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INTRODUCTION

1.1 NATURAL WASTEWATER TREATMENT

Natural wastewater treatment systems (NWT) are biological treatment systems that require no or very little electrical energy. This is in contradistinction to conventional treatment systems such as activated sludge (Table 1.1).[1] Instead they rely on entirely natural processes, principally biochemical and in particular photosynthetic reactions, to provide the energy required for wastewater treatment. NWT systems are anaerobic or aerobic, and some have both aerobic and anaerobic zones. Because they are not energy-intensive processes, they require a greater volume or area to enable wastewater treatment to proceed to the level required. There is thus a trade-off: either more money is spent on land (either by purchase or by leasing) for NWT, or more money is spent on electromechanical equipment and electrical energy for conventional treatment processes such as activated sludge. Land, of course, is an appreciating asset − a good example of this is from the city of Concord in California, where the city bought land in 1955 for waste stabilization ponds at a cost of USD 50 000 per ha, and in 1975 the land was worth USD 370 000 per ha; inflation in this 20-year period was ~100 percent, so the profit in real terms was USD 270 000 per ha (Oswald, 1976).[2]

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[1] The UK water industry is a major consumer of electrical energy. Figures from Water UK (2003, 2004) show that energy consumption for wastewater treatment increased substantially from 437 kWh per Ml of wastewater treated in 1998/99 to 814 kWh per Ml in 2002/03; it decreased to 645 kWh per Ml in 2003/04 (Water UK, 2005). For a wastewater flow of 200 litres per person per day, the energy consumption for wastewater treatment is therefore ~48 kWh per person per year. The CO_2 emission from electricity generation from natural gas is 0.1 million tonnes of C (i.e., 0.37 million tonnes of CO_2) per TWh (Department of Trade and Industry, 1998), so the CO_2 emission due to wastewater treatment is ~17 kg per person per year.

[2] The profit is quoted in 1975 dollars. Expressed in 2005 dollars, it is close to USD 1 million per ha (Sahr, 2005).

Table 1.1. Typical electrical energy requirements of various treatment processes treating a wastewater flow of 1 million US gallons per day (3780 m^3/d)

Treatment process	Electrical energy usage (kWh per year)
Activated sludge	1 000 000
Aerated lagoons	800 000
Rotating biological contactors	120 000
Waste stabilization ponds	Nil

Source: Middlebrooks *et al*. (1982).

In the United Kingdom large areas of land for wastewater treatment are not generally available, and this limits the application of NWT to small populations of a few hundreds where sufficient land is normally available. This last statement is often disputed ("land is just not available"), but in 2003 there were ~680 000 ha of 'set-aside' land (land which the farmers are paid not to farm) in the UK (Department for Environment, Food and Rural Affairs, 2004). The population of the UK was ~60 million in 2003 (Office for National Statistics, 2005), so there were then ~110 m^2 of set-aside land per person − i.e., theoretically more than enough for natural wastewater treatment for in fact the whole of the UK population, and certainly in practice for small villages. So land *is* available. Furthermore it should be available at reasonable cost: in 2003 the annual payment to farmers in England for set-aside land was £240 per ha.[3] Farmers often have an emotional attachment to their land and they may not always be willing to sell it (current farmland prices are approaching £8000 per ha; RICS, 2005), but they might well be prepared to lease it (as, for example, in the case of the land for the waste stabilization ponds at Scrayingham in North Yorkshire − Chapter 4). If the overall land area requirement for NWT were taken as 20 m^2 per person (which is a very high value), a village of 500 people would require 1 ha of land for NWT; and even if the farmer were paid as much as £2000 per year for the use of 1 ha of land for NWT (i.e., ~8 times the 2003 set-aside payment and ~25 percent of its sale value), the land rental cost would be only £4 per person per year.

For small rural communities in the UK where NWT is appropriate the wastewater can be expected to be wholly domestic and with essentially no persistent pollutants that would contaminate the land and require removal or remediation prior to the land being put to alternative uses when at some stage in the future it is no longer needed for NWT. If the land is being returned to farmland, then no special precautions are necessary; if for some

[3] Set-aside payments have been replaced by the Single Payment Scheme, but set-aside itself continues (Rural Payments Agency and Department for Environment, Food and Rural Affairs, 2004).

other purpose (housing, for example), then it may be prudent to let the subsoil rest for a few months prior to being covered with new topsoil.

