COMPUTER AIDED TECHNIQUE APPLIED FOR ACTIVATED SLUDGE PROCESS CONTROL

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ABSTRACT

The aim of this paper is to assess the feasibility of some control schemes applied to the dynamic operation of activated sludge process, with more focus on practical aspects. Two control strategies are evaluated using dynamic modeling and computer simulations.

Keywords: Activated Sludge, Operational Control Step Feed, Dynamic Modeling.

INTRODUCTION

Most activated sludge plants operate in a dynamically changing conditions. Fluctuations in inputs such as influent flow rate, concentration and compositions cause changes in process operation and efficiency. Disturbances related to the process inputs have to be met in a relevant time-scale by operational control techniques [1].

Berthouex et al. [2] investigated a large number of wastewater treatment plants. They stated that among the well operated plants, 60 % of the upsets were due to operational problems. Other reports confirm that inadequate plant operation is responsible for the majority of wastewater treatment plant failures [3,4]. *Consequently, careful design of control strategies* become necessary to maintain the process operation and to meet the more stringent requirements imposed on efflunt quality.

Basically, activated sludge can be regulated by varying certain inputs such as sludge recycle, wastage rate, the wastewater feed point, and aeration rate. Extensive literature reviews on activated sludge control can be found in [1,5,6,7,8,9]. From such research, a number of control strategies were developed and evaluated using mathematical and pilot plant simulation.

These strategies are usually based on control equations with feedforward and feedback elements derived from mass balance considerations.

The specific oxygen utilization rate (SCOUR) proposed by Andrews [10] is a dynamic indicator of sludge activity. Control of SCOUR would provide a method of control for the activated sludge process exposed to transient loadings. Olsson [11,12] presented systematic approaches to control sludge inventory in order to maintain a given SCOUR setpoint.

The scope of this work is to assess the feasibility of some control schemes applied to the dynamic operation of activated sludge process. The control schemes proposed are based on Olsson's theoretical work [11,12], with more focus on practical aspects.

SYSTEM MODELING

The system model contains linked aerator settler models to depict the actual behavior of the activated sludge process. The hydraulic characteristics of the aeration tank are modeled to represent 3 continuously stirred tank reactors (SCTRs) in series with constant volumes. There are provisions in the model for the influent to be distributed differently to any tank, to allow simulation of step feed process.

The aerator model employed is the one proposed by the IAWPRC Task Group [13].

The settler model has two constituent functions: (1) clarification and (2) thickening. Several settler models have been reported in the literature [14,15,16]. These models are based on the discretization of a first-order partial differential equation derived from solids mass balances for modeling the thickening function of the settler.

Some rely on empirical relationships for modeling the clarification function. The models which are based on the discretization of first-order partial differential equations cannot predict continuous variation of solids concentration with depth [17]. To overcome this problem [14] imposed a limiting flux when the concentration in a layer exceeds a limiting concentration. The others [15,16] introduced a continuous gradient when an unacceptable discontinuity occurs. A parabolic second-order partial differential equation would naturally predict a continuous concentration profile. Inclusion of a Fickian dispersion term in a first-order partial differential equation converts it into a parabolic differential equation [18, 19, 20].

The settler model employed is that developed by Vitasovic [20]. The clarification function of the settler which was based on empirical relationships in Vitasovic's model will be replaced by the modification of Takacs et al. [21] to provide estimates of effluent suspended solids. In the model, the settler is divided into a number of horizontal layers (10 layers) of constant thickness. Each layer is assumed to be uniform in concentration, the mixed liquor is fed at some depth below the surface (assumed to be in the 6th layer), the model is developed by performing solids balance around each layer.

Some biological reactions take place in the settler especially if substrate and oxygen are available. In order to incorporate soluble COD utilization in the settler model it has been assumed that each layer acts as a single continuous stirred tank reactor (CSTR). Each CSTR is modeled according to the IAWPRC task group model [13].

Aerobic and anoxic growth of Heterotrophs results in soluble COD removal, while hydrolysis of particulate COD products soluble COD. The difference is the soluble COD utilized in each layer. Aerobic growth of biomass also depends on the dissolved oxygen concentration, which is assumed to act as a complementary limiting nutrient through adoption of a double Monod expression.

