CHAPTER 1 INTRODUCTION

1.0 Introduction

This thesis is about waste stabilisation ponds, a low-cost technology for sewage treatment, in the UK. The application of waste stabilisation ponds in the UK will be for small treatment works for population equivalents of less than 2000.

1.1 Sewage treatment in the UK

About 96% of the UK population is connected to sewers leading to over 9000 sewage treatment works. The remaining 4% of the population are served by private treatment works, septic tanks or cesspits (Water UK, 2002). The water industry supplies 18 million cubic metres of water every day and collects over 11 million cubic metres of wastewater.

The Water Act (1973) established ten unitary regional water authorities in England and Wales, each responsible for water quality, water supply and sanitation for its area. In 1989, the ten public water authorities became private companies and the National Rivers Authority (NRA) was set up to monitor river and environmental pollution. In 1996, the Environment Agency (EA) was formed and took over the responsibilities of the NRA. The regional companies created in 1989 were: Anglian Water, Dwr Cymru, North West Water, Northumbrian Water, Severn Trent Water, Southern Water, South West Water, Thames Water, Wessex Water and Yorkshire Water.

Prior to 1996, water and sewerage services in Scotland had been managed by local government in nine mainland regions and three island regions. In April 1996, the services were transferred to three authorities: East of Scotland Water, North of Scotland Water and West of Scotland Water. In 2002, these three were merged to form Scottish Water, a public sector company which is answerable to the Scottish Parliament. Scottish Water serves approximately 5.3 million people (Scottish Water, 2002), and discharges from sewage works in Scotland are regulated by the Scottish Environment Protection

Agency (SEPA). In Northern Ireland, the Water Service operates 918 sewage treatment works, and is accountable to the Northern Ireland Assembly.

1.2 European legislation

The UK is subject to the EC Urban Waste Water Treatment Directive (UWWTD) (91/271/EEC) (Council of the European Communities, 1991) which sets minimum standards for the collection and treatment of sewage and effluent discharges. The level of treatment required depends on the size of the discharge and the sensitivity of the receiving water. The levels of treatment are classified as: preliminary, primary, secondary and tertiary. Preliminary treatment involves screening to remove floating rags and grit removal. Primary treatment is defined as solids sedimentation by physical or chemical means to remove at least 50% of the SS and 20% of the BOD. Secondary treatment is some sort of biological treatment to reduce BOD and SS to levels suitable for discharge. Tertiary treatment can involve disinfection, nutrient removal and/or the removal of toxic substances.

The UWWTD requires that all discharges from sewage treatment works with population equivalents (p.e) of greater than 2000 to inland waters and estuaries, and over 10 000 p.e to coastal waters, receive secondary treatment. For discharges of less than 2000 p.e, the Directive requires “appropriate treatment” by 31 December 2005. The Directive defines “appropriate treatment” as *“treatment of urban waste water by any process and/or disposal system which after discharge allows the receiving waters to meet the relevant quality objectives…”.* The Environment Agency for England and Wales interpret “appropriate treatment” to be: septic tank, rotating biological contactor (RBC), trickling filter, activated sludge plant, reed bed or equivalent system.

The Directive allows for the designation of “sensitive areas” and “less sensitive areas”. “Sensitive areas” are those where the waters need special protection and thus sewage discharges within them require some tertiary treatment. By June 2002, there were 297 such areas identified in England (Department for Environment Food and Rural Affairs, 2002a). “Less sensitive areas” are some estuarine and coastal waters, where primary treatment is expected. In 1998, all “less sensitive area” designations in England and Wales were revoked, thus significant discharges to these areas now all require secondary treatment.

There is now pressure on the water companies to deliver improvements to their smaller works and construct new ones to meet the European Union standards. Increasingly, new, lower cost technologies are being investigated to enable the industry to meet these targets, especially in rural areas. The operational costs of providing power to conventional processes are substantial. In 1999, the water and sewerage companies spent a total of £54 million on power for wastewater treatment and £15 million on sludge treatment. On average this accounted for one third of the total operational expenditure (Darlow, 2000).

