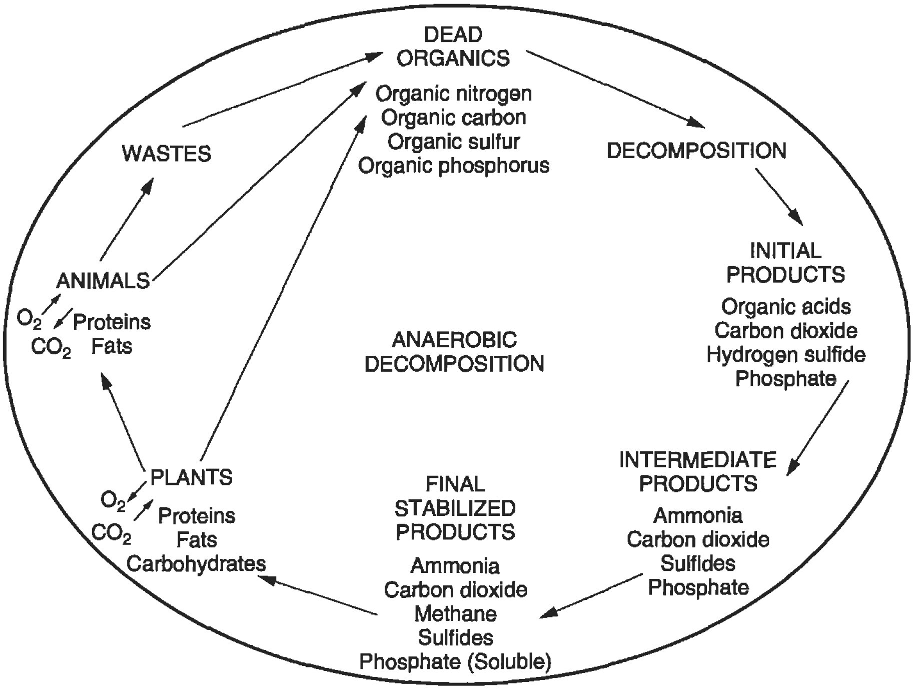

Figure 4-4. Anaerobic carbon, nitrogen, phosphorus, and sulfur cycles. (After McGauhey, P.H., *Engineering Management of Water Quality*. New York: McGraw–Hill, 1968.)

sulfhydryl compounds like hydrogen sulfide (H_2S), and can be used as an energy source by aerobic bacteria. Phosphates released during anaerobic decomposition are very soluble in water and do not bind to metal ions or sediments. Soluble phosphate is easily taken up by plants and used as a nutrient.

Biologists often speak of certain compounds as *hydrogen acceptors*. When energy is released from high-energy compounds a C=H or N=H bond is broken, and the freed hydrogen must be attached somewhere. In aerobic decomposition, oxygen serves the purpose of a hydrogen scavenger or hydrogen acceptor, and forms water. In anaerobic decomposition, oxygen is not available. The next preferred hydrogen acceptor is nitrate (NO_3^-) or nitrite (NO_2^-), forming ammonia (NH_3). If no appropriate nitrogen compound is available, sulfate (SO_4^{2-}) accepts hydrogen to form sulfur (S°) and H_2S, the compound responsible for the notorious rotten egg smell.

EFFECT OF POLLUTION ON STREAMS

The effect of pollution on streams depends on the type of pollutant. Some compounds are acutely toxic to aquatic life (e.g., heavy metals), and will cause dead zones downstream from the pollutant source. Some types of pollutants are health concerns to

humans, but have little impact on stream communities. For example, coliform bacteria are an indicator of animal waste contamination, and are therefore an important human health concern, but most aquatic organisms are not harmed by the presence of coliforms.

One of the most common types of stream pollutants is the introduction of biodegradable organic material. When a high-energy organic material such as raw sewage is discharged into a stream, a number of changes occur downstream from the point of discharge. As the organic components of the sewage are oxidized, oxygen is used at a rate greater than that upstream from the sewage discharge, and the dissolved oxygen in the stream decreases markedly. The rate of reaeration, or solution of oxygen from the air, also increases, but is often not enough to prevent total depletion of oxygen in the stream. If the dissolved oxygen is totally depleted, the stream becomes anaerobic. Often, however, the dissolved oxygen does not drop to 0 and the stream recovers without a period of anaerobiosis. Both of these situations are depicted graphically in Fig. 4-5. The dip in dissolved oxygen is referred to as a dissolved oxygen sag curve.

The effect of a biodegradable organic waste on a stream's oxygen level may be estimated mathematically. Let

$z(t)$ = the amount of oxygen still required at time t, in milligrams per liter (mg/L), and

k_1' = the deoxygenation constant, in days^{-1}.

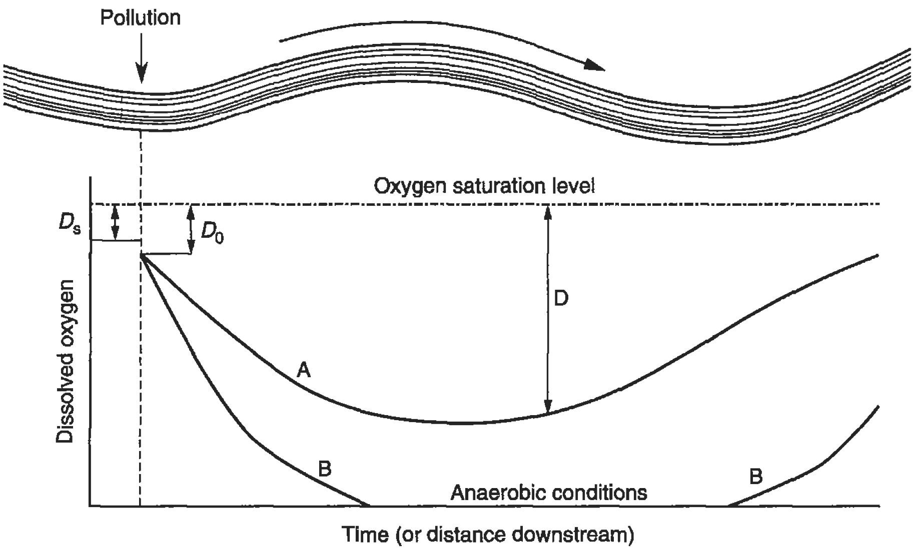

Figure 4-5. Dissolved oxygen downstream from a source of organic pollution. Curve A depicts an oxygen sag without anaerobic conditions; curve B shows an oxygen sag curve when pollution is concentrated enough to create anaerobic conditions, D_0 is the oxygen deficit in the stream after the stream has mixed with the pollutant, and D_s is the oxygen deficit of the upstream water.