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The co-treatment of sewage and mine waters in aerobic wetlands

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Abstract

A trial aerobic wetland in NE England is the first passive system ever designed to treat both a polluted mine water and a secondary sewage effluent. Both of these discharges currently enter a small third-order stream (the River Team), significantly degrading its water quality. As the total mine water and sewage water discharges to the river are ~300 and 100 L/s respectively, the pilot-scale wetland (25 × 25 m) has been designed to treat a small portion of each discharge in the same 3:1 ratio. The main drivers for remediation are Fe (~3 mg/L in the mine water), BOD (~14 mg/L in the sewage water), N–NH_3 (~2 mg/L in the sewage water), suspended solids (~23 mg/L in the sewage water) and PO_4 (~7 mg/L in the sewage water).

The combined treatment has many potential advantages over separate treatment of the discharges. Besides the mutual benefits of mixing these two wastewaters (which each tend to be low in pollutants which are high in the other), the biogeochemical properties of the wastewater types can be expected to yield real synergies in treatment. For instance, suspended solids in the sewage water should encourage iron flocs to form by Fe entering in the mine water, expediting the precipitation of oxyhydroxides. Similar processes may also accelerate manganese removal. Phosphate, which is generally difficult to remove using either active or passive treatment can be removed via sorption onto iron oxyhydroxide precipitates. The same oxyhydroxides are also likely to provide numerous ideal sites for the attachment of nitrifying and denitrifying bacteria.

Although the wetland is still immature, initial results suggest that co-treatment is highly successful. Effluent concentrations have consistently been lower than Environment Agency effluent design standards and removal rates for all parameters are likely to improve with time as both biological and microbiological communities become established.

Keywords: Wetland; Co-treatment; Mine water; Sewage water; Iron; Manganese; Phosphate

1. Background

The River Team is a modest third-order stream (an underfit stream in a large glaciated U-valley) which flows generally northwards from Stanley in County Durham to join the major river in the area, the River Tyne, near the city of Newcastle upon Tyne (UK). Water quality in the River Team is poor: it is currently graded as a "Class 4" watercourse (i.e. the lowest category) by the Environment Agency. The two largest discharges into the stream are the secondary sewage effluent from the Birtley Sewage Treatment Works (STW) (~100 L/s Dry Weather Flow (DWF)) owned by Northumbrian Water Ltd. (NWL) and the net-alkaline pumped mine water discharge (~300 L/s) from Kibblesworth shaft operated by the Coal Authority (CA) as part of a long-standing regional mine dewatering system (Younger, 1993), which is nowadays retained for

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environmental purposes. The River Team Revival Project has been set up by the Environment Agency to improve the status of the river and the surrounding environment. As part of this aim, all industries operating in the catchment are being encouraged to invest in further environmental improvements. For NWL, the improvements most sought at Birtley STW were previously identified in their 4-year Asset Management Plan (a binding financial agreement with government) as lowering concentrations of BOD, N–NH_3 and SS in their final effluent (currently averaging ~14, 2 and 23 mg/L respectively). The CA is interested in reducing the impact of iron concentrations (currently ~3 mg/L) on the River Team. Knowing both NWL and the CA's concerns, the authors suggested a novel solution: co-treatment of their discharges in a combined wetland system. Although there were no suitable precedents upon which to draw, the Environment Agency devised a formula for consenting a discharge from a jointly owned wetland, leaving the way open for this pioneering effort in co-treatment. Technological proof of concept was the crucial next step: this paper describes how biogeochemical principles were harnessed in process design and pilot-scale testing, and then presents some of the early results obtained from monitoring the pilot wetland.

2. Introduction

Wetlands are a common form of treatment for both sewage effluents (e.g. Weedon, 2001) and for mine waters (e.g. Younger et al., 2002). However, no wetlands have yet been devised to co-treat these two rather different sources of pollution. If co-treatment was proved possible it would have potentially wide application, as many mine water pumping stations closely adjoin urban areas which historically grew up around coal mines.

There are good grounds for supposing that the combined treatment of both sewage and mine water might be advantageous. For instance, in warm climates where algal growth can be sustained year-round, it has been shown that tannery effluents (which are similar to, but more concentrated than sewage effluents) can be co-treated with mine waters using a combination of upflow anaerobic bioreactors and algal facultative ponds (Rose et al., 1998). However, this approach is not feasible in cool areas such as the UK; it also has the drawback of being an active treatment process, requiring vigilant operation. Passive treatment utilises naturally available energy sources such as topographical gradient and microbial metabolic energy to treat contaminated water and requires regular but infrequent maintenance to operate successfully over its design life (Younger et al., 2002). While there is some experience in the UK of using solid organic wastes as substrates in passive mine water treatment wetlands (e.g. Younger and Rose, 2000; Batty and Younger, 2004), to the best of our knowledge, co-treatment of aqueous sewage effluents with mine waters has never yet been attempted anywhere in the world. One possible doubt over wetland co-treatment arises from the very different forms of wetland for separately treating mine waters (Younger et al., 2002) and sewage (Weedon, 2001). Because of the non-biodegradable nature of ochre which accumulates during mine water treatment, the subsurface flow designs commonly used for sewage treatment are not feasible for co-treatment wetlands also receiving mine waters. But can sewage-like waters be treated in wetlands which more closely resemble classic mine water treatment wetlands? Encouragement is provided by data presented by Surface et al. (1993) which show that constructed wetlands similar to those used for mine water treatment, were able to successfully remove BOD, organic carbon, P, NH_4^+, Fe, Mn and K from a landfill leachate.

Biogeochemical concepts also favour the co-treatment of sewage and mine waters. Although traditional thermodynamics suggests that iron (and manganese especially) will not be oxidised until ammoniacal nitrogen has been oxidised (via nitrite to nitrate) (Vandenabeele et al., 1995) several authors have found (Gouzinis et al., 1998; Mouchet, 1992) that when ammonium concentrations are low (<2 mg/L) iron removal proceeds unhindered. For this reason it was predicted that combined treatment would have many advantages over separate treatment of the discharges. Of course, a wetland which will treat both discharges is also an attractive option both from a logistical (in terms of land required) and most probably a financial point of view. From a hydrochemical point of view, the synergistic relationship between the two waters may result in greater removal rates for all the main contaminants. Suspended solids in the sewage water can be expected to provide nuclei for the formation of iron flocs, thus expediting the precipitation of iron oxyhydroxides (ochre). Phosphate, which is generally difficult to remove using either active or passive treatment can be removed via sorption onto these iron oxyhydroxide precipitates (Cooke, 1994; Drizo, 1999; Heal et al., 2004). In addition, the ochreous deposits should also provide numerous ideal sites for the attachment of nitrifying/denitrifying bacteria (Surface et al., 1993; Demin et al., 2002).

While the theoretical basis for the proposal of co-treatment seems sound, there are obviously no pollutant