# Chapter 4

# Fieldwork methodology

## 4.1 Construction of the pilot-scale baffled primary facultative pond

The pilot-scale baffled primary facultative pond was constructed at Esholt Wastewater Treatment Works situated to the north of Bradford, owned by Yorkshire Water plc to provide validation data for the CFD model results. Details of the excavation and construction procedures for the unbaffled pilot-scale ponds are available in Abis (2002). The excavation of the pond was lined with a 1.0 mm high-density polyethylene membrane underlain with a 300 g/m$^2$ geotextile to prevent seepage of the wastewater. It was necessary to install this as any wastewater seepage could have affected the hydraulic flow pattern, so making validation of the CFD model inaccurate.

The pilot-scale pond had the top water surface dimensions of 10.2 m long, 3.87 m wide and 1.5 m deep, giving an estimated volume of 55.3 m$^3$. Two and four baffle configurations were installed at equal distance along the longitudinal axis of the pond. The length of baffles was 2.71 m (70% pond-width) and this gave a width of 1.16 m at the baffle opening (30% pond-width). The 70% pond-width baffles were adopted in the experiment following the recommendation of Mangelson and Watters (1972) that these baffles achieve maximum improvement in the hydraulic and treatment performance in facultative ponds.

The baffle material was made from a high-quality plasticized PVC polymer that was coated on both sides of a polyester substrate (Figure 4.1 and 4.2). The baffles were hanged from steel poles that were 0.5 m above the top water surface level. The baffles were designed and constructed to overlap the pond liner for estimated width of 1.5 m. Rectangular concrete blocks with dimensions of 0.1 m × 0.1 m × 1.5 m were placed along the baffle overlap width to seal the joint that existed between the baffle sheet and the pond liner. The first configuration used two baffles. The baffles were spread equally at a spacing of 3.4 m (Figure 4.1). The second configuration was investigated with four baffles. The baffles were spread equally at a spacing of 2.04 m along the longitudinal axis of the pond. Five baffle compartments were created that changed the hydraulic flow pattern in the pilot-scale pond. Figure 4.1 and 4.2 show the pilot-scale primary facultative ponds when fitted with two and four baffle configurations, respectively.

**Figure 4.1** Layout of the two-baffle configuration in the pilot-scale pond

**Figure 4.2** Layout of the four-baffle configuration in the pilot-scale pond

### 4.1.1 Design of inlet and outlet structures

A 110-mm PVC pipe was used to construct the inlet and outlet structures. The inlet structure was designed to hold the inflow tubing away from the edge of the pond and allow the inflow to enter at a depth of 1 m; it was constructed by connecting 1.25 m and 0.95 m sections pipe via a $45^o$ – elbow connector and set into concrete at the pond edge. Two 15.9-mm PVC hoses were used to load the pilot-scale pond. One 15.9-mm PVC hose was carrying raw sewage from the inlet via a peristaltic pump and the other 15.9- mm hose carried fresh water to achieve a mean hydraulic retention time of 30 days.

The outlet structures were constructed from a single piece of drainpipe inserted into the embankment at a vertical height of 1.5 m from the base on the pond, with a "T" piece fitted to allow effluent to discharge at 100 mm below the water surface.

## 4.2 Operation of the pilot-scale facultative pond

The two-baffled pilot-scale facultative pond was the first to be operated. The pond was filled with final effluent from the secondary tanks of the tickling filter from the Esholt works. Screened sewage was introduced into the pond via the Watson-Marlow 604S/R peristaltic pump with 12-mm Marprene internal tubing. The flow was carried by 15.9-mm dia. flexible tubing with 6- mm dia. strainers attached to remove excess screenings from the sewage. The pump was housed in a small garden shed.

Abis (2002) observed that the influent $BOD_5$ concentration of the Esholt Sewage treatment works was about 485 mg/l. With this high $BOD_5$ concentration and the existence of low temperature in the UK, a long retention time, in the range of 60 - 90 days, would be recommended. With the limitation of time for this research, it was necessary to reduce the hydraulic retention time to 30 days. This was achieved by introducing freshwater that controlled the hydraulic loading of the pilot-scale baffled pond.

Abis (2002) noted that the average temperature that can be used to design safe waste primary facultative ponds in the UK is about 8 $^{o}C$. Using Mara's (1987) surface $BOD_5$ loading equation, gives the design surface loading of 80 kg per ha per day. This was the surface $BOD_5$ loading that was applied in the pilot-scale baffled primary facultative pond. The two-baffle pilot-scale pond was run for twelve months covering both winter and summer seasons.

When the operation of the two-baffle pilot-scale primary facultative pond was completed, the pond was desludged. The four-baffle pilot-scale primary facultative pond was fitted the 70% pond-width baffles. The operation was again based on the surface $BOD_5$ loading of 80 kg per ha per day and the mean hydraulic retention time of 30 days. The influent $BOD_5$ concentration varied significantly on a daily basis and this resulted into the adjustment of the sewage flow by changing the speed of the pump and the flow of the freshwater. Measurements were done using a 1-litre measuring cylinder and a stopwatch.

In order to assess the improvement in the treatment efficiency of the baffled primary facultative ponds, the control pond was used to provide the baseline investigation. This was achieved using unbaffled pilot-scale pond with similar geometric dimensions, $BOD_5$ loading and the mean hydraulic retention.

### 4.2.1 Site sampling and data collection

#### 4.2.1.1 Water temperature

Temperature measurements were logged at 0.25 m depth intervals using *i-buttons* (Abis and Mara, 2006). The DS1921G thermochron *i-button* was used to measure the temperature in the pilot-scale pond to define thermo-stratification. The buttons logged hourly temperatures for up to 80 days. Each button was heat sealed into a plastic bag and clipped onto a piece of string, before suspending in the pond from a plastic bottle and weighed down with a bottle full of aggregate. After 80 days, the buttons were retrieved and the temperatures downloaded using the *i-button* TMEX software. The temperature data were then used to investigate the occurrence of isothermal and thermo-stratification conditions in the pilot-scale ponds.

