Industry specific guidelines also exist for a number of industries. Effluent concentrations are often based on the amount of raw material processed, although stream assimilative capacity may override guidelines based on the amount of production.

8.10 WASTEWATER CHARACTERISTICS

Domestic wastewater varies widely from community to community depending on water quality, use and conservation practices, cultural attributes of the population, industries present and treatment applied at industry locations, as well as other factors such as infiltration in the sewer system. The major source of organics in domestic wastewater is human excreta. Feachem et al. (1981) arrive at typical daily BOD_5 contributions to sewage per adult from excreta ranging from 39 to 42 g (urine, 10.3 g; fecal material, 24.7–30.6 g; and anal cleansing materials, 2.0–3.5 g). Most adults produce 1 to 1.3 kg of urine per day, which is a rich source of nitrogen. The ammonia and urea (which is readily hydrolyzed to ammonia) content of urine is typically around 550 and 24 000 mg/L, respectively. Sullage and industrial wastes will alter the per capita contributions of organics and other substances. Table 8.18 provides information on typical composition of medium strength domestic wastewater. Nemerow and Dasgupta (1991) provide information on quality of wastewater produced from various industries.

Size ranges of organic particulate matter in wastewater are given in Table 8.19. The size distribution of particulates is site specific but a significant fraction of the organic matter is in the colloidal and supracolloidal size ranges. As wastewater passes through treatment operations, degradation and other removal processes shift the distribution of organic matter toward smaller sizes.

Raunkjær et al. (1994) analyzed the protein, carbohydrate, and lipid fractions in domestic wastewater and reviewed results from other studies. The ranges of average results for these components expressed as a percentage of total COD from all studies were 8–28, 6–18, and 12–31 for protein, carbohydrates, and lipids, respectively.

TABLE 8.18 Composition of Medium Strength Untreated Domestic Wastewater[a]

Constituent	Concentration, mg/L
Bacteria[b]	10^7–2×10^8
Total solids	450
Total volatile solids	300
Suspended solids	250
Volatile suspended solids	200
Total dissolved solids	200
BOD_5	150–250
Nitrate and nitrite nitrogen as N	<0.6
Organic nitrogen as N	25–85
Ammonia nitrogen as N	15–50
Total phosphorus	6–12
Soluble phosphorus	4–6

[a]From MOE (1978).
[b]Bacteria are given as No./100 mL.

TABLE 8.19 Size Distribution of Organic Matter in Treated and Untreated Domestic Sewage[a]

	Percent of organic matter contained in indicated size range, μm							
	<0.001		0.001–1		1–100		>100	
Wastewater sample	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range
Untreated wastewater	31	12–50	14	9–16	25	10–30	37	15–43
Primary effluent	43[b]	35–51[b]	10[b]	2–19[b]	24[b]	13–34[b]	28[b]	5–60[b]
Activated sludge effluent	52	74–79	3	2–5	22	16–31	2	1-3
	33[b]	26–46[b]	5[b]	2–9[b]	35[b]	20–49[b]	27[b]	13–49[b]
Trickling filter effluent[c]	40	—	60	—	—	—	—	—
Wastewater sludges[c]								
Primary	5	—	1	—	4	—	90	—
Secondary	3	—	0.1	—	1	—	96	—
Anaerobic	5	—	3	—	19	—	72	—

[a]Reprinted from A. D. Levine, G. Tchobanoglous, and T. Asano, "Size Distribution of Particulate Contaminants and Their Impact on Treatability," *Water Research,* 25, pp. 911–922, Copyright 1991, with kind permission from Elsevier Science Ltd., The Boulevard, Langford Lane, Kidlington 0X5 1GB UK.
[b]Size ranges of <0.1 μm; 0.1–1 μm; 1–12 μm, and >12 μm apply to these data.
[c]Results are for only one study.

Graywater

Graywater is defined as all wastewater produced from a household excluding toilet wastes. There may be potential for reuse of graywater, reducing demands for domestic water consumption; however, fecal coliforms and other indicator microorganisms can be found in graywater in significant numbers. Rose et al. (1991) found fecal coliforms ranging from 10^4 to 10^7/100 mL. Other data on the quality of graywater are given in Table 8.20.