The material balance for soluble substrate, particulate substrate and dissolved oxygen have been included for each horizontal layer in the settler. The model has been written in the simulation language SIMNON [22]. A detailed description of the full model and its verification (against laboratory, pilot plant and full scale data) can be found in [23,24,25,26].

SYSTEM CONTROL

Two control strategies are presented here:

1- *Return Sludge Flow Control*

Due to the dynamic environment, the process is difficult to control. In order to consistently control the process the strategy must compensate for process variations. This can be accomplished by careful design of return sludge flow control, which may be controlled instantaneously in response to influent flow variations by adjusting the recycle pump speed.

Olsson [11] proposed a systematic approach to return sludge control. It is suggested that the recycle should be controlled so as to maintain a given specific oxygen uptake rate setpoint ($SCOUR_{sp}$). This defines a desired solids concentration in the aerator (X_{ad}):

$$X_{ad} = \frac{OUR}{V\,(SCOUR)_{sp}} \qquad (1)$$

where V is the aerator volume and OUR the estimated value of the oxygen uptake rate.

It is proposed that the system should have a computer to be used as a basic work station, equipped with data acquisition system to monitor the plant performance by using certain sensors (flow rate. dissolved oxygen, OUR, suspended solids......). According to the collected data a solids mass balance around the aerator gives calculated recycle flow ratio (r_{cal}).

The steady-state recycle flow ratio under normal flow rate is reference (r_{ref}). It could be calculated by solving the system for steady-state, or can be optimized using PID controller [12]. In this work it is assumed 0.1.

From the practical point of view, the system can be controlled using a recycle pump working in time intervals controlled mainly by the difference between r_{cal} and r_{ref} ± a tolerance value δ_r. δ_r is added to or subtracted from r to allow the pump to work with reasonably on/off times. It has been found that a value within 0.2 of r_{ref} for δ_r gives a satisfactory time constant for the whole system.

The system transfer function is shown in Figure (1). The control circuit objective is to operate the recycle pump automatically whenever r_{cal} exceeds r_{ref} plus δ_r. On the other hand the control circuit aims to stop the recycle pump according to the following rules:

If $(r_{cal} - (r_{ref} + \delta_r)) > 0$ then pump ON

If $(r_{cal} - (r_{ref} + \delta_r)) \leq 0$ then pump OFF

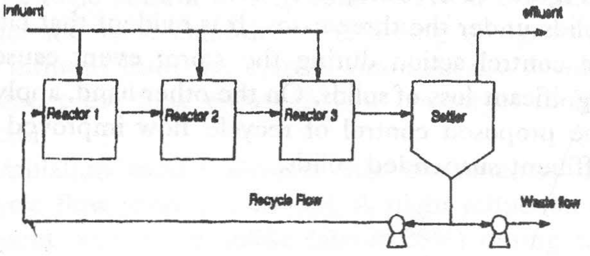

Figure 1. System transfer function.

Figure (2) shows the recycle pump control system, while Figure (3) shows the control circuit components in details. As the change in input flow Q_{in} takes a comparatively long time, counted in hours, so the discontinuous operation of the recycle pump is accepted.

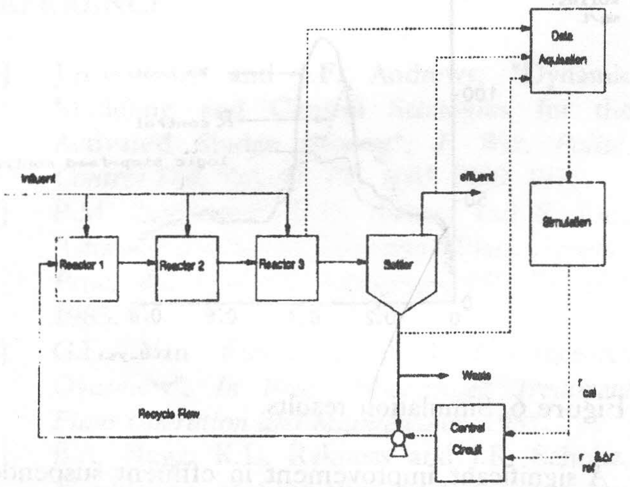

Figure 2. The control system (recycle control).