#### 4.2.1.2 Depth profiles for dissolved oxygen, redox potential and pH

Depth profile measurements were taken at 0.15-m intervals for dissolved oxygen, pH and redox potential using a YSI 6820 sonde probe fitted with a YSI 610-DM display logger. The probe was suspended from a pole with hook on its end, 1.5 m from the edge of the pond at the centre of the baffle compartments. The results were downloaded to computer using the YSI "EcoWatch" software (version 3.12.10). These in-situ measurements were carried out to monitor facultative conditions in the baffled pilot-scale primary facultative ponds. This enabled the assessment of the $BOD_5$ overloading condition in the baffle compartments (see Chapter 6). The occurrence of the $BOD_5$ overloading reduces the algae concentration due to increased loading of ammonia and sulphide.

#### 4.2.1.3 Influent, effluent and column samples

In order to assess the treatment performance of the pilot-scale baffled pond, influent and effluent grab samples were collected weekly at about 10:00 am for the analysis of the indicator parameters (*E. coli*, $BOD_5$, SS, ammonia and TKN). Column samples were collected to a depth of 0.75 m to analyse the chlorophyll *a* concentration in the pond. The analyses were performed on the same day of collection in the laboratory in Leeds University (10 miles away). The results of the effluent *E. coli* count and $BOD_5$ concentration were used to validate the CFD model.

## 4.3 Laboratory methods

### 4.3.1 Settleable solids

Settleable solids (ml/l) were measured on the influent grab samples according to method 2540 F (APHA, 1998) using a PVC Imhoff cone with removable base. Readings were taken at 1 and 2 hour intervals. The test was carried out to predict sludge settlement and compaction after 24 hours. After two hours' settlement, a sample of supernatant liquid was removed and analysed for $BOD_5$ and SS.

### 4.3.2 Suspended solids

Suspended solids were measured on influent and effluent according to the method 2540 D (APHA, 1998). The papers were dried for at least one hour in a Gallenkamp Hotbox oven set at 105$^{o}$C, and then weighed on a Mettler (AE100) 4-place balance. The filtrate was collected and analysed for $BOD_5$, ammonia and TKN.

### 4.3.3 $BOD_5$

$BOD_5$ concentration was measured according to method 5210 B (APHA, 1998) on all collected samples and their filtrates. In addition, $BOD_5$ was measured on the supernatant from the settleable solids test. The test employed 250-ml glass stoppered bottles, incubated at 20$^{o}$C in a Gallenkamp cooled incubator; a YSI 52 dissolved oxygen meter with YSI 5905 dissolved oxygen probe were used to read dissolved oxygen. The dilution water was prepared in a 15-l Nalgene "Lowboy".

### 4.3.4 Chlorophyll a

Chlorophyll a was measured on column samples less than 2 hours after collection using the methanol extraction method of Pearson *et al.* (1987).

### 4.3.5 *E. coli*

*E. coli* counts were determined on influent and effluent grab samples employing the membrane filtration method 9223 D (APHA, 1998) using coliform chromogenic medium and incubation at 37$^{o}$C for 24 hours. Ringers solution was prepared in 9 ml quarter strength to enable the numeration of the *E. coli*.

### 4.3.6 Ammonia

Measurements of ammonia concentration were employed on grab samples of filtered and unfiltered effluent and influent using distillation and titrimetric method according to 4500-$NH_3$ C (APHA, 1998). A distiller machine was used to distil the ammonia, and the samples were titrated using 0.02N sulphuric acid.

### 4.3.7 Organic nitrogen

Measurements of total Kjeldahl nitrogen (TKN) were used on grab samples of filtered and unfiltered effluent and influent samples using the macro-kjeldahl method according to 4500-$N_{org}$B (APHA, 1998). The samples were digested in a Buchi digester and scrubber and later distilled for titration process as in the method for ammonia.

## 4.4 Tracer experiment

Tracer experiment was carried out using rhodamine WT to assess the hydraulic performance of the three pilot-scale primary facultative ponds. Dispersion number and the mean hydraulic retention times were the hydraulic indicator parameters that were observed in the pilot-scale ponds. The experiment was run for duration of three-retention times (3θ). Measurements of rhodamine WT and hydraulic retention time at the pond outlet were achieved using a YSI 6820 sonde probe fitted with a YSI 610-DM display logger.

## 4.5 Summary of the methodology for the fieldwork

The pilot-scale primary facultative pond was run with two and four baffle configurations covering both winter and summer seasons. The baseline investigation of the pond performance was carried out in a control pond that was not baffled. Laboratory experiments were carried to provide validation experimental data for the CFD model results. The experiments that were conducted include measurements of *E. coli* count, $BOD_5$, ammonia nitrogen, total Kjeldahl nitrogen (TKN), chlorophyll-*a* and suspended solids.

In-situ tests were also used to assess the stability of the facultative conditions in the baffle compartments. Profiles of dissolved oxygen and pH were measured in the pilot-scale pond. In addition, *i-buttons* were installed in the pilot-scale pond to monitor the temperature profile. This allowed thermo-stratification effects to be simulated in the CFD model.

Finally, tracer experiments were conducted to assess the hydraulic performance of the pilot-scale baffled ponds. Dispersion number and the mean hydraulic retention time were indicator parameters of the hydraulic efficiency of the pilot-scale pond. In conclusion, the experimental data from the pilot-scale primary facultative pond is used to provide validation data of the CFD model that is employed in this research.