TABLE 8.20 Characteristics of Graywater[a]

Constituent	Units	Range	Average	Average in tap water
pH		5–7	6.54	6.6
Alkalinity	mg/L	149–198	158	131
Ammonia nitrogen	mg/L	0.15–3.2	0.74	0
Nitrate	mg/L	0–4.9	0.98	1.0
Total nitrogen	mg/L	0.6–5.2	1.7	1.0
Chloride	mg/L	3.1–12	9.0	10
Hardness	mg/L	112–152	144	142
Phosphate	mg/L	4–35	9.3	3.1
Sulfate	mg/L	12–40	22.9	0
Turbidity	NTU	20–140	76.3	0.8

[a]Reprinted from J. B. Rose, G. S. Sun, C. P. Gerba, and N. A. Sinclair, "Microbial Quality and Persistence of Enteric Pathogens in Graywater from Various Sources," *Water Research,* 25, pp. 37–42, Copyright 1991, with kind permisison from Elsevier Science Ltd., The Boulevard, Langford Lane, Kidlington 0X5 1GB UK.

TABLE 8.21 Design Sewage Flows[a]

Source	Average daily flow[b]
Domestic sewage	225–450 L/cap/d (60–120 gal/cap/d)
Shopping centers	2 500–5 000 L/1 000 m^2 (60–120 gal/1 000 ft^2) (based on total floor area)
Hospitals	900–1 800 L/bed (240–480 gal/bed)
Schools	70–140 L/student (18–36 gal/student)
Travel trailer parks	
Without individual hookups	340 L/site (90 gal/site)
With individual hookups	800 L/site (210 gal/site)
Campgrounds	225–570 L/campsite (60–150 gal/campsite)
Mobile home parks	1 000 L/unit (265 gal/unit)
Motels	150–200 L/bed (40–53 gal/bed)
Hotels	225 L/bed (60 gal/bed)
Industrial areas	
Light industrial area	35 m^3/ha/d (3 750 gal/acre/d)
Heavy industry	50 m^3/ha/d (5 350 gal/acre/d)

[a]From MOE (1985b).
[b]These are design values for Ontario.

8.11 WASTEWATER PRODUCTION

Flows for sewage treatment plants are based on the design population and commercial and industrial activity. Historical data should be gathered to find existing flow information. The plant must be able to handle all flows anticipated in the design period. In Ontario, design periods for sewage treatment plants have generally been for 10–20 years as opposed to sewer systems which are designed for 20- to 40-year periods (MOE, 1985b). Accepted practice has been to add an extraneous flow allowance of 90 L/cap/d (24 gal/cap/d) to the average flow and 227 L/cap/d (60 gal/cap/d) to the peak flow. These are approximately equivalent to 3.7 m^3/ha/d (400 gal/acre/d) (average) and 9.2 m^3/ha/d (1 000 gal/acre/d) (peak). Table 8.21 gives typical design sewage flows from various sources. Actual flows and design criteria will vary from region to region. Small communities generate lower flows than larger cities. In northern Canadian communities, nearly all of the water consumed is returned as wastewater and the design values given in Table 8.15 apply for wastewater flows. A typical rule of thumb for estimating domestic wastewater flows is 380 L/cap/d (100 gal/cap/d).

Peaking factors are multiplication factors used to estimate high and low flows with respect to the average flow. Design peaking factors are usually specified by the authority. Gaines (1989) has studied the distribution of sewage flows and the city of Denver used the following technique to determine peaking factors.

The distribution of wastewater flows approximately follows a normal distribution. Minimum, maximum, and peak flows are related to the average flow with an equation of the following form.

$$Q_x = a(Q_{ave})^b \tag{8.2}$$

or

$$\ln Q_x = \ln a + b \ln Q_{ave}$$

where

Q_x is the instantaneous or average peak flow, maximum 1- or 6-h flow, or other flow specification
a and b are regression coefficients
Q_{ave} is the average flow

The coefficients in Eq. (8.2) are developed from linear regression of historical data for the flow specification (e.g., 1 h peak flow). The coefficients a and b in Eqs. (8.3a) and (8.3b) depend on the confidence level and the flow factor defined below. From linear regression, the coefficients a and b are dependent on the desired confidence level given by the following relations:

$$\ln a = A \pm Z \times S_1 \tag{8.3a}$$

$$b = B \pm Z \times S_2 \tag{8.3b}$$

where

A is the linear regression intercept
B is the linear regression slope
S_1 and S_2 are the standard deviations of the intercept and slope, respectively
Z is a factor related to the desired confidence level

The confidence level is the probability that an event will not be exceeded.

$$q = 1 - p \tag{8.4}$$

where

q is the confidence level
p is the probability of the event being exceeded

A plot of the data on normal probability paper (which should yield an approximately straight line) readily shows the event that exceeded p percent of time. For instance, data on the maximum 1-h flows for each day are gathered over any time period. The percent of these flows that are less than specified values of flow are plotted on probability paper and the best fitting straight line is drawn through them, which provides a cumulative frequency distribution. From the plot the maximum 1-h flow that is exceeded 1% (or any other percent) of the time is readily determined.

