2.7 Wetlands

Both natural and constructed wetlands have been used to capture farm runoff and, in rare cases, to treat dairy effluent.

While it is possible to use constructed wetlands as one component of a wastewater treatment system, their value for treating dairy effluent has not been demonstrated. The use of wetlands linked to waterways, usually practised in districts where wetlands are perennial rather than ephemeral, is strongly discouraged.

Natural wetlands

Natural wetlands have dwindled markedly since European settlement. Despite regulations on the disposal of effluent, the discharge of farm runoff and dairy effluent has helped maintain some natural wetlands. But the associated changes in nutrient, salt and water balances are rarely positive.

The range of natural wetlands which have been modified to receive effluent is difficult to quantify owing to landscape modification and loss of habitat. Some sites are acceptable owing to their isolation and impervious soil, but impounding wastewater in permeable stream beds cannot be condoned. Downstream water quality has no doubt received a measure of protection from some sites, but rarely can these sites be managed effectively to demonstrate isolation from the catchments in which they are installed. Some wetlands holding dairy effluent are dewatered by pumping during times of low flow time and allow passage of flood flows. This use is expedient rather than optimal and requires extensive long time with minimal human influence. Upon effluent discharge, most of the area may monitoring to demonstrate compliance with regulations.

The hydrology and associated hydraulic regime in natural wetlands have evolved over a be 'wetted', but owing to channelisation, most of the water flows through a relatively small proportion of the total wetland. Only a small volume of the effluent may come into contact with parts of the wetlands which offer the best treatment prospects. It is not possible to correct this problem by limited land forming and installing banks while preserving the values of the original natural wetland. The lack of control and the presence of an open system limits the value of natural wetlands for dealing with dairy effluent.

Declining water quality in domestic water supply catchments and blue green algal blooms in the early 1990s placed controls on wetland exploitation. The onset of drought in the late 1990s favoured the recycling of effluent and emphasised the need to use constructed wetlands for treatment to avoid the further deterioration of existing waterways and associated wetlands.

Rarely are natural or modified wetlands subject to design criteria for their use as effluent treatment facilities. Monitoring indicates that the characteristics of influent entering natural wetlands vary markedly, ranging from BOD levels of <10 $mg{\cdot}L^{-1}$ to >500 $mg{\cdot}L^{-1}$. Despite this range, the quality of the treated effluent is usually fairly consistent and usually <10 mg BOD L^{-1}. The introduction of sedimentation traps before entry and the installation of a conventional treatment pond to slow down the rate of influent flow bring dramatic improvements in the performance of natural wetlands.

Constructed wetlands

Constructing a wastewater treatment wetland in a terrestrial landscape where no wetland existed before avoids the regulatory and environmental entanglements associated with natural wetlands and allows for the design of the wetland for optimum hydrological performance, hydraulic flows and enhanced wastewater treatment. A constructed wetland should yield higher-quality effluent than a natural wetland of equal area, since the inflow and outflow can be regulated, the bed can be graded and the period of detention can be controlled. Process reliability is also improved because the vegetation and other system components can be managed as required. Of primary importance is the recognition that a constructed wetland serves a role in a waste management system and is not isolated. Research confirms that the performance of a wetland as a treatment stage is contingent upon the nature of detention and the period of wastewater storage before receipt of additional wastewater. If the previous stage of treatment is inadequate, the wetland will not compensate for poor performance.

A range of propriety wetland systems are used for polishing wastewater following primary and secondary treatment. The design criteria for a range of facilities are provided in Hammer (1989), Kadlec and Knight (1996), Polprasert (1996) and Reed *et al*. (1995). Additional research on constructed wetlands for dairy effluent was undertaken at Ruakura, New Zealand, in the mid 1990s (MAF 1997) and in the Hunter region of NSW (DRDC 1997). Although these studies demonstrated that effluent quality improved, they failed to demonstrate the economic viability of the systems under study.

Wetland treatment systems are generally divided between free-water-surface and subsurface-flow systems. In a free-water-surface wetland the water surface is exposed to the atmosphere, and the bed contains emergent plants, soil for rooting, a liner to protect the groundwater, and inlet and outlet structures designed to distribute wastewater evenly. The wastewater depth ranges from 20 mm to 800 mm or more, depending on the purpose of the wetland (batch or continuous treatment) and on whether or not it can be permitted to dry out. A normal operating depth of about 300 mm is required for the maintenance of aerobic conditions through the penetration of sunlight. Most of the wetlands evaluated for treating dairy effluent were of this type.

