Impacts of Aeration on Effluent TSS in Stormwater Ponds: A Literature Review

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Introduction

World wide, aeration is perhaps the most widely used tool for managing aquatic systems. Aeration is most commonly used for treatment of wastewater (EPA, 1989), improvement of fisheries, mosquito control, ice management, reduction of nutrient loading, sediment management, improvement of water clarity and control of algae. Stormwater detention ponds are created primarily to act as settling basins for urban stormwater runoff. These detention ponds have been shown to reduce effluent, nutrients, chemical oxygen demand and heavy metals. Their primary function though, is to reduce effluent total suspended solids (TSS) (Prey, 1994).

Wet detention basins tend to be shallow (3-7 feet) and fertile due to high nutrient loading. Therefore they are prone to noxious algae blooms. They also tend to be stagnant and anoxic due to a small surface to volume ratio. These conditions discourage fish life and encourage production of insects, such as mosquitoes. Many stormwater ponds are located in residential areas where these factors produce health concerns, reduce aesthetics and depress real estate values. As a result, many municipalities, homeowners, neighborhood associations and real estate developers have employed aeration technology in order to mitigate the negative aspects of stormwater ponds.

This report attempts to explore the potential impacts of aeration on the primary function of stormwater ponds: reduction of effluent TSS.

Methods

This report is the result of a review of scientific texts and journals, government technical bulletins and industry case studies pertaining to the impacts of aeration on aquatic environments. It should be cautioned that all references in this report pertain to wastewater lagoons, natural lakes and manmade ponds. No direct studies of aeration in stormwater ponds could be found. However the same physical laws that govern other water bodies apply to stormwater ponds. Therefore it should be possible to make valid inferences to stormwater pond management from these findings.

Results and Discussion

Aeration Systems

Before any discussion of aeration can be made it should be understood that there are a vast array of aeration systems, each having different attributes. **Air injection systems** employ a compressor on shore that delivers air to diffusers that are placed on the bottom of the lake or pond – often in the deepest areas. These units are often used to de-stratify lakes and ponds. **Axial flow pumps** utilize a floating platform to carry a motor that drives a propeller suspended a few feet below the surface. These systems push water downward to create a circulation pattern. **Surface agitators** and **fountains** consist of a float supporting an electric motor-driven impeller. The impeller pulls water up a vertical tube and throws it in a pattern where atmospheric re-aeration occurs. **Flow generators** are submersed electric motors that drive a propeller. These are typically mounted horizontal to the bottom, and aerate by exposing more water to atmospheric diffusion. **Impeller – Aspirator systems** consist of a motor-driven impeller enclosed in a shaft that extends into the water. The impeller draws air into the shaft and ejects bubbles into the water. **Pump and Cascade Systems** draw water uphill from the lake or pond and allow it to cascade back over baffles or rocks – waterfall fashion (Hudson and Kirschner, 1997).

From a technical standpoint, aeration systems are categorized by several measurable criteria. These include **Standard Aerator Efficiency** (SAE) – the lbs. of oxygen transferred per hour per HP, **Standard Oxygen Transfer Efficiency** (SOTE) – the percentage of oxygen transfer per foot of submergence, **Standard Head Loss** (HL) – air flow per inches of water column (Mix Air Technologies, 2000), and **Aeration Power Intensity –** HP per million gallons of inversion (Rich, 1999). Different aeration systems vary markedly in these criteria.

Given the wide variety of aeration systems and variations in their performance criteria, it is not safe to make too many generalizations about the impacts of aeration.

