Domestic Wastewater - Treatment and Design

An Online Continuing Education Course for Engineers

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DOMESTIC WASTEWATER – TREATMENT AND DISPOSAL

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I. INTRODUCTION

The treatment of domestic waste water (simply called wastewater in this course) and also called sewage includes conversion of the raw wastewater into an accessible final effluent, and disposing of the solids removed in the process. It is therefore required to determine the characteristics of the raw wastewater and the required characteristics of the effluent or the required treatment, before proceeding with the design process. It is generally necessary to obtain the approval of a regulatory agency before proceeding with construction of any treatment facility. The regulations of the agency usually establish many of the basic design considerations. Many states have established classifications for various streams within their boundaries. These classifications generally establish "treatment standards" or "effluent standards" which limit the pollutants in the effluent. The "treatment standard" or the "effluent standards" are established taking into consideration the ability of the receiving waters to assimilate the waste and the uses to which the receiving waters are put.

Periods of design for treatment plants vary. A normal design period would require treatment units to be designed for population and wastewater flows anticipated some 15 to 20 years after completion of construction. Units are designed to be readily expandable as the population increases.

Water consumption records, where available, are a good basis for determining domestic wastewater flow rates. About 70 to 80% of domestic water consumption may be expected to reach the sewer as wastewater. In the absence of any better basis, many regulatory agencies accept a rate of 100 gallons per capita per day (gpcd). If commercial wastewater flow is quite small in communities, the commercial flow is included as domestic flow. The design average flow rate is the average flow during some maximum significant period such as 4, 8, 12, or 16-hr, depending on circumstances.

Determination of the important characteristics of wastewater is essential to the proper design of treatment works. Where only population data are available, acceptable equivalents for design of treatment works are 0.20 lb of suspended solids (SS) per day per capita or 250 parts per million (ppm) and 0.17 lb of biochemical oxygen demand (BOD) per day per capita or 200 ppm.

Wastewater treatment processes may be classified as "preliminary", "primary', "secondary" (biological) or "advanced" (tertiary). The purpose of preliminary treatment is to remove deleterious materials which would damage equipment, interfere with the satisfactory operation of a process or equipment, or cause objectionable shore-line conditions. Primary treatment can usually be expected to remove 50 to 60% suspended solids and 25 to 35% BOD. Secondary treatment using conventional biological processes may remove up to 90% of suspended solids and 75 to 90% BOD. Different biological process units are deployed in secondary treatment. Advanced (tertiary) treatment may be expected to remove over 95% of both BOD and SS in addition to reducing some undesirable chemicals.

Prior to disposing of the effluent, it is subjected to disinfection by injecting chlorine or ozone in to the effluent or exposing the effluent to ultra-violet rays.

The effluent disposal methods in use are: discharge to streams and rivers, land disposal to irrigate certain crops, deep well injection, and submarine outfalls extending into the ocean.

Sludge is collected and subjected to the following treatment prior to disposal: thickening (either gravity or flotation), digestion (aerobic or anaerobic), and dewatering using sand beds or equipment such as vacuum filter or centrifuge.

Dewatered sludge is disposed of on land, processed as compost and sold to farmers, deposited in sanitary land fill, or incinerated.

II. PRELIMINARY TREATMENT

Domestic wastewater treatment sequentially consists of preliminary treatment, primary treatment, secondary (or biological) treatment, and advanced (or tertiary) treatment. This course is intended to describe the preliminary treatment.

Preliminary treatment of domestic wastewater includes the following operations:

1. Screening
2. Grinding
3. Grit removal
4. Grease and scum removal
5. Flocculation, and
6. Equalization.

Screening, grinding, and grit removal are necessary for the protection of equipment in the treatment plant. Flotation and flocculation help remove suspended solids in the primary clarifier resulting in a smaller biological load to the secondary treatment process units. Equalization is required to dampen diurnal flow variations and to equalize flows to the treatment facilities. (Pre-chlorination or pre-aeration may also be practiced if odor is a problem).

