A LOW-COST COMPUTER-BASED TRAINING SIMULATOR FOR WASTE WATER TREATMENT PLANT OPERATORS

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Statement of Problem

The increasing numbers of waste water treatment plants coupled with strict environmental legislation enacted over the last decade have resulted in a shortage of well-trained plant operators in this country. Unfortunately, there is an inherent time lag in responding to this need.

Today, operator trainees are required to take specified classes on plant operations/processes, pass a written exam, and have a specified number of years of experience in plant operation to obtain their first operators license. They can then advance to higher levels of operator certification by taking additional course work and gathering additional operations experience. Clearly, these reqirements take time, especially in gaining the field experience. Also the new plants are becoming more sophisticated and complex to meet the higher effluent treatment standards.

A further consideration in training is the fact that waste water plants are based on time-dependent biological processes. This, combined with a large flow requirement, produce a plant with an extended time constant so that a process disturbance caused by change in the influent flow and/or operator action typically takes several days to arrive at a new steady state condition. Also the plant can easily remain in an upset condition if the operator is inexperienced and makes the wrong control decisions. Accordingly, an operator seeking experience must gain it slowly under the tutledge of an advance operator so that plant perturbations are avoided. Such on-the-job training is always slow and costly since it requires one-on-one personal instruction. In addition, on-the-job training can never instruct the operators in the full spectrum of process variations/emergencies which may be encountered since such plant operations can not be risked for the sake of this instruction. A model or simulator on the other hand can be exercised to provide this hands-on training.

Technical Approach

There are a number of wastewater treatment processes and all incorporate some form of biological process. Unfortunately a biological process is difficult to model and it has been traditionally assumed that it cannot be simulated with the degree of validity required by a Training Simulator. It was believed, however, that this problem could be overcome with some creative use of steady state design equations and the iterative processing capabilities of microcomputers.

One of the more common biological approaches used in today's plants is the Activated Sludge Process. It was therefore determined to make it the heart of the Waste Water Treatment Plant Simulator which, if it could be successfully modeled, would then demonstrate the possibililty of the simulator approach.

Generally an Activated Sludge plant consists of three primary subsystem treatments. Primary treatment includes bar rack and screens, prechlorination, aeration, grit removal, and sedimentation basins. The bar racks and screens are used to remove heavy solids and debris such as rags and sticks. Prechlorination and aeration are used to retard putrefaction. Grit removal consists of the abstraction of heavy food particles such as corn and rice added to the influent from garbage disposals. Sedimentation basins are detention facilities that place the influent wastewater in a quiescent state for the removal of settleable organic matter. The removal efficiency of these basins is 50 to 65% for suspended matter and 25 to 40% for BOD. This lessens the organic strength of the wastewater for further treatment. This section was not included in the model since it is a well defined, basic hydraulic process not subject to operator control.

Secondary treatment consisted a typical activated sludge treatment process as shown in Figure 1. The influent, after some initial screening and sedimentation, enters the aeration tank, or tanks. Here the organic substrate mixes with the present tank population of microorganisms. Air is continually injected into the tank to provide the necessary oxygen to the microorganisms to sustain their growth. After a sufficient length of contact time, usually several hours, the suspended solids are returned to the aeration tank to start the process again. A portion of the solids are removed from the settling tank as waste sludge. The nearly organic free water is transferred from the upper part of the settling tank and/or clarifier to a chlorine contact tank for final chemical processing.

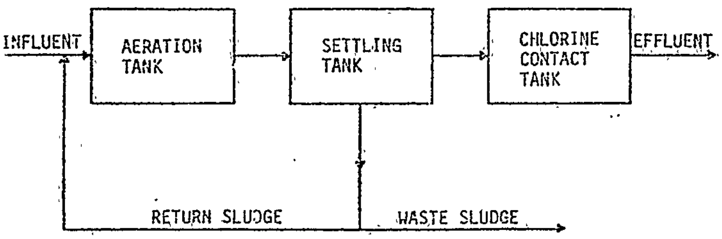

Figure 1

Simple activated sludge treatment process

The chlorine treatment shown in Figure 1 is part of a tertiary treatment used for further removal of suspended matter and other chemicals such as nitrogen and phosphorous. Chlorine is added to ensure a residual which will attack any remaining organisms which may have survived the treatment. This is a chemical process and again is well defined by stoichiometric equations.

The simulation thus reduces to the modeling of the hydraulic and biological processes involved in operation of an activated sludge system. It is also noted, that the intent was not to duplicate these processes but rather to cause the simulator to behave the same as the real system.

Waste Water Treatment Plant Trainer System

The training simulator consists of four major subsystems as shown in Figure 2: Control Board, D/A & A/D Interface, Computer/Software and Memory. Also shown are the input/output interface points for the student and instructor.

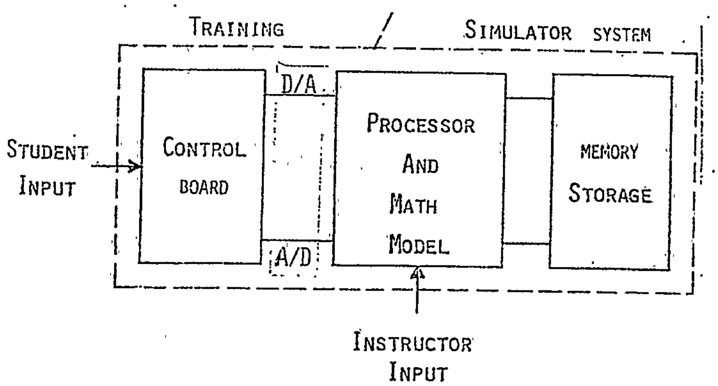

Figure 2

Figure 3 is a photograph of the actual control board and equipment.