A subsurface-flow wetland consists of a basin filled with a porous medium, usually gravel, in which the water level is maintained below the top of the gravel. The depth of the gravel is typically 300 to 600 mm. The vegetation is planted in the upper part of the gravel. The same plant species are used as in free-water-surface wetlands, with the exception of floating macrophytes. A liner may be needed to protect groundwater.

There is no single design criterion for sizing constructed wetlands; the techniques used include:

- multiple regression analysis of performance data from operating systems to derive design criteria that can then be used as a ‘recipe’—the experimental ‘suck it and see’ approach
- an areal loading approach in which performance is related to the volume of effluent or mass of organic matter entering per unit time divided by the surface area; this assumes that the wetland behaves like an aerobic pond
- a biological reaction approach that assumes that the wetland responds to waste in a similar manner to other attached-growth-media treatment systems; this assumes minimal particulate matter in the influent.

Organic matter loading rate

Most wetlands can cope with daily organic loads of up to 100 $kg{\cdot}ha^{-1}$, but with higher loadings it is recommended that proprietary design loadings be followed. Hydraulic residence time is a major factor: a minimum period of 3 days is specified for subsurface flow systems. Under this requirement, the surface area and storage requirements for wetlands catering for dairy effluent are very high. The free-water-surface wetland demands a large surface area, yielding high evaporation losses and salt concentration, but it is generally cheaper and easier to construct and maintain than a subsurface flow wetland.

There are advantages and disadvantages with both systems. The biological reactions in both types of wetland are due to attached growth organisms. Since the gravel medium has more surface area than the open-water-surface wetland, the gravel bed will have higher reaction rates and therefore can have a smaller area. Since the water surface is below the top of the medium and not exposed, the subsurface-flow type does not have the mosquito problems associated with an exposed water surface and suffers from lower evaporation rates. Much greater experience has been derived from research on free-water-surface wetlands serving dairy farms than from subsurface wetlands. The latter type is used mainly for urban applications, individual households and polishing secondary-treated effluent before waterway discharge.

Both types of wetlands rely upon the formation of a biofilm to provide contact between nutrients in the wastewater and organisms in the wetlands. The film is made up of a consortium of bacteria, fungi and algae embedded in a polysaccharide matrix. It provides a critical mass of microbes which absorb and retain organic and inorganic colloids and nutrients, and produce enzymes that act on particulate and dissolved organic material. It forms a potential external energy reserve for low light situations, night time or when there are stark changes in organic loading.

The rate of breakdown of molecules by hydrolytic enzymes determines the rate of decomposition of organic materials. In this process, large organic molecules are broken down to a size which bacteria are capable of assimilating. Aquatic plants continually supply organic material to the microbial layers in their root zone. This supply maintains the concentrations of enzymes that hydrolyse polymeric material in the nearby biofilm. In exposed sediment, the enzyme concentrations in biofilms are much lower, supporting the use of media with a high surface area to volume ratio. The plants are important also because they transfer oxygen to the sediment via their roots, maintaining aerobic conditions for wastewater treatment.

Performance of wetlands

The rates of removal of settleable organics in well designed wetlands are very high on account of quiescent conditions in free-water-surface systems and deposition and filtration in subsurface-flow systems. BOD removal rates vary, but usually range from 50% to more than 90%. If both macrophytes and microphytes (such as algae) are harvested, good nutrient removal rates can be achieved; if not, nutrients accumulate and only N is exhausted. P and K concentrations in treated effluent are reduced, but the medium traps the surplus, increasing the concentrations.

All wetlands rely on macrophyte growth, and anything which compromises this growth detracts from the treatment process. Wetlands need to be well designed in terms of hydrology and hydraulics. If the flow rate is too great and contact time between the effluent and the medium is not adequate, treatment will deteriorate. If the flow rate declines and the wetland receives excessive solids, the contact area will be reduced and the wetland could clog. Similarly, if the macrophytes and algae grow excessively, the root and algal mats can clog flow passages as they die. Although wetlands are effective treatment systems for removing suspended sediment and reducing BOD, pathogens and N loads, they accumulate P, K and trace elements when the plants are not harvested.

For dairy farm use, wetlands need a lot of relatively flat land and need to be managed. Because it is difficult to harvest the plants, wetlands fail to make effective use of nutrients on a farm and encourage loss of water through evaporation and transpiration from plants of lower economic significance than crops or pastures. Their main application appears to be in effluent polishing and for improving the quality of farm runoff, which generally has a high volume and a high organic matter content.

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