1.3 Small sewage works and non-sewered discharges

Seventy four percent of the sewage works in the UK are for populations of less than 2000: these works treat approximately 4% of the total sewage generated in the UK. These proportions vary from region to region: for example, in the Thames Water region, 55 % of sewage works are for less than 2000 people, whereas in the North of Scotland, 94% are for less than 2000 (and 67% are for less than 100 people). According to Griffin and Pamplin (1998), these small works present the greatest risk to compliance with the EC UWWTD.

Small sewage treatment plants have very varied flows, augmented by large point sources such as schools, pubs etc. Griffin and Upton (1999) suggested that an ideal small works would be able to deal with excessive flows, zero flows and provide effective, reliable treatment throughout the year. Boller (1997) stated that, compared to large works, small works are subject to operation and maintenance problems, and large per capita costs, thus the emphasis should be on simple, but reliable, systems. The process selection in the

Severn Trent region for small sewage treatment works, as given by Griffin and Upton (1999), is based on the following criteria: visual impact, footprint, safety, performance, sustainability. In his survey of the water industry, Darlow (2000), found the most important criteria for small works were: capital costs, reliability, operating costs, simplicity, energy demand and the minimisation of sludge production.

For non-sewered effluent discharges, where the connection to sewer is not practicable, the EA and SEPA recommend the following treatment options: septic tanks, package treatment plants, reed bed systems, waterless toilets, cesspools, or some combination of these. Reed beds require some prior solids settlement to avoid clogging. Septic tanks are good for this, but require desludging at least every 12 months: septic tank effluent usually requires further treatment before discharge to water. Package plants can treat the water to a high standard, but require electrical power and regular skilled maintenance to ensure effective operation. Composting toilets are particularly suitable for very remote areas where there is no mains water supply. Cesspools are not sustainable as they require frequent, expensive emptying services.

1.4 The problem of sewage sludge

Sewage sludge is the solid material remaining after the sewage treatment process. As more sewage is treated to a higher standard, more sludge is produced and the problem of sludge treatment and disposal increases. In 1999, the UK produced over 1.1 million tonnes of sewage sludge (dry solids); this averages to about 20 kg per person per year. Two thirds of the sludge was produced at large sewage works serving >150 000 p.e; 4% of the sludge was produced at small works serving < 10 000 p.e. Prior to 1998, about a quarter of the sludge produced was dumped at sea or discharged to surface water. After 1998, sea disposal was banned and mostly replaced with incineration and landfill. In 1999/00, 52% of sludge was applied to land, 17% was landfilled and 21% was incinerated (Department for Environment Food and Rural Affairs, 2002b; Environment Agency, 2002). In 1997, 78% of the sludge applied to land was treated beforehand by either anaerobic digestion, dewatering, composting and the average annual application rate was 3.4 tonnes of dry solid /ha for arable land. The amount of sludge which may be applied to land depends on the quantities of potentially toxic elements, and is regulated by the implementation of European Directive 86/278/EEC on the protection of soil (Council of the European Communities, 1986). Sewage sludge application to land is also regulated to protect groundwater from nitrate contamination. The "Safe Sludge Matrix" which sets minimum acceptable levels of treatment and use for any sewage-sludge-based product used in agriculture was agreed by Water UK (representing 14 UK Water and Sewage Operators) and the British Retail Consortium (representing major retailers) and came into force in 1998 (ADAS, 2001).

1.5 Waste stabilisation pond use in the UK

Waste stabilisation ponds are a low rate technology which, unlike reed beds, has not yet been formally investigated in the UK. These systems are extensively employed for rural communities in Europe and the United States. In France there are more than 2500 systems and in Germany there are more than 1000. In the US, one third of all sewage treatment plants are waste stabilisation ponds. In comparison to these countries, the UK has a high population density: 275 people/km^2, compared, for example to France, with 106 people/km^2. However, large parts of the UK are rural: for example, the population density in Scotland, which accounts for 30% of the land area, is 66 people/km^2 (Darlow, 2000).

