Aeration performance of weirs

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Abstract

The concentration of dissolved oxygen (DO) in the waters of rivers and streams is very important to the quality and existence of aquatic life. Hydraulic structures increase the amount of DO in a river system, even though the water is in contact with the structure for only a short period of time. The same quantity of oxygen transfer that normally would occur over several kilometres in a river can occur at a single hydraulic structure. The primary reason for this accelerated oxygen transfer is that air is entrained into the flow in the form of a large number of air bubbles which greatly increase the surface area available for mass transfer. Plunging overfall nappes from weirs are a particular instance of this, and the aeration properties of such structures have been studied widely in the laboratory and field over a number of years. This paper looks at the aeration performance of weirs having different cross-sectional geometry. It is demonstrated that the aeration efficiency of the triangular notch weir generally is better than for the other weirs.

Nomenclature

a	the specific surface area (A/V), or surface area per unit volume
A	surface area associated with the volume V, over which transfer occurs
b	crest width of weir
C	DO concentration
C_d	DO concentration downstream of a hydraulic structure
C_s	saturation concentration
C_u	DO concentration upstream of a hydraulic structure
E	transfer efficiency at the measured water temperature
E_{20}	transfer efficiency at 20°C
f	term to adjust from 20°C to T°C
h	drop height
H	tailwater depth
K_L	liquid film coefficient for oxygen
L	the experimental channel width
Q	weir discharge
r	oxygen deficit ratio
s	difference between crest and top of weir
t	time
T	water temperature
W	difference between base and crest of weir

Introduction

Currently there is much emphasis on water quality and maintaining water quality parameters in our freshwater hydrosphere (rivers, lakes, and reservoirs). Dissolved oxygen (DO) concentration is one of the most widely cited parameters. DO is often used as an indicator of the quality of water used by humans or serving as a habitat for aquatic flora and fauna. It is maintained by many natural chemical and biological processes that either increase or decrease local oxygen concentrations. Respiration by aquatic life serves to reduce DO, as does biodegradation of organic material in the sediments, along with a host of other oxygen-consuming chemical reactions. Photosynthesis by aquatic plant life can be a significant source of oxygen to a water body, as can oxygen exchange with the atmosphere.

Weir aeration occurs in rivers, fish hatcheries and water treatment plants. Often, the hydraulic head is naturally available and incurs no operating cost. In some cases, however, weir aeration is economically competitive with alternative aeration technology such as surface aeration, even when energy costs for pumping the water are included.

Before breaking up into drops, the flow over a weir or waterfall would be classified as a free nappe, as shown in Fig. 1. Typically most of the oxygen transfer is accomplished in this type of structure during the breakup of the nappe, and the subsequent collision of the free nappe with the bottom of the channel. If the free nappe plunges into a downstream water pool, air entrainment and turbulence will contribute to oxygen exchange. In addition, the depth of the downstream water pool can enhance the absorption because of the increased hydrostatic pressure on the entrainment of air bubbles. Avery and Novak (1978) found that the transfer efficiency is at its maximum at a tailwater depth of approximately 0.6 times the drop height, indicating that a trade-off exists between bubble residence time, pressure and turbulence levels. Oxygen absorption efficiencies vary widely, but for low-head overflow weirs, efficiencies of up to 70% have been measured.

Gameson (1957) was the first to report on the aeration potential of weirs in rivers. Since then a number of laboratory investigations into weir aeration have been carried out, notably Van der Kroon and Schram (1969a;b), Apted and Novak (1973), Avery and Novak (1978), and Nakasone (1987). Investigations have also been reported on the aeration performance of existing hydraulic structures and these are reviewed by Wilhelms et al. (1992). Gulliver and Rindels (1993); in particular, problems associated with field measurements of oxygen transfer and the degree of uncertainty involved are discussed. Much of this work has dealt with straight weirs and free overfalls, among other structures, and none has concentrated specifically on the aeration performance of differently shaped weirs.

This paper describes an experimental investigation into the aeration performance of weirs, and in particular, the effect of varying the shape of the weir (Fig. 2). The shape of the weir dictates

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