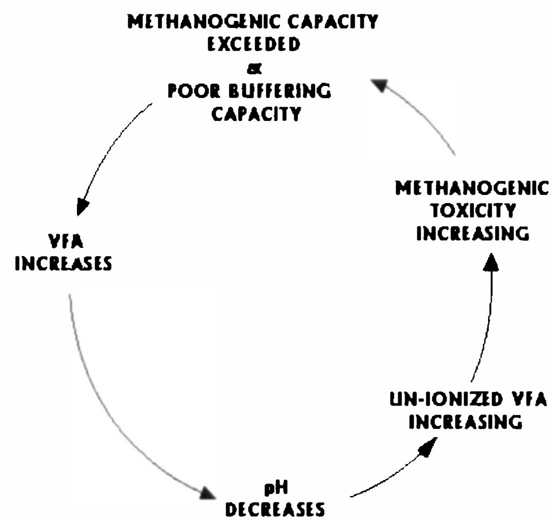

FIGURE 5
Cycle of a Reactor Upset

(VLR=Kg-TCOD/ m^3 day), the daily COD load the reactor can handle divided by the reactor volume). The loading rate depends on the temperature, sludge activity, and sludge mass. Confirmation of the reactor upset will be seen in a sharp increase in the effluent VFA tests results.

Reactor overloading must be corrected immediately. Figure 5 shows the cycle of a reactor upset. Without adequate pH control, a prolonged imbalance can lead to total inhibition. Once the problem has been identified and corrected, stable operation can be regained. Gradual increases in flow and loading to the anaerobic system can be started in increments of 10 percent per day. The frequency of VFA grab samples should be increased from once to twice per day to check process stability. If VFAs increase, the flow should be reduced by 10 percent to allow time for the system to stabilize before the load is increased again.

TABLE 3
Comparison of major system components and chemicals

		SYSTEM #1	SYSTEM #2
Preacidification tank	gallons	400,000	400,000
Reactor volume	gallons	319,000	475,000
Internal recirculation	gpm (estimated)	240	0
External recirculation to preacidification tank	gpm	0	560
Reactor hydraulic retention time	hours	4.5	6.7
Volumetric loading rate	Kg-TCOD/m^3 day	31	21
Excess sludge storage	gallons	67,000	91,700
Odor control		Compost Filter 1 cell 600 cu ft.	Compost Filter 2 cells-1344 cu. ft.
pH adjustment	Acid	HCl (10,000 gal storage)	None
pH adjustment (depends on operating pH)	Alkali (average flow)	NaOH @50% 2 pumps x 600 gpd usage est. at 21 gph	Mg (OH)^2@ 50% 672 gpd usage est. at 14 gph
Macro-micronutrient-addition		Ammonium hydroxide Phosphoric acid	Ferric chloride Phosphoric acid Provision for micro-nutrient feed if required, cobalt, nickel, molybdenum, ect
Biogas H_2S control		NaOH scrubber	Ferric chloride feed to reactor
Biogas compressor		Sliding vane 355 scfm @ 25 psig	Liquid ring 322 scfm @ 25 psig

Technical Issues with System Vendors

Accurate assessment of the technical know-how and ability of system vendors is a critical factor in ensuring consistent, reliable, long term anaerobic system operation. Since anaerobic digestion systems are less understood and applied less frequently than their aerobic counterparts, it may prove challenging to ensure that a vendor understands the brewery's process dynamics and problems in system application. To illustrate this point, table 3 outlines alternate system components and chemicals designed by two system vendors. The alternate designs were proposed for a 1.7 million-gallon per day system treating 82,200 pounds of total COD per day.

As shown in the table, the proposals offer significantly different approaches to equipment sizing and chemical addition for the same design wastewater characteristics. Vendor #2 designs for ferric chloride as a sludge nutrient addition; vendor #1 does not. Vendor #1 designs for high pH excursions; vendor #2 does not. Vendor #1 designs for nitrogen as a macronutrient addition; vendor #2 does not. Vendor #2 designs for ferric chloride to precipitate out dissolved sulfides in wastewater; vendor #1 provides a biogas scrubber to remove sulfides in the gas phase only. Vendor #2 designs for external wastewater recirculation to maintain constant flow and granular bed expansion to the reactor, while vendor #1 relies on variable bed expansion through internal recirculation as COD loading and gas production change. Since the elements of efficient anaerobic digestion are quantifiable scientific facts, it is evident that parts of the proposed design are subject to significant differences in professional opinion concerning the best approach. If equipment is not designed with a sound scientific basis, prolonged inefficient operation can result while troubleshooting of system performance occurs. During this time, the benefits initially attributed to the project are not realized.

Comparing proposals for anaerobic systems is best accomplished by consultants qualified in anaerobic technology and experienced in treating brewery wastewater. In addition to comparing equipment design, it is imperative to evaluate vendor expertise and laboratory support facilities that are available for troubleshooting. It may be in the brewery management's best interests to require that the vendor provide onsite support for three to twelve months after a successful startup. This onsite field support would operate the anaerobic system and provide hands-on guidance should upset conditions occur, and train onsite personnel to effectively handle system operations.

CONCLUSION

The integrity of the project management process requires an accurate accounting of the expected capital costs and operating expenses for a reliable, trouble-free installation. The risk assessment process must be a critical component of project management especially when projects involve technology that is new to a brewery, outside a brewery's core business activity, or involving new vendors and consultants.

Since an anaerobic system is based on more complex bacterial inter-relationships than its aerobic counterpart, it therefore requires a more comprehensive understanding of its intricacies to be used successfully.[16] Anaerobic technology has a promising future in brewing applications. However, for successful technology application, brewery engineers must master the critical system concepts of pH/alkalinity effects, nutrient addition, toxicity potential, temperature control, and odor management. Educating and training workers who operate the anaerobic system is important to maintaining a system that operates within acceptable environmental parameters.

Finally, management clearly has choices with regard to equipment components and types of chemicals used to reduce costs and minimize risks. The anaerobic system design must be optimal for the site specific brewery wastewater characteristics. The two most important risks that brewery management, vendors, and consultants must consider are 1) adequately testing the wastewater for treatability and toxicity potential, and 2) providing the necessary system monitoring and operator control to avoid the possibility of reactor upsets.

QUESTIONS & ANSWERS

Q. 1 In the expanded granular sludge blanket reactor example for System #1, what is the upflow velocity?

A. 1 The design average flow is 6435 cubic meters per day. The reactor has an area of 50.3 square meters, so the design upflow velocity is about 5.3 meters per hour.

Q. 2 Have you experienced any problems with filamentous bacterial growth in the reactor?

A. 2 No. This issue was not considered in our risk analysis. The vendor's operating manual has a process troubleshooting section, but this problem is not listed.

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