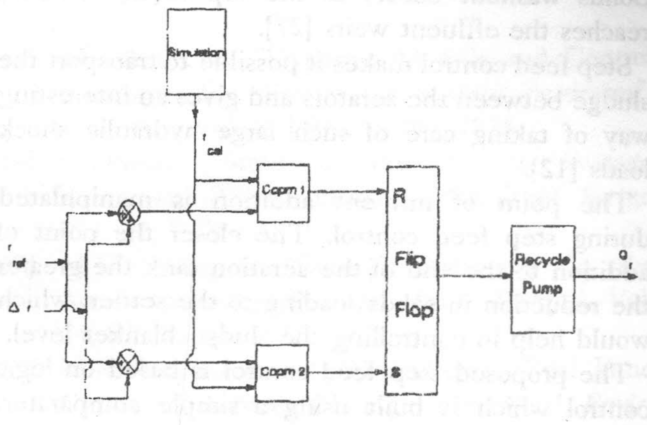

Figure 3. Control circuit components.

Figure (4) shows the operating and stopping periods of the recycle pump.

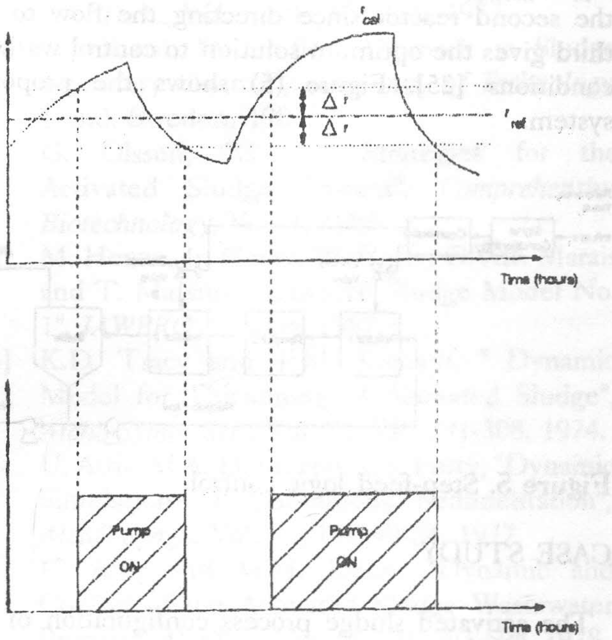

Figure 4. Operating and stooping periods of the recyle pump.

2 - *Step Feed Control*

Because conventional activated sludge plants have limited hydraulic dampening capacity, high flow rates transfer additional solids from the aerator to the final settler and increase the sludge blanket depth.

Solids washout occurs as the top of the blanket reaches the effluent weirs [27].

Step feed control makes it possible to transport the sludge between the aerators and gives an interesting way of taking care of such large hydraulic shock loads [12].

The point of influent addition is manipulated during step feed control. The closer the point of addition to the end of the aeration tank the greater the reduction in solids loading to the settler, which would help in controlling the sludge blanket level.

The proposed step feed control is based on logic control which is built using a simple comparator. The comparator chooses to open either valve 1 (influent flow to first reactor) or valve 3 (influent flow to last reactor) according to the transferred signal of Q_{in} , which has been discussed before.

The system is designed to make valve 1 open when $Q_{in} < Q_{normal}$, while valve 3 open when $Q_{in} > Q_{normal}$, there is no need to direct the flow to the second reactor since directing the flow to the third gives the optimum solution to control washout conditions [25]. Figure (5) shows the proposed system.

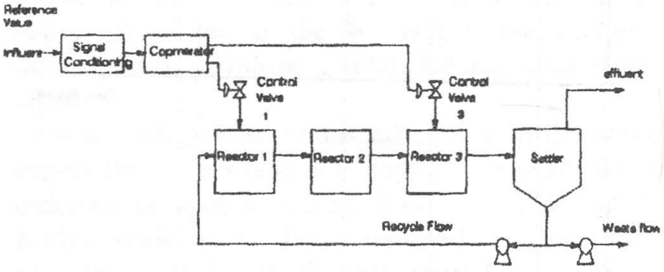

Figure 5. Step-feed logic control.