The values of Z are the distance from the mean in terms of standard deviations for various confidence levels. Values of Z at selected confidence levels are given in Table 8.22.

TABLE 8.22 Z Factor at Various Confidence Levels

Confidence level %	Z
99.9	3.08
99	2.33
95	1.64
90	1.28
75	0.67
67	0.44
50	0.00

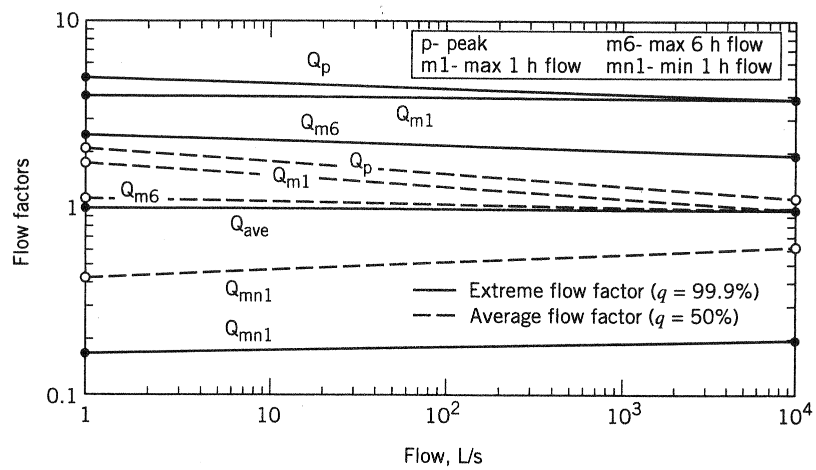

Figure 8.4 Average and extreme flow factors. From J. B. Gaines (1989), "Peak Sewage Flow Rate: Prediction and Probability," *J. Water Pollution Control Federation,* 61, 7, pp. 1241–1248, © WEF, 1989.

The instantaneous peak flow (Q_p) is defined as the maximum flow during a 24-h period. The maximum (Q_{m1}) and minimum (Q_{mn1}) 1-h flows are defined as the flows that are exceeded for 1 and 23 h, respectively. Similarly the flow that is exceeded for 6 h is Q_{m6}. Flow factors are used to design sewers and wastewater treatment facilities. The flow factor for a flow specification, Q_x is given by

$$F_x = \frac{Q_x}{Q_{ave}} = e^{(A \pm ZS_1)} \times Q^{(B-1 \pm ZS_2)} \tag{8.5}$$

where

F_x is the flow factor (e.g., F_{mn1} is the 1-h minimum flow factor corresponding to Q_{mn1}/Q_{ave}.)

In the exponents, use $A + ZS_1$ and $B - 1 + ZS_2$ when peak or maximum flows are being considered; use $A - ZS_1$ and $B - 1 - ZS_2$ when minimum flows are being considered.

The flow factors are a function of the confidence level or exceedance probability that the designer chooses.

Fig. 8.4 is a typical plot of peaking, maximum, and minimum flow factors constructed using Eq. (8.5). Note that the level of confidence (solid lines in the figure are the 99.9% confidence level and dashed lines are the 50% confidence level) significantly influences the comparisons. The average (q = 50%) instantaneous peak flow is actually lower than the 99.9% confidence level estimate of the maximum 6-h flow rate. Which confidence level to use depends on the severity of the situation and the regulations in effect.

Ideally measurements of inflow and infiltration (I/I) should be made when collecting flow data and the wastewater flows should be corrected for I/I but this is not usually done. Therefore the regression equations reflect I/I as well as wastewater production and applying them to a future condition assumes that the amount of I/I is approximately the same. If I/I is a significant portion of the wastewater flow and measures are definitely going to be taken to correct the situation, best estimates of current I/I should be used to modify the current data and arrive at the equations. Then anticipated I/I can be added after the projected wastewater flow is estimated from the equation.