# APPENDIX D – POLLUTANT REMOVAL MECHANICS

## Section D.1 Pollutant Removal Mechanics

## D.1 Pollutant Removal Mechanics

The removal of pollutants from highway runoff by BMP facilities can occur in a number of ways including sedimentation, decay and biological uptake, filtration, adsorption, nitrification/denitrification, plant uptake, and microbial degradation. Each of these pollutant removal mechanisms is discussed below.

### D.1.1 Sedimentation

The removal of particulates from the water column is the best first approach to addressing post-construction runoff from highways. BMPs that achieve this may often be used in series with other types of BMPs to lower their maintenance burden and increase performance. Pollutant removal in stormwater management ponds and detention facilities occurs primarily through the gravitational settling or sedimentation of suspended solids. There are upper limits to the amount of pollutant removal that can be achieved in this way and most removal is achieved in the first six (6) to 12 hours. Two different types of sedimentation processes can occur within these basins: quiescent settling and dynamic settling.

### D.1.2 Decay and Biological Uptake

Some dissolved pollutants and pathogenic bacteria in urban runoff may be removed from the water column by decay or die-off. Other dissolved pollutants may be removed through biological uptake (e.g., nutrients such as organic Nitrogen and orthophosphate ion) by means of vegetation in stormwater management ponds and wetlands. The removal efficiencies of these pollutants are often approximated using first-order kinetics. Pollutant removal by decay or biological uptake may also occur under long detention times and favorable environmental conditions.

### D.1.3 Filtration

Many particulate pollutants are physically strained out as they pass through the filter bed of sand, soil, or organic matter and are trapped on the surface or among the pores of the filter media. The effect of filtration can be very strong. For example, Pitt et al. (1995) report that as much as 90 percent of small particles commonly found in urban runoff (6 to 41 microns) are trapped by an 18-inch layer of sand and presumably an even greater percentage of larger particles.

The filtration pathway is not effective in removing soluble pollutants and the smallest particles upon which pollutants are often attached. In addition, the importance of the filtration pathway is a function of the media used in the filter. In relatively tight media, such as soil or sand, filtration is very important; whereas, in more porous media such as compost or peat, the filtration effect is comparatively weak.

### D.1.4 Adsorption

The ability of a filtering system to remove soluble nutrients, metals, and organic pollutants is often due to the adsorption pathway in which ions and other molecules attach to binding sites on filter media particles. In general, the adsorption potential of a filtering system increases when the filtering media has a high content of organic matter or clay, a high cation exchange capacity (CEC), and a neutral to alkaline pH.

Each of the media used for filtering systems exhibit sharply different adsorption potentials. Pure sand, for example, initially has little or no organic matter, clay, or cation exchange capacity and therefore little potential for adsorption. Over time, most sand filters develop a thin layer of organic matter and fine particles at the surface layer of the filter media as a result of sediment deposition, thereby increasing the adsorption potential. Organic filter media such as soil, peat, and compost, on the other hand, have a much greater potential for adsorption if the pH of the media is in the optimum range.

### D.1.5 Nitrification/Denitrification

Nitrification is an important Nitrogen removal pathway as organic matter is gradually decomposed. Microbes break down organic Nitrogen into ammonia, which is then transformed into soluble nitrate-Nitrogen. The nitrification process generally requires an aerobic (oxygen-rich) environment which is characteristic of many filtering systems. As a result, nitrification occurs rapidly in many filtering systems, resulting in the export of low concentrations of ammonia.

Denitrification is the final step in the Nitrogen cycle. It is the conversion of soluble nitrate into Nitrogen gas that is returned to the atmosphere. To proceed, the denitrification process requires a moist, anaerobic environment, an abundant supply of both organic carbon and nitrate, and the presence of denitrifying bacteria. These conditions are not always met in most filtering systems. Consequently, most filtering systems actually export more soluble nitrate than they receive. In recent years, designers have attempted to create suitable conditions for denitrification within filtering systems and have demonstrated a capability to remove nitrate.

### D.1.6 Plant Uptake

Several filtering systems incorporate plants, such as algae, emergent wetlands, or grass to improve removal rates. Examples include vegetated open channels (grass), sand or organic filters (that have a grass cover crop), bioretention, filter strips, and gravel wetland filters (algae, wetland plants). Plants can increase pollutant removal in several ways. During periods of stormwater runoff, for example, grass and emergent wetland plants provide resistance to flow, thereby reducing runoff velocities. Slower runoff velocities translate into more time for other pollutant pathways to work (such as settling, filtering, infiltration, and adsorption). In addition, the roots of grass and emergent plants help bind up the filter media, preventing loss of sediments and attached pollutants via erosion.

The growing plants also create a continual supply of thatch, or detritus, which provide the organic matter needed for greater adsorption. During periods of growth, the plants also take up nutrients and metals from the filter bed and incorporate them into their biomass. If plant biomass is harvested or mowed, pollutants are removed. Taken together, however, the use of plants in a filtering system is usually of secondary importance as a pollutant removal pathway in comparison to the other five pathways.

### D.1.7 Microbial Degradation

Microbial degradation, or biodegradation, is "a process by which microbial organisms transform or alter (through metabolic or enzymatic action) the structure of chemicals introduced into the environment" (U.S. Environmental Protection Agency, 2009). Microbial degradation of pollutants harnesses the naturally occurring ability of microbial xenobiotic metabolism to degrade or transform a range of compounds including hydrocarbons, polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), and metals. Biological processes play a major role in the removal of contaminants and they take advantage of the astonishing catabolic versatility of microorganisms to degrade or convert such compounds.