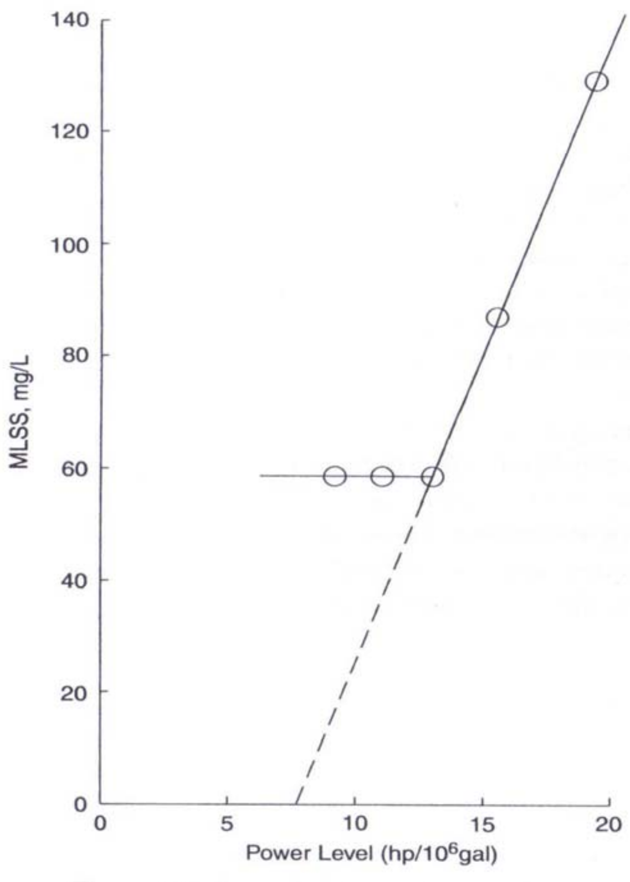
Total Suspended Solids

TSS is a common measure of water quality and refers to all suspended particulate matter in the water column. TSS is express as mg/l. High TSS is indicative of poor water quality (Shaw, 2000). TSS can be separated into inorganic (mineral) and organic components. The organic component can be further separated into living (bacteria and algae) and non-living components. TSS can also be categorized into settleable and non-settleable components, where settlability is a function of particle size (mass), flow and turbulence (FWPCA, 1968). Sources of TSS in stormwater ponds can change throughout the life of the pond. Construction site erosion may be the main source of TSS early in the life of the pond. This TSS may be predominately inorganic in nature. As homes are developed around the pond, and as the watershed becomes stabilized in lawns and impermeable surfaces, TSS may shift to a predominance of organic matter. Increased nutrient loading from lawn fertilizers may lead to TSS that is predominately living organic matter in the form of bacteria and algae (Holdren, et al., 2001).

Impacts of aeration-induced turbulence on particle suspension
As with stormwater ponds, the primary function of wastewater lagoons is to reduce effluent TSS. Aeration is the primary means accomplishing this task. Air injection systems employing a high number of diffusers are typically used to keep solids in suspension long enough for microbial decomposition of organic matter to occur, while allowing denser inorganic solids to settle out (Metcalf and Eddy, 1972).

There is a direct linear correlation between Aeration Power Intensity and the ability to maintain solids in suspension (Figure 1). Rich (1999) reported that a threshold power intensity of 8.5 hp/10^6 gals. was required for surface agitators before any settleable solids could be maintained in suspension. This application was for wastewater lagoons. It is unlikely that any stormwater ponds would be aerated at this intensity. For comparison, several industry specifications for aerating recreational ponds to improve water quality and reduce algae would equate to 0.01 to 0.25 hp/10^6 gals.

Figure 1. Suspended solids concentration as a function of aeration power intensity (Source: Fleckseder and Malina, 1970)



Effects of aeration on planktonic algae

Aeration technology is widely employed to control planktonic algae in lakes, ponds and wastewater lagoons. Since planktonic algae may be the main component of TSS in stormwater ponds, algae control will be an important consideration.

There are several mechanisms by which aeration can control algae. Direct mixing is probably the most readily understood method. Planktonic algae are photosynthetic organisms that require access to sunlight for survival. Aeration systems, such as air injection systems, that can de-stratify a lake or pond can force algae into hypolimnetic waters where they are starved of sunlight (Hudson and Kirschner, 1997). Kortman, et al. (1994) found dramatic increases in transparency due to elimination of cyanobacteria blooms as a result of aeration in natural lakes.

Nutrient abatement is another mechanism by which aeration can control algae. Phosphorus concentrations are often directly correlated to algal abundance (Fitzgerald, 1970) (Cole, et. al., 1993). In shallow lakes and ponds, when anoxic conditions occur, sediments can release phosphorus at levels comparable to external sources (from 30 – 100%). Anoxia is the controlling factor in maintaining elevated phosphorus levels in the water column (Kelton and Chow Fraser, 2005). Under oxic (aerobic) conditions, phosphorus remains trapped in the sediments and unavailable to algae (Nurnberg, 1984). Aeration has been shown to be effective in restoring oxic conditions at the sediment layer (Lock, et. al., 2000) (Fitzgerald, 1970).