II.1 Screening – The first unit operation encountered in wastewater treatment plants is solids-liquid separation which is a filtering operation and is accomplished by means of providing screens or hydrosieves. A screen is a device with openings, generally of uniform size, used to retain coarse solids. The screening element may consist of parallel bars, rods or wires, grating, wire mesh, or perforated plate, and the openings may be of any shape, generally circular or rectangular slots. Screens are classified as coarse screen (or bar rack) and fine screen depending upon the size of the openings. Both types of screens are composed of parallel bars. The material removed by the screening devices is known as screenings or rakings. According to the method of cleaning, screens are designated as hand-cleaned or mechanically-cleaned.

II.1.1 Coarse screens – These are also called bar racks and are made of bars of steel welded in to a frame that fits across the channel with opening between bars ranging from 3 to 6 in. These are mainly used in wastewater treatment plants to protect pumps, valves, pipe lines, and other appurtenances from damage or clogging by rags and large objects. The bars run vertically or at a slope varying 30 to 80^0 with the horizontal. Large objects are caught on the rack, carried up by traveling rakes, and scraped and collected. The approach velocity of the wastewater in the raking or screening channel shall not be below a self-cleaning value (1.25 ft/sec) or rise to a magnitude (3.0 ft/sec) at which the rakings or screenings will be discharged from the bars or screens or the loss of head through the rack or screen shall be such as not to back up the flow to place the entrant sewer under pressure. Figure II.1 (a) shows a hand-cleaned rack and Figure II.1 (b) shows a mechanically-cleaned rack.

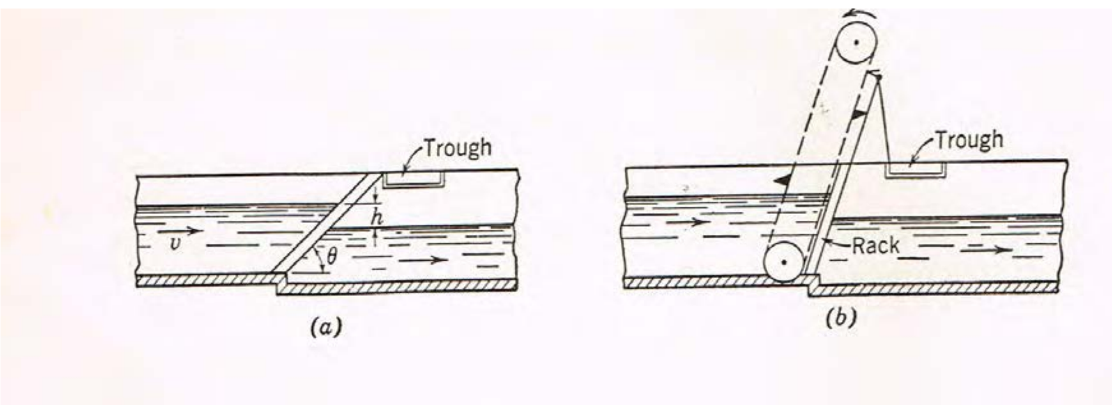

Figure II.1 (a) Hand-cleaned rack (b) Mechanically-cleaned rack

Hydraulic loss through bar racks is a function of bar shape and the velocity head of the flow between the bars. Velocities of 2 to 4 ft/sec through the open area have been used satisfactorily. The following equation is used to calculate the head loss.

$h_L = \beta(w/b)^{1.33}h_v\sin\theta$……………………………..Eq. (II.1)

where h_L = head loss, ft

β = a bar-shape factor

w = maximum cross sectional width of bars facing direction of flow, ft
b = minimum clear spacing of bars, ft
h_v = velocity head of flow approaching rack, ft
θ = angle of rack with horizontal

Values of β for several shapes of bars are given in Table I.1 below.

Table II.1 Values of β

Bar type	β
Sharp-edged rectangular	2.42
Rectangular with semicircular upstream face	1.83
Circular	1.79
Rectangular with semicircular upstream and downstream faces	1.67

Example II.1 below illustrates head loss calculation in a bar screen.

