FLORIDA RURAL WATER ASSOCIATION

2970 Wellington Circle West • Suite 101 • Tallahassee, FL 32309-6885
Telephone: 850-668-2746 ~ Fax: 850-893-4581

Calculating Wastewater Treatment Rates for Supernatant

Separating solids from liquids is one of the primary functions in wastewater treatment. The products of domestic wastewater treatment are effluent (water) and sludge (solids). In sludge dewatering treatment by mechanical means liquids are removed using a variety of means, such as gravity thickeners, drying beds, gravity belt thickeners, belt filter presses, dryers, centrifuges, etc. Water separated from the sludge, supernatant liquor has a high oxygen demand and odor, see Table 1.

Table 1 ~ Characteristics of Domestic Sludge Supernatant Liquors [1]

Parameter	Untreated Domestic Wastewater	Thickened Digested Sludge	Thickened Raw Sludge	Belt Press	Centrifuge
TSS (mg/L)	165	2,000	2,000	1,000	1,000
BOD_5 (mg/L)	300	1,000	2,000	2,000	500
Ammonia (mg/L)	25	500	100	300	400

The design and operation of wastewater treatment process must account for the return of sludge supernatant liquors to the front of the plant. The biological loading and potential odor issues should be understood and addressed. This is important when supernatant is collected from a number of other facilities and processed at a single wastewater treatment plant.

Supernatants are an abundant source of liquid food for microorganisms including proteins and amino acids, but lack the basic carbohydrates to sustain healthy biological activity (endogenous respiration). Additionally supernatants also contain organic and inorganic forms of sulfur, mercaptans, ammonia, amines, aromatics, hydrocarbons, and organic fatty acids. These are identified as the most offensive odor causing compounds associated with biosolids and wastewater treatment. [2]

FRWA recommends the use of COD[3] to measure the strength of supernatants, or amount of organic compounds in the liquor. Because supernatants are high in nutrients but low in some of the essential components to sustain biological activity, BOD_5 [4] is not a good indicator of true supernatant strength. BOD_5 by definition is the amount of dissolved oxygen consumed in five days by biological processes breaking down organic matter, or a measure of the organic content of wastewater.[5] COD by definition is the amount of dissolved oxygen consumed chemically as a complete measure the amount of organic compounds in water.

FRWA's recommendation for supernatant introduction into a domestic wastewater treatment plant collected from a number of other facilities is to pour the supernatant into the central

[1] Rendell, Frank, Water and Wastewater Project Development, 1999, Thomas Telford, p. 162 and Metcalf & Eddy, Inc., Tchobanoglous, Burton, & Stensel, "Wastewater Engineering: Treatment and Reuse" MacGraw-Hill, March 2002, 4th Edition
[2] US EPA, "**Biosolids and Residuals Management Fact Sheet - Odor Control in Biosolids Management**" September 2000, EPA 832-F-00-067
[3] COD denotes Chemical Oxygen Demand, expressed in milligrams per liter measured using Standard Methods
[4] BOD_5 denotes Biological Oxygen Demand, measured after 5 days using Standard Methods
[5] Metcalf & Eddy

biological treatment unit using a submerged pipe or hose such that the flow can be mixed and incorporated into the exiting biomass without turbulence or splashing. The supernatant should be mixed a thoroughly as possible in the central biological treatment unit before it has the opportunity to mix with the air and release offensive odors. The aerobic biomass (mixed liquor) in a central biological treatment unit such as an oxidation ditch is a perfect environment to place the supernatant. The biological uptake and degradation of the supernatant nutrients and odor causing compounds is very effective and efficient.

Rate Calculations for Treating Supernatant. Wastewater rates revenues must be greater than expenses for the operation and maintenance requirements of the utility and include salaries, wages, employee fringe benefits, power, chemicals, minor equipment, contract services (engineering, laboratory tests, auditors, etc.), office space, fittings, materials, supplies, other general overhead expenses, and capital depreciation or renewal and replacement expenses. [6]

The basic concepts for wastewater rates are as follows:

Wastewater (WW) Cost per Gallon Calculations. The cost per gallon for treatment involves (most systems will have performed this calculation to establish or check rates):

$$\text{WW Cost per gallon} = \frac{\text{Total wastewater system costs (\$ per year)}}{\text{Total wastewater treatment flows (gallons per year)}}$$

The WW Cost per gallon is often a small number, so it is multiplied by 1,000 and expressed in the engineering literature as treatment costs per thousand gallons.

