**Article 65**

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# Irreducible Pollutant Concentrations Discharged From Stormwater Practices

Load reduction has traditionally been the criteria used to evaluate the performance of urban stormwater management practices. Simply put, the mass of stormwater pollutants entering a practice are compared against the mass leaving it (over a suitable time frame), and a percent removal efficiency is quickly computed. While load reduction is a useful criteria to compare the relative performance of different practices, it does have some limits. For example, it tells us very little about the concentration of pollutants leaving the practice. Outflow concentrations can be of considerable interest to a watershed manager. For example, is there a background level or irreducible concentration of stormwater pollutants discharged downstream that represents the best that can be achieved with current technology?

The concept of irreducible concentrations has been explicitly recognized for some years in process models used to design of wastewater treatment wetlands (Kadlec and Knight, 1996; Reed, 1995). The consensus of expert opinion is that surface flow wastewater wetlands cannot reduce sediment and nutrient concentrations beyond the rather low levels indicated in Table 1, no matter how much more surface area or treatment volume is provided.

Figure 1 illustrates the effect of an irreducible concentration on the treatment efficiency of a hypothetical stormwater practice. When incoming pollutant concentrations are moderate to high, for example, an increase in a treatment variable (such as area or volume) will result in a proportional reduction in the concentration of a pollutant leaving the practice (line A). If, however, the incoming pollutant concentration approaches the irreducible concentration, (denoted as C-star), it is not possible to change the outflow concentration very much, regardless of how much additional treatment is provided (line B). Indeed, when the incoming concentration is equal to or falls below the irreducible concentration, it is possible to experience negative removal, i.e., an increase pollutant concentration as it passes through the practice (line C).

Why do irreducible concentrations exist? To begin with, they often represent the internal production of nutrients and turbidity within a pond or wetland, due to biological production by microbes, wetland plants and algae. Some of these internal processes inevitably return some pollutants back into the water column, where they may be displaced during the next storm event. In other cases, the irreducible concentration may simply reflect the limitations of a particular removal pathway utilized in a stormwater practice. For example, a practice that relies heavily on sedimentation for removal can have a relatively high C*. This is evident in the settling column data presented in Figure 2 developed by Grizzard *et al.* (1986). When sedimentation is the sole removal pathway, the removal rates for a range of pollutants eventually become asymptotic, no matter much more detention time is provided.

Does a C* exist for pollutants controlled by urban stormwater practices? Two recent studies suggest that irreducible concentrations do indeed exist. In the first study, Kehoe and his colleagues systematically analyzed the quality of stormwater in a series of 36 stormwater ponds and wetlands located in the greater Tampa Bay, Florida area. Researchers characterized the sediment, metal and dissolved oxygen content of water discharged from stormwater wet ponds (N=24) and pond/wetland systems (N=12) over a two-year period. Grab samples were collected from each site one to three days after storms occurred to represent post-storm discharges.

A summary of the study results are shown in Table 2 for the wet ponds and pond/wetland systems. Outflow TSS levels were remarkably consistent, at slightly less than 10 mg/l. Dissolved oxygen levels tended to be more variable, with slightly lower oxygen levels reported in wetland systems than ponds. Similarly, pH levels of pond/wetland systems were slightly more acidic than pond systems, presumably due to the greater amount of organic matter that accumulated in the wetlands. The

**Table 1: Irreducible Concentrations in Wastewater Wetlands and Stormwater Management Practices**

| **Water Quality Parameter** (mg/l) | **Wastewater** *(Kadlec and Knight 1996)* | **Wastewater** *(Reed 1995)* | **Stormwater** Practices *(this study)* |
|---|---|---|---|
| Total Suspended Solids | 2 to 15 | 8 | 20 to 40 |
| Total Phosphorus | 0.02 to 0.07 | 0.5 | 0.15 to 0.2 |
| Total Nitrogen | 1.0 to 2.5 | 1.0 | 1.9 |
| Nitrate-Nitrogen | 0.05 | 0.00 | 0.7 |
| TKN | 1.0 to 2.5 | 1.0 | 1.2 |