

Effects of inorganic metals on respirometric oxygen uptake and related Sag curve formations in streams

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Abstract

Inorganic metals besides their direct toxic effects, carry the potential of causing serious variations on existing ecosystems in receiving waters. A self purification mechanism is vital for the continuity of the existing micro and macro living organisms in the streams. This mechanism is effected from the existence of metals. In this study, interferences of HgCl_2 , HgSO_4 , $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, $\text{K}_2\text{Cr}_2\text{O}_7$, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ and $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ metal compounds on respirometric BOD and related effects on the self purification, were investigated with representative formations of Sag curves. In the presence of these metals, streamwater BOD parameters and the related Sag curve formations were significantly effected.

Keywords: respirometer, BOD, DO, metal toxicity, stream pollution, self purification, Sag curve

Introduction

After the classical DO Sag curve model developed by Streeter and Phelps (1925), Theriault (1927) and Fair (1939) summarised the methods for estimating the model's parameters, and Thomas (1948) accounted for settleable BOD in the DO Sag equation.

Although other modelling approaches have been presented (Adrian and Sanders, 1992; Mayou, 1990), the first order kinetics equation has been widely applied to describe the oxygen uptake rate (BOD) of wastewaters.

$$y = L_o [1 - \exp(-k_1 t)] \quad (1)$$

where:

- y = BOD
- k_1 = BOD reaction rate constant
- L_o = ultimate BOD
- t = time

Adrian and Sanders (1992) cautioned against assuming that all BOD data were described by a first-order model. Thomas (1957), Young and Clark (1965), Nemerow (1974) and Berkun and Tebbutt (1976) pointed out that second-order reactions also describe the stabilisation of wastewaters. Berkun (1974) investigated the suitability of the first- and second-order models using BOD data obtained from extensive experiments using a respirometer and conventional dilution technique. Falkner (1972) gave a model for predicting the deoxygenation-re-aeration process in a long reach of the Wisconsin River, indicating the theory developed by Streeter and Phelps (1925) which had been used to model the process for relatively short reaches of rivers. In their study, the variational effects of flow, temperature, and river parameters were also ap-

proximated by step functions that divided the river into subreaches. Adrian and Sanders (1998) developed a Sag equation for a second-order BOD decay and compared it with a first-order model. The Sag equation which progressed from the pioneering work of Streeter and Phelps (1925) has been used extensively as a tool in stream pollution. The general form of this equation can be given as follows:

$$D_t = \frac{k_1 L_o}{k_2 - k_1} [\exp(-k_1 t) - \exp(-k_2 t)] + D_o \exp(-k_2 t) \quad (2)$$

where:

- D_t = DO deficit at time t
- D_o = DO deficit at time zero
- k_1 = BOD reaction rate constant
- k_2 = reaeration constant
- L_o = ultimate BOD
- t = time

Reliable determinations of the first-order oxygen uptake rate constant (k_1), ultimate BOD (L_o), and reaeration coefficient (k_2) parameters in this equation are of importance. k_1 can be obtained from BOD data using some mathematical techniques (Reed and Theriault, 1931; Fair, 1936; Lee, 1951; Thomas, 1950; Moore et al., 1950) discussed by Berkun (1982), Marske and Polkowski (1972) and Cutrera et al. (1999). k_2 can be determined under field or laboratory conditions. Reliability of parameter estimations is to be questioned in the presence of inorganic chemical interactions in the reactions. Although Sag analysis was extensively used for the investigations of river pollution, not much attention was given to the toxicity interferences. These effects can be either investigated by direct measurements of DO variations or using the DO Sag and BOD equations, with the related first- and second-order (L_o , k_1) and k_2 parameters. Numerous researches and mathematical modelling studies on stream systems have been carried out (Chen et al., 2000; Mohamed, 2000; Onal, 2000). In some studies effects of settleable BOD were also taken into account (Tyagi et al., 1999), but metal-related deoxygenation data are limited. Some inhibiting effects of

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