5

ROCK FILTERS

5.1 TYPES OF ROCK FILTER

Rock filters (RF) are subsurface horizontal-flow units filled with a coarse granular bed medium (40−200 mm). They are thus similar to SSHF gravel-bed constructed wetlands (Chapter 3) but unplanted and with a larger-size medium. There are two types of RF: unaerated and aerated.

Unaerated RF have been used in the United States for over 30 years mainly to ‘polish’ maturation pond effluents (i.e., to remove algal SS and BOD) (O’Brien *et al*., 1973; Swanson and Williamson, 1980; Middlebrooks, 1988, 1995; EPA, 2002). Aerated RF are a recent development in the UK and so far have only been evaluated at pilot scale (Johnson, 2005; Johnson and Mara, 2005; Mara and Johnson, 2005).

In the UK it has been common practice to surround the outlet of each pond in a series with rock, so creating a small in-pond rock filter (Figure 5.1). While this reduces the number of algae leaving the pond, it does little (except in the case of the last pond in the series) to improve final effluent quality as algae grow in the next pond. A more recent development by Iris Water and Design[1] is to follow a facultative pond by a long shallow, partially planted pond containing several ‘cross-pond’ gravel filters (Figure 5.2). This may be expected to improve effluent quality significantly, but no performance evaluation of this innovation has yet been undertaken.

[1] Castleton, North Yorkshire.

Figure 5.1. Rock filter around the outlet of the facultative pond at Scrayingham, North Yorkshire.

Pond design by Iris Water and Design, Castleton, North Yorkshire.

5.2 UNAERATED RF FOR BOD AND SS REMOVAL

Middlebrooks (1995) compared the performance and costs of RF, SSHF-CW (Chapter 3), intermittent sand filters, macrophyte (duckweed and water hyacinth) ponds and microstrainers for upgrading WSP effluent. He found that, while further development was needed to design RF to produce effluents of a consistent quality, “the advantages of rock filters on a purely cost basis are dramatic”: costs were ~50 percent lower than SSHF-CW. Swanson and Williamson (1980) investigated the relationship between RF performance and the applied hydraulic loading rate (HLR, defined as m^3 of wastewater per m^3 of gross RF volume per day; i.e., with units of day^{-1}); their data from the RF treating primary maturation pond effluent in Veneta, Oregon, yield the following equations:

(a) Percentage BOD removal (R_{BOD}):

$$R_{BOD} = 72 - 109(HLR) \tag{5.1}$$

Figure 5.2. Shallow partially planted pond receiving the effluent from the facultative pond at Scrayingham, North Yorkshire, showing the cross-pond gravel filters (top, February 2005; left, August 2005).

Pond design by Iris Water and Design, Castleton, North Yorkshire

(b) Percentage SS removal (R_{SS}):

$$R_{SS} = 97 - 137(HLR) \qquad (5.2)$$

In the United States the range of HLR applied to unaerated RF is ~0.1−0.3 day^{-1}, which produces BOD and SS removals of ~40−60 percent and ~55−80 percent, respectively.

5.3 AERATED RF FOR AMMONIA REMOVAL

Two of the disadvantages of unaerated RF, because they rapidly become anoxic, are slight odour release due to H_2S and no removal of ammonia. Aeration of the RF (using a dome aerator of the type used in diffused-aeration activated sludge tanks) eliminates H_2S generation, significantly improves BOD and SS removals (Figure 5.3), and provides the conditions for nitrification to occur (Figure 5.4) (Johnson, 2005; Johnson and Mara, 2005; Mara and Johnson, 2005).[2] This work was done on pilot-scale RF at Esholt, Bradford (Figure 5.5) which were fed with facultative pond effluent (rather than maturation pond effluent) at an HLR of 0.3 day^{-1}; the aerated RF effluent quality was 5 mg BOD/l, 6 mg SS/l and 4 mg ammonia-N/l throughout the year.

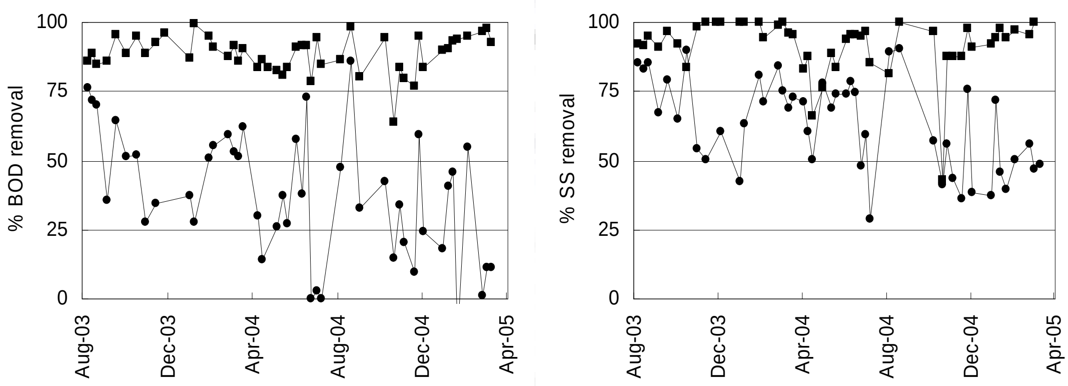

Figure 5.3. BOD and SS removals in aerated (■) and unaerated (●) rock filters at Esholt, Bradford.

