A typical waste-treatment operation employing biological treatment includes the following steps:

1. **1.** Primary treatment includes the removal of coarse solids and suspended matter (screening, sedimentation, filtration) and conditioning of the waste-water stream by pH adjustment and nutrient additions (e.g., PO_4^{3-}, NH_4^+).
2. **2.** Secondary treatment is the major step in biological treatment; it includes biological oxidation or anaerobic treatment of soluble and insoluble organic compounds. Organic compounds are oxidized to CO_2 and H_2O by organisms under aerobic conditions. Unoxidized organic compounds and solids from aerobic treatment (e.g., cell wall material, lipids–fats) are decomposed to a mixture of CH_4, CO_2, and H_2S under anaerobic conditions. A *sludge* of undecomposed material must be purged from either system.
3. **3.** Tertiary treatment includes the removal of the remaining inorganic compounds (phosphate, sulfate, ammonium) and other refractory organic compounds by one or more physical separation methods, such as carbon adsorption, deep-bed filtration, and in some cases membrane-based techniques, such as reverse osmosis or electrodialysis.

16.6.2. Biological Waste Treatment Processes

Biological waste-water treatment usually employs a mixed culture of organisms whose makeup varies with the nature of the waste. Biological treatment may be aerobic or anaerobic. The major aerobic processes (or reactor types) used in waste-water treatment are (1) activated sludge, (2) trickling filter, (3) rotating biological contractors, and (4) oxidation ponds.

Activated-sludge processes include a well-agitated and aerated continuous-flow reactor and a settling tank. Depending on the physical design of the tank and how feed is introduced into the tank, it may approximate either a PFR or CFSTR. A long narrow tank with single feed approaches PFR behavior; circular tanks approach CFSTR. The concentrated cells from the settling tank are recycled back to the stirred-tank reactor. Figure 16.7 is a schematic of a typical activated-sludge process. Usually, a mixed culture of organisms is utilized in the bioreactor. Some of these organisms may produce polymeric materials (polysaccharides), which help the organisms to agglomerate. Floc formation is a common phenomenon encountered in activated-sludge processes, which may impose some mass transfer limitations on the biological oxidation of soluble organics; but good floc formation is essential to good performance of the system, since large dense flocs are required in the sedimentation step. Cell recycle from the sedimentation unit improves the volumetric rate of biological oxidation (i.e., high-density culture) and therefore reduces the residence time or volume of the sludge reactor for a given feed rate. The recycle ratio needs to be controlled to maximize BOD removal rate.

The selection of aerator and agitators is a critical factor in the design of activated-sludge processes. The aeration requirements vary depending on the strength of the waste water and cell concentration. Oxygen requirements for a typical activated-sludge process are about 30 to 60 m^3 O_2/kg of BOD removed. Various aeration devices with and without