CASE STUDY

The activated sludge process configuration of the case study is the pilot plant located at the Wastewater Technology Center in Burlington (Ontario, Canada). This pilot plant consists of three 22 m^3 aeration tanks in-series followed by a final settler 2.7 m depth. Settled sewage entering the plant at normal flow rate of 288 m^3/d, and can be fed to any of the three reactors (Figure (1)). The characteristics of the plant are summarized in detail in ref. [28].

The model parameters are the ones adopted [24,25,26]. Computer simulations were carried out to evaluate the proposed control strategies (recycle flow and step feed). Three simulations were performed by subjecting the plant to storm event with change in flow rate from 288 to 590 m^3/d (Figure (6-a)).

First simulation was performed under the storm flow with constant recycle flow rate of 86.5 m^3/d (No control). In the second one the proposed recycle flow control was applied with keeping all other variables constant. The third simulation was to examine the logic control of step feed with constant recycle flow rate of 86.5 m^3/d.

Figure (6-b) compares the effluent suspended solids under the three cases. It is evident that taking no control action during the storm event causes a significant loss of solids. On the other hand, applying the proposed control of recycle flow improved the effluent suspended solids.

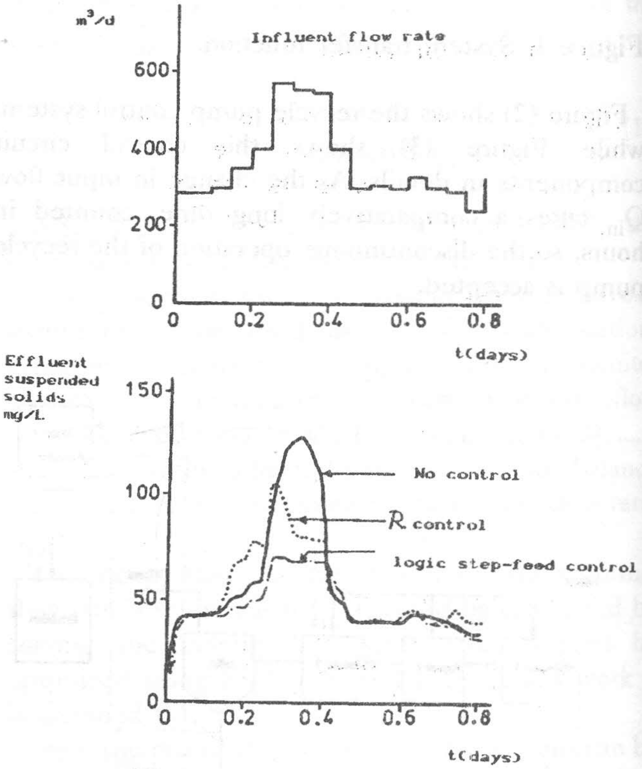

Figure 6. Simulation results.

A significant improvement in effluent suspended solids occurred by applying the logic control of step feed (Figure (6-b)).

CONCLUSIONS

This paper describes two control strategies for the activated sludge process with focusing on the practical aspects.

The first control strategy is proposed to control recycle flow rate by controlling the recycle pump operation according to plant performance.

This control aims to keep the SCOUR at constant value in the aerator. The adopted technique is based on/off control strategy, which has been applied to the recycle pump.

The logic control of step feed was also evaluated under the same conditions. According to signals of the influent flow, the system automatically decides to direct the flow either to first reactor or to last reactor.

Simulation results showed that the potential for recycle flow control is limited. A slight reduction in effluent suspended solids (about 28%) during the storm event was observed.

On the other hand, simulations also showed that the logic control of step feed is more efficient during the same storm event. About 46% reduction in effluent suspended solids occurred, which reflects the capability of step in minimizing the impact of hydraulic shock loading.

Both techniques could be practically executed based on measured and estimated values, which translate the previous theoretical work into reality.

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