1.2 MAIN TYPES OF NWT IN THE UK

In the UK the types of NWT systems in current use are:

1. Septic tanks,
2. Constructed wetlands (CW) (Figure 1.1), and
3. Waste stabilization ponds (WSP) (Figure 1.2).

Septic tanks are briefly considered in Chapter 2. CW and WSP are described in some detail in Chapter 3 and 4, respectively. Although they are not much used in the UK, rock filters (Chapter 5) are a proven low-cost tertiary treatment process used to 'polish' WSP effluents which are generally high in algal suspended solids. Guidelines for NWT technology selection, based on land area requirements, performance and costs, are presented in Chapter 6.

Advice on small NWT systems for populations up to ~50 is given in *Sewage Solutions* by Grant *et al*. (2005). The New Zealand manual *Sustainable Wastewater Management: A Handbook for Smaller Communities* (Ministry of the Environment, 2003) is also very useful.

1.3 ADVANTAGES AND DISADVANTAGES OF NWT FOR UK VILLAGES

The advantages of NWT systems for UK villages are low costs (both CAPEX and OPEX), simple maintenance requirements and, assuming good design and good operation and maintenance, high performance and robustness. Their principal perceived disadvantage is the large land area that they require; they are also often (but erroneously) thought to present odour problems and to be unable to produce effluents of an acceptable quality. Specific advantages and disadvantages are detailed in Chapters 3 and 4 for CW and WSP, respectively.

1.4 FLOWS AND LOADS

The most recent UK Code of Practice (British Water, 2005) recommends the following values for small wastewater treatment systems, with 'small' being defined as up to 1000 population equivalents (p.e.):

Wastewater flow:	200 litres per p.e. per day
BOD:	60 g per p.e. per day
Ammonia ($NH_3 + NH_4^+$):	8 g N per p.e. per day

Figure 1.1. Constructed wetland (within the black lines) at Airton wastewater treatment works, North Yorkshire

Figure 1.2. One of the four secondary facultative ponds at Hawkwood College, near Stroud, shortly after commissioning and planting of the marginal plants in August 2005 (see also Figure 4.8).
Pond design by Ebb & Flow Ltd, Nailsworth, Gloucestershire.

This Code of Practice is for package plants, but these values are equally applicable to NWT systems. Designers may consider a BOD contribution of 60 g per p.e. per day to be on the high side. This value is the formal definition of 1 p.e. in the Urban Waste Water Treatment Directive (Council of the European Communities, 1991), but in rural areas it is much lower − in rural France, for example, it is 35−40 g per p.e. per day (Pujol and Liénard, 1990). In this Manual a value of 50 g per p.e. per day is used.

All types of wastewater treatment plants, including NWT plants, serving small rural communities can be adversely affected by the discharge of toxic materials by householders (e.g., water-soluble paints, paint-strippers, wood preservatives, biocides of all types, disinfectants) as the available dilution with wastewater from other households is small. To avoid this the community needs advice on the safe disposal of toxic material. Similarly, to protect NWT serving motorway service areas and those receiving wastewater from restaurants and/or fast food outlets, grease traps must be installed prior to discharge to sewer; the grease traps require regular inspection to ensure that they are being used properly (again, advice on grease disposal must be provided).

Wastewater effluent flows <50 m^3 DWF per day (equivalent to a population of up to 250, assuming a dry-weather wastewater flow of 200 litres per person per day) in England and Wales are not required to be self-monitored under the Environment Agency's monitoring certification scheme ('MCERTS'); self-monitoring is also not required for effluents with only descriptive consents (Environment Agency, 2005).

1.5 PRELIMINARY TREATMENT

Preliminary treatment (screening, grit removal, flow measurement) is fully described in a separate CIWEM Manual of Practice (forthcoming) (see also Marais and van Haandel, 1996, and US Environmental Protection Agency, 2003). In general, preliminary treatment ahead of NWT processes is very simple: there may be only coarse (e.g., 50-mm) screening and no grit removal. If the wastewater is pumped to the treatment site, even screening is often omitted.

1.6 HEALTH AND SAFETY

The Health and Safety aspects of NWT plants are not arduous: the site should be enclosed by a chain-link fence; access should be via a gate which is normally kept locked. There should be suitable notices fixed to the fence at several locations advising what the works are and what danger exists (for example, "Sewage Treatment Ponds. Danger: Deep Water. Keep Out").

Maintenance workers should be provided with (and required to wear) protective clothing (including high-visibility jackets, gloves and boots), and their vehicle should contain a lifebuoy (in the case of waste stabilization ponds), a first-aid kit and a mobile telephone.