Wastewater Cost per ERU. For a wastewater Equal Residential Unit (ERU), which uses an estimated 185 gallons per day,[7] the equation would look like this:

$$\text{Monthly ERU Cost } (\$_{ERU}) = \frac{\text{WW Cost (\$)}}{\text{gallon}} \times \frac{\text{185 gallons}}{\text{day}} \times \frac{\text{30 days}}{\text{month}}$$

The Monthly ERU Cost should be roughly equivalent to current wastewater rates. Also an ERU equates to 5,500 gallons per month.

Rate Calculations for Treating Supernatant. There are two components to consider when treating supernatant: 1) flow volume and 2) liquor strength as measured by COD. The equation measures both volume and strength components and multiplies them to approximate the volumetric and biological loading impacts that accepting supernatant would have on the domestic wastewater plant.

Supernatant Flow Volume Calculations. The supernatant flow volume charge ($\$V_S$) is found by multiplying the volume of supernatant (V_S) delivered in any month times the Monthly ERU Cost ($\$_{ERU}$) and divided by the 5,500 gallons per month for a wastewater Equal Residential Unit. The result is the volumetric loading component.

---

[6] Rates should sustain utility operations in the short-term as well as the long-term. FS 153.83, prohibits providing free water and sewer services. FS 153.11(b) states that, "such rates, fees and charges shall be so … sufficient at all times to pay the cost of maintaining, repairing and operating the system or systems including the reserves for such purposes and for replacements and depreciation..." FS 180.13(2) requires that established rates or charges be just, equitable and reasonable. FS 180.191 puts limitations on surcharges to consumers outside city limits not to exceed 25% based on the same factors used in fixing rates, fees, and charges for consumers inside the municipal boundaries; unless a public hearing is held for all users then the surcharge to consumers outside city limits shall not exceed 50%.

[7] 185 gallons per day is typical for residential wastewater flows throughout Florida by FRWA experience. If the wastewater flows are different for your residential customers then this value should be adjusted appropriately.

$$\text{Volume Charge } (\$V_S) = \frac{\text{Monthly Volume of Supernatant } (V_S) \times \text{ERU Cost } (\$_{ERU})}{5{,}500 \text{ gal/mo ERU}}$$

or

$$\$V_S\ (\$) = \frac{V_S\ (\text{gal}) \times \$_{ERU}\ (\$/\text{mo})}{5{,}500\ (\text{gal/mo})}$$

Supernatant Liquor Strength Calculations. The supernatant liquor strength is compared to the expected average wastewater BOD_5 of 300 mg/L.[8] The cost ratio is found by dividing COD supernatant liquor strength in mg/L by 300 mg/L BOD_5 then multiplying that quantity by the Monthly ERU Cost ($\$_{ERU}$). This allows for applying a charge in ratio to supernatant strength. The result is the biological loading component. The equation looks like this:

$$\text{Liquor Strength Charge } (\$S_S) = \left(\frac{COD_{Super}\ \text{mg/L}}{300\ \text{mg/L } BOD_5} \right) \times \$_{ERU}$$

or

$$\$S_S\ (\$) = \left(\frac{COD_{Super}}{300} \right) \times \$_{ERU}$$

Supernatant Flow Volume and Supernatant Liquor Strength Calculations.

Total Cost for treating supernatant on a monthly basis is:

Monthly Supernatant Treatment Cost Total -- $\$Total_S = \$S_S \times \$V_S$

$$\$Total_S = \$_{ERU}\ (\$/\text{mo}) \times \left(\frac{COD_{Super}}{300} \right) \times \left(\frac{V_S\ (\text{gal})}{5{,}500\ (\text{gal/mo})} \right)$$

One of the arguments against this equation could be that utility costs include the wastewater collection system, but the extra expenses and manhours used for accepting, monitoring, measuring, and supervising supernatant deliveries to the plant offsets any of these concerns.

Example #1

Given: Typical monthly residential wastewater bill = $25.15 / month

Supernatant deliveries during the month consisted of 10,000 gallons at an average COD of 1,200 mg/L

$$\text{Charge} = \$25.15 \times \left(\frac{1{,}200\ \text{mg/L}}{300\ \text{mg/L}} \right) \times \left(\frac{10{,}000\ \text{gal}}{5{,}500\ \text{gal/mo}} \right) = \$182.91$$

Example #2

Given: Typical monthly residential wastewater bill = $20.00 / month

Supernatant deliveries during the month consisted of 45,000 gallons at an average COD of 750 mg/L

$$\text{Charge} = \$20.00 \times \left(\frac{750\ \text{mg/L}}{300\ \text{mg/L}} \right) \times \left(\frac{45{,}000\ \text{gal}}{5{,}500\ \text{gal/mo}} \right) = \$409.09$$

[8] Metcalf & Eddy