In the UK all full-scale waste stabilisation pond systems for full treatment are privately owned. Only polishing lagoons for tertiary treatment are used by the water companies and authorities. Pilot-trials have taken place with wind-assisted lagoon systems by an American company called Lake Aid Systems Ltd. These systems differ from natural or unassisted ponds as they are deeper and require surface aeration. There have been no trials on unassisted ponds, consequently there is a lack of operational data. Designing an effective waste stabilisation pond system for the UK is difficult due to this lack of information. Only a small quantity of data is available from the existing pond systems.

Mara *et al*. (1992) stated that waste stabilisation ponds have the following advantages:

- Simple construction
- Low construction costs
- Little or no machinery, resulting in simple plant operation and low maintenance costs
- High microbial quality of final effluent
- Consistent final effluent quality with respect to SS and BOD
- Ability to cope well with fluctuating hydraulic loads and stormwater due to the long hydraulic retention time
- Suitable for tourist locations as summer conditions (higher temperatures) allow increased loading.
- Have integrated sludge treatment

The main disadvantage stated is the large land area required: 0.29 ha for three ponds treating the wastewater from a population of 250 (Mara *et al.*,1992).

According to the criteria required for small sewage treatment works, waste stabilisation ponds could be an appropriate treatment for discharges from populations of less than 2000 in the UK. However, the British Standard, which is based on the European Standard on “Lagooning processes”, gives no operational data for the UK (British Standards Institution, 1999) and there is no mention of waste stabilisation ponds at all in the recommendations of the EA and SEPA.

Bond (1998) did an analysis of the feasibility of waste stabilisation ponds at three sites in Yorkshire, taking into account: land cost and quality; land availability, effluent quality, nuisance factors and access. He found that at one of the sites, a waste stabilisation pond system was overall the most feasible option. However, he also found that Yorkshire Water did not include this in their list of options for the site. This is a common pattern in many of the water companies. Darlow (2000) found that, although many companies were aware of the use of waste stabilisation ponds in France, Germany and the US, they did not think they would be suitable for the UK due to land availability and the climate. Waste stabilisation ponds were effectively written-off and not even included as a possible option for any development.

In 1999, Yorkshire Water determined that 70 new wastewater treatment plants would be required in the region to serve populations of less than 250. The first step was to assess potential treatment solutions on a desk-top basis, the systems assessed were: package plants and septic tanks followed by a reed bed or filter. Pond systems were not included because "it was felt that obtaining planning permission would be problematic". Hence, pond systems were not considered at all, even at desk-top level. Although pond systems would not be suitable in many cases, it is very hard to believe with the widespread use in France and the private use in UK, that a pond system would be not be the best option in some cases.

Sewage treatment is big business: many new technologies are being developed and marketed vigorously. Bond (1998) stated that the water companies are strongly subject to this marketing. Low-tech, established technologies are less profitable and thus there is less (or no) marketing incentive.

This thesis aims to provide performance data for companies or individuals who wish to build ponds in the UK. The luxury of this research work is that it could be carried out with no thought for profit. It has enabled data to made available on a technology which may be a benefit to many small communities in the UK. Furthermore, the data are presented entirely as found.

1.6 The thesis

This thesis covers the performance of primary facultative ponds, it is arranged as follows:

Chapter 2 is a review of literature divided into three sections. The first section covers the background theory to facultative pond operation, design and performance. The second section examines the experience of facultative ponds in other countries with a similar climate to the UK. The third section brings together the published knowledge about waste stabilisation pond use and performance in the UK.

Chapter 3 presents the results of a survey, carried out in 2000, of the existing facultative ponds in the UK (all privately owned). It includes performance data from pond systems spread throughout the country.

Chapters 4-7 present the data from the operation of three pilot-scale primary facultative ponds, each with a different surface BOD loading, over 2 years from July 2000 to June 2002. The objectives of these experiments were the determination of:

1. The optimum surface BOD load (kg/ha.d) for BOD removal.
2. The optimum surface BOD load (kg/ha.d) for SS removal.
3. The optimum surface BOD load (kg/ha.d) for ammonia removal.
4. The maximum surface BOD load (kg/ha.d) permissible to maintain facultative conditions.
5. The volume of sludge accumulated, the degree of degradation and the estimation of the desludging interval.
6. The contribution of algae (as measured by the chlorophyll-a concentration) to the effluent SS and BOD concentrations.