Example II.1

A bar screen consisting of 3/8-in rectangular bars is installed at an angle of 60^0 to the horizontal in a rectangular channel. Clear opening between the bars is ¾ in and the bar shape factor is 2.42. The approach velocity of wastewater is 2 ft/sec. Calculate the head loss as the wastewater passes through the bar rack.

Solution

Substituting in Eq. (II.1) above,
B = 2.42., w = 3/8 in., b = ¾ in and θ = 60^0
Head loss h = 2.42 x $\{(3/8 \text{divided by } 3/4)\}^{4/3}$ x 2 x Sin60^0
= 2.42 x(½)$^{4/3}$ x 2 x0.866 = 2.42 x 0.3978 x 2 x 0.866
= 1.67 ft

The head loss calculated using the above equation is applicable only if the bars are clean. Head loss increases with the degree of clogging. A minimum allowance for head loss through hand-cleaned screen is 6 in. For mechanically cleaned screens, manufacturer's literature provides the allowance for head loss.

II.1.2. Fine screens – These are mechanically cleaned devices using a medium of perforated plate, woven-wire cloth, or closely placed bars through which the wastewater flows. The openings are usually

3/16 in or less. One variety of fine screens used is the drum type, with stainless steel or nonferrous wire-mesh screen cloth. In this type of screen, the filter medium is a cylinder furnished with a mechanical means of rotation, and with self-cleaning devices. The drum is approximately 1/3 to 2/3 submerged in the wastewater. The liquid passes through the screen and flows out at one end. The solids which are removed from the liquid are raised above the liquid level as the drum rotates and are removed by brushes, scrapers, and/or a backwash. The backwash may utilize water, air, or steam. Drum screens are available in various sizes, from 39 in. to 5 ft in diameter and from 4 to 12 ft in length.

Another variety of fine screen is the disk-type screen. These screens consi... of a round flat plate revolving on an axis inclined 10^0 to 25^0 from the verti... ws through the lower two-thirds of the plate. As the plate ... e the liquid where brushes remove them for dispos... . Head loss through fine screens may be obtaine... ed by means of the common orifice formula:

h_L = (1/2g) (Q/(...

Where C = coefficient of d...

Q = discharge throu...

A = effective subme...

g = acceleration due...

Figure II.2 (c) shows a brush... cleaned drum screen

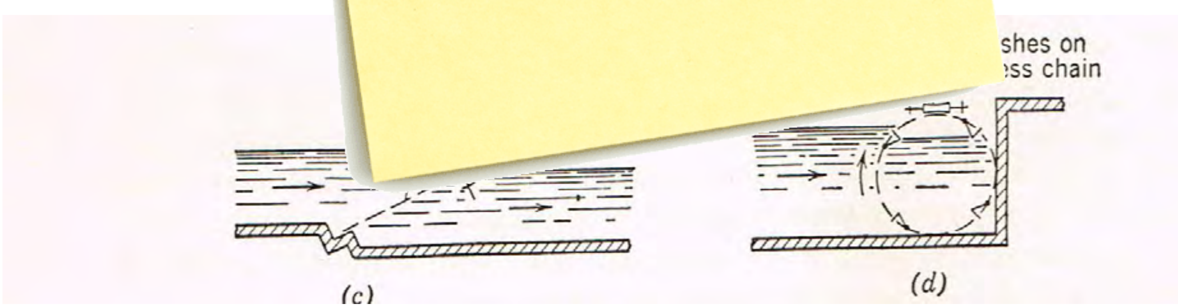

Figure II.2 (c) Brush-cleaned disk screen

Figure II.2 (d) Brush–cleaned drum screen

II.1.3. Hydrosieves – This is an economical and efficient sieve designed for solid liquid separation. The sieve screen is made of stainless steel bars with a triangular cross section. The velocity of the raw influent waste water is utilized to separate the solids. As the influent flows over the screen, the solids are retained on the screen and the liquid flows down the screen openings to the outlet channel. The screenings caught on the screen slide down to a chute from where they are conveyed to disposal system. A cross sectional view of the hydrosieve with an enlarged view of the screen openings is shown in Figure II.3 below.