Source: Mara and Johnson (2005).

[2] Strictly speaking, aeration of the RF makes the process no longer ‘natural’. Aerated RF are included here as they are a land-saving alternative to maturation ponds or constructed wetlands used to treat facultative pond effluents.

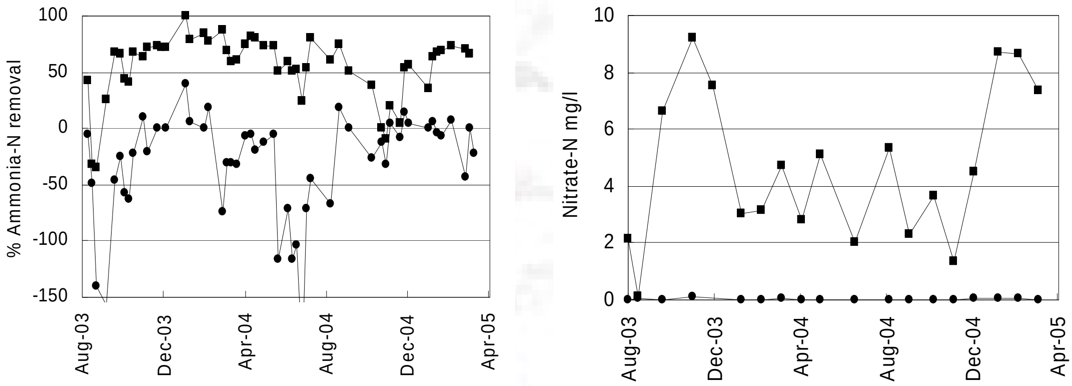

Figure 5.4. Ammonia removal and nitrate production in aerated (■) and unaerated (●) rock filters at Esholt, Bradford.

[The negative ammonia removals in the unaerated filter are due to the partial ammonification of the algal organic nitrogen in the influent from the facultative pond.]

Source: Mara and Johnson (2005).

Figure 5.5. The pilot-scale rock filters (bottom, aerated RF; middle, unaerated RF) and subsurface horizontal-flow constructed wetland (top) at Esholt, Bradford. Each unit is 4 × 0.5 × 0.5 m.

Right, early summer; left, winter.

5.4 COMPARISON WITH CONSTRUCTED WETLANDS

As shown in Figure 3.4, SSHF-CW are not good at removing ammonia during winter. Aerated RF, on the other hand, do remove ammonia in winter. Figure 5.6 shows ammonia concentrations in the effluents of the pilot-scale aerated RF and SSHF-CW (planted with *Typha*) at Esholt, Bradford; the influent to both is effluent from a primary facultative pond loaded at 80 kg BOD/ha day at an HLR of 0.3 day^{-1}. The SSHF-CW is better than the aerated RF in summer, but worse in winter.

5.4.1 Sludge accumulation

Sludge accumulation in the first third of the lengths of the RF and SSHF-CW at Esholt over 24 months was:[3]

Aerated RF:	8 cm
Unaerated RF:	50 cm
SSHF-CW:	50 cm

In the last third of the lengths sludge accumulation was undetectable (<1 cm).

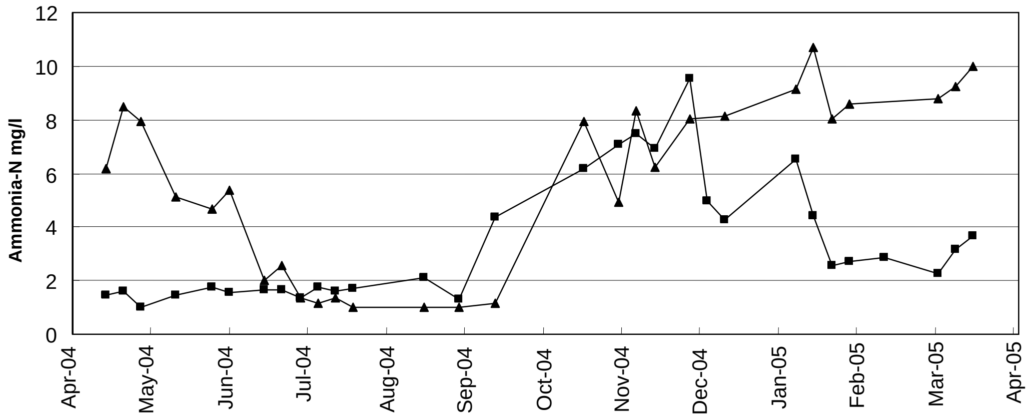

Figure 5.6. Ammonia concentrations in the effluents of the pilot-scale aerated rock filter (■) and subsurface horizontal-flow constructed wetland (▲) at Esholt, Bradford.

Figure courtesy of Michelle Johnson, School of Civil Engineering, University of Leeds.

[3] Unpublished observations, Michelle Johnson, School of Civil Engineering, University of Leeds.