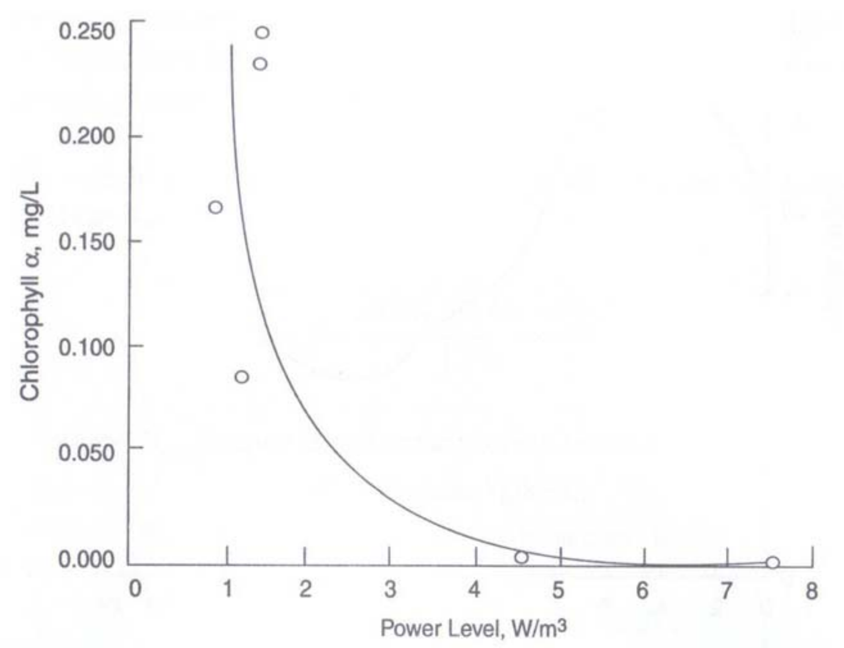
Nutrient reallocation is an indirect means by which aeration can control algae. Increased water transparency due to aeration may encourage growth of rooted aquatic plants, which can then out-compete algae for available nutrients (Agriculture and Agri-Food Canada, 1999).

Carbon dioxide removal is yet another mechanism by which aeration can control algae. Like phosphorus, carbon dioxide can become a growth limiting factor for algae. Aeration can remove significant quantities of carbon dioxide from water (Rich, 1999). Figure 2 shows the relationship between chlorophyll *a* concentration (as a measure of algal abundance) and Aeration Power Intensity.

Effects of aeration on stormwater pond storage capacity

As sediments collect in stormwater ponds, ponds lose volume. A loss in volume equates to an increase in flow and a subsequent loss of efficiency in capturing TSS. The ability of a stormwater pond to capture suspended solids is referred to as *trap efficiency*, and is one of the most important parameters of detention ponds (Verstraeten and Poesen, 2000). Not only does a loss of volume reduce trap efficiency, but it also increases algae production and decreases phosphorus adsorption (Hafner and Panzer, 2005). Managing sediment accumulations then, is of paramount importance in maintaining stormwater ponds.

Figure 2. Chlorophyll *a* concentration in effluents of aerated lagoon basins as a function of aeration power intensity (Source: Rich, 1978)



Dredging has been considered the primary method of removing sediments from stormwater ponds, and may be the only viable method for removing inorganic sediments. Problems associated with dredging as a maintenance tool include high cost, disposal of spoils, inadequate monitoring of ponds and poor compliance with maintenance requirements (Hafner and Panzer, 2005). In contrast to stormwater ponds, the primary method of sediment removal in wastewater ponds is through aeration. By maintaining aerobic conditions at the sediment interface, microbial decomposition of organic matter is greatly increased. Several studies have show significant reductions in organic bottom sediments in aerated natural lakes where aeration power intensity was much less than in wastewater ponds (Dunst, et al., 1974) (Laing, 1999). It should be noted that aeration systems must be capable of de-stratifying the waterbody as well as meeting biological oxygen demand before significant decomposition of sediment occurs. Engstrom and Wright (2002) found that sediment profiles were unaffected in five Minnesota Lakes that were partially aerated to prevent winter fish kills.

Aeration may be an effective sediment management tool in wastewater ponds where a significant portion of sediments are organic. While dredging will eventually be needed, aeration could potentially reduce the frequency of dredging and the problems associated with it.

Conclusions

Can aeration lead to increases in effluent TSS in stormwater ponds? Theoretically, yes. For stormwater ponds having predominantly inorganic influent that are aerated with a very powerful system, effluent TSS could be higher than that of a similar non-aerated pond. In practical terms however, few, if any, aeration systems commonly employed in stormwater ponds would have sufficient energy for this to occur. For stormwater ponds having significant organic influent (which may be the majority of established ponds), certain types of aeration systems should be effective in reducing effluent TSS from that of a similar non-aerated pond.

Based on the findings of this literature review, aeration has the potential to enhance the primary function of stormwater ponds. The potential of aeration to also reduce algae growth, reduce effluent total phosphorus and maintain trap efficiency further support the use of aeration in stormwater ponds.

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