PRECIPITATION 8

Precipitation is a unit process in which a settleable and/or filterable solid is formed by the chemical joining of two or more inorganic dissolved chemical species, the objective of which is to remove one of the chemical species.

8.1 INTRODUCTION

The conceptual framework for precipitation is presented in Figure 8.1. Precipitation may be natural or induced, the latter by the addition of a chemical to promote the precipitation process. Natural precipitation may occur in wet pool systems such as wet ponds and constructed wetlands, but is more likely to occur in filtration systems such as sand filters and infiltration systems. Successful precipitation requires the companion process of coagulation, which is described in Chapter 9. Chemicals added to precipitate the pollutant of interest also typically serve the function of enhancing the coagulation process. Whether natural precipitation occurs depends upon initial concentrations of the participating ions, their solubility, and the elements of the principles shown in Figure 8.1. These factors are also important determinants of dosage requirements and efficiency of chemical precipitation.

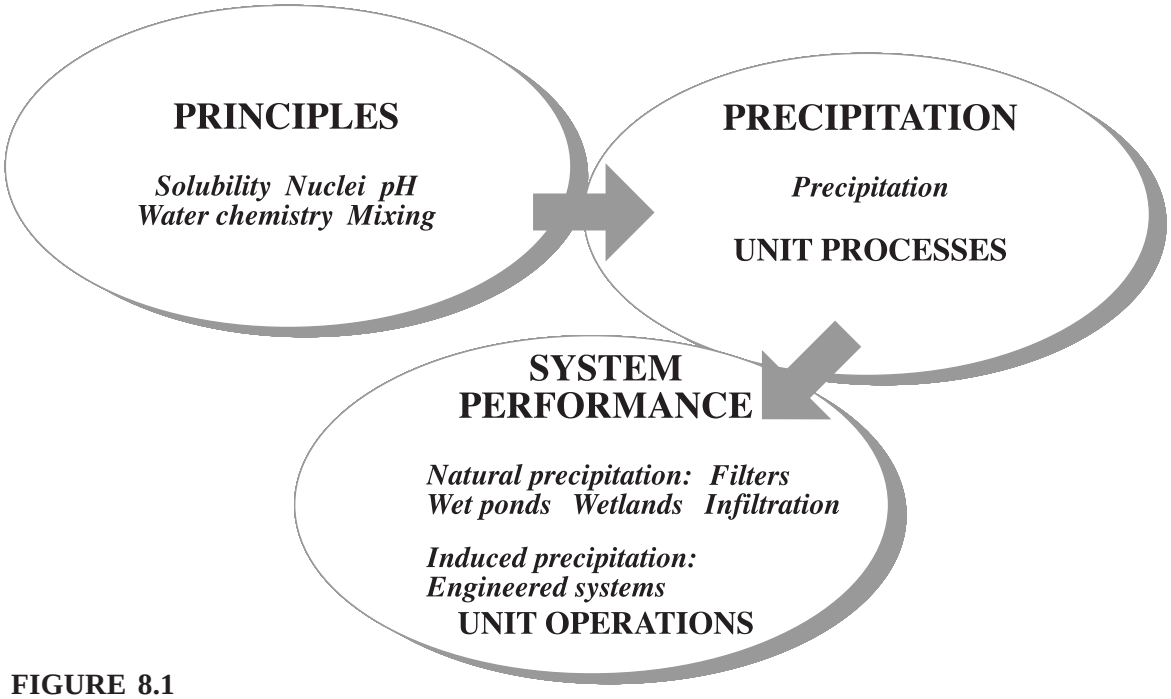

FIGURE 8.1
Unit process - Precipitation

Presented in Table 8.1 are the dissolved constituents most commonly removed by precipitation in water and wastewater treatment.[47,747] Also shown are those pollutants of interest in stormwater that can be removed by precipitation. Side benefits occur with precipitation. With chemical precipitation of wastewater, 80 to 90 percent of colloids and fine solids resistant to simple gravity separation are removed, plus 80 to 90 percent of bacteria and viruses are reduced.[747] The final product is a clear effluent with very low suspended solids, typically less than 5 mg/L.

TABLE 8.1
Contaminants of interest

TYPE OF WATER	CONTAMINANT
Water treatment	Manganese, iron, calcium, magnesium, arsenic
Wastewater treatment	Phosphorus
Stormwater treatment	Phosphorus, copper, zinc, cadmium

8.2 CHEMICAL PRECIPITATION

With induced precipitation, chemicals are added to remove the pollutants of interest, or the surface of the filter media is altered to enhance precipitation. The latter concept is presented in Chapter 11. The information presented here focuses on the addition of chemicals to form precipitates. An example is the addition of aluminum or iron salts to precipitate phosphorus. Alternatively, a chemical is added to alter the pH of the water thereby lowering the solubility of the pollutant: for example, making a metal less soluble by the addition of lime. In both cases, a metal hydroxide also forms which improves coagulation leading to improved clarification or filtration.

Care is advised when using solubility constants derived in simple water solutions (Chapter 3) to estimate the residual concentration of the dissolved pollutant. The complex nature of stormwater chemistry may lead to concentrations higher than predicted by an order of magnitude. This is particularly the case with metal ions as the presence of inorganic anions and humic compounds skews the solubility picture.

Metal hydroxide formation

Ferric and aluminum salts are added to induce coagulation (Chapter 9) by the formation of metal hydroxide precipitates. Figure 8.2 indicates an optimum pH for each metal hydroxide. The addition of either aluminum or iron salts depresses the pH due to production of hydrogen ions, as shown in Equations 8.1 and 8.2. The limit of pH depression is a function of the dosage and the buffering capacity or alkalinity of the water, in particular the carbonate concentration. If there is insufficient alkalinity to buffer the effect of the chemical, a buffering chemical such as sodium bicarbonate is added. The addition of aluminum and iron coagulants may therefore be of concern with low alkalinity stormwater.

$$Fe^{+3} + 3H_2O = Fe(OH)_3 + 3H^+ \quad (8.1)$$

$$Al^{+3} + 3H_2O = Al(OH)_3 + 3H^+ \quad (8.2)$$

Dissolved phosphorus removal

Chemicals commonly used to precipitate dissolved phosphorus are aluminum sulfate (alum), ferric sulfate, ferric chloride, and calcium hydroxide (lime). The process produces both a metal-phosphate precipitate and a metal-hydroxide precipitate as noted above. The latter flocculates the former. Calcium phosphate precipitate is induced by the addition of calcium and the increase in pH above 9 from the hydroxide in the lime. Lime is not likely feasible for stormwater treatment, as the pH must be lowered before the water is discharged. Figure 3.5 in Chapter 3 indicates the theoretical minimum concentration of phosphate in the presence of iron. Also indicated is that minimum concentrations occur at a particular pH, 5 and 6, respectively, which may not be realistic with stormwater treatment. As with metal hydroxide formation, metal precipitate formation produces hydrogen ions, decreasing the pH if there is insufficient buffering capacity, demonstrated with Equations 8.3 and 8.4.