The Control Board consists of a rectangular plywood board, 2'x4' faced with a flow diagram which describes the physical components and process piping for the plant being simulated. This gives the trainee a visual picture of the plant and the controls/instrumentation which exist in the field. If enlarged it would be a duplicate of the actual plant control panel. All control valves are shown and adjustment is provided via potentiometer knobs. Live readout meters are mounted in the board to provide indication of the values of the key operating variables. Thus the trainee can quickly grasp the flow process of the plant, be appraised of the operating conditions, and make adjustments to change these conditions if he decides.

Figure 4 is the flow diagram as presented to the trainee with key variables, control values, and meters identified by symbol. The valve controls are linear and the meters are calibrated to read in units commensurate with the variable they represent. The trainee input via valve adjustments is routed to the computer which is programmed to cause this to change the operating conditions of the plant which in turn is displayed on the meters.

The input potentiometers and display meters are mounted on the back of the control board together with a power supply so that this part of the system can be mounted upright on a standard desk. The trainee can then be seated, view the plant operations, calculate his actions, and make his adjustments.

A TECMAR analog to digital (A/D) converter with a capability of single-ended inputs with 12 bit accuracy is used to communicate the signals to the computer. Only 6 of the input ports are presently being used:

Port 1: Sludge Waste Rate (Qw)
Port 2: Sludge Return Rate (Qr)
Port 3: Air Flow (Af)
Port 4: Influent Suspended Solids (Xi)
Port 5: Influent Substrate (So)
Port 6: Influent Flow Rate (Q)

The appropriate input voltages are mapped into the digital end with the smallest voltage corresponding to 111110000000, mid voltage corresponding to 0000000000000000, and the highest voltage corresponding to 0000011111111111. These input values are converted to decimal equivalents by appropriate subroutines.

The TECMAR digital to analog (D/A) converter board is capable of four independent D/A conversions with 12 bit accuracy. Each of these D/A units are accessed through addressing two out of eight possible I/O ports. The highest of the two I/O ports receives a byte in which the lowest four bits are the highest four bits of the 12 bit output. The lower I/O port receives a second byte which contains the lower 8 bits of the 12 bit output. What this means is that by accessing the two I/O ports an output digital number must be mapped into; 1111100000000 corresponding to the smallest output possible,0000000000000000 corresponding to the middle value of the output, and 0000011111111111 corresponding to the maximum output value possible. A subroutine was used to accomplish this task.

The control board was wired so that I/O ports

16 and 17 were used for effluent substrate, S, ports 20 and 21 were designed for the reactor tank suspended solids, X, and 22 and 23 were designated for the oxygen required Oreg. The other I/O ports were not used.

Figure 5 is a schematic wiring diagram of the control board together with the terminal board connections for the A/D and D/A converters.

Two different computers were used during this Research. At the University of Central Florida (UCF) a Radio Shack, TRS-80, Model I, with an expansion interface, 32K memory and dual five inch floppy disk drives as mass storage devices was used. Later, a TRS-80, Model I, 16K, with a cassette recorder was used for the majority of the programming. On both computers the only language used was Level II Basic.

The TRS-80 at UCF has an external S-100 bus interface adaptor for communication to the analog to digital (A/D) and digital to analog (D/A) converter boards which provide communication to the simulator control board.

Operational Description of Training Simulator

To operate the training simulator, the instructor selects a plant operation program keyed to the operator trainee's background and experience. This is read from cassette tape of diskette into computer memory. The display/control board controls are set, the unit powered and the computer instructed to assume control.

Steady state plant operating conditions would then be displayed on the control board.

At this time the instructor should brief the trainee on how the simulator works, how he must respond, and review with him the characteristics of the particular plant being simulated. Additionally, some time should be allowed for the trainee to study the plant parameters and view the steady state performance.

When the trainee is ready, the instructor selectively changes one or more of the input variables to the plant such as BOD and/or flow to a new value. This value is known to upset the plant as configured and cause the effluent parameters to exceed prescribed limits. The trainee is then invited to adjust the plant operations to bring the plant back under control by resetting valves controlling airflow, sludge waste/return etc.

The simulator will immediately begin to respond to the new settings the trainee has dialed on the control board. It is also programmed to compress the time base of the plant process so that each manually controlled update corresponds to 1 hour of actual plant operation. In this manner the trainee can follow the plant performance at his pace as it responds to his input and thus learn more about the plant and its characteristics. This output can also be recorded such that the various system parameters can be plotted over a time base which can then be reviewed in discussions with the instructor.

A more sophisticated training scenario would typically incorporate intermediate or predetermined time events other than the initial perturbation. These may include various equipment malfunctions as well as changes in the input variables. For example, what adjustments should be made if the plant suddenly loses 50% of its air flow capacity?

Conclusions/Observations

The use thus far has demonstrated that the computer-driven waste water treatment plant training simulator works and should be a very useful tool in training new operators and/or maintaining skills of an experienced operator. The computer program permits a full transient of plant operation, steady state to steady state, to be simulated in a matter of minutes, if desired. Also the simulator training is more effective and less costly than on-the-job type.

The research in this project has demonstrated that the biological process as well as the more defined hydraulic and channel flow processes used in a waste water plant can be effectively simulated. While the computer program does not reproduce the actual treatment processes, it does react to system perturbations in a manner similar to those experienced in a real system.

On this basis it is observed that computer technology utilizing a modular software structure could be used to reconfigure the waste water process model to describe any given plant facility that used these processes. This would require a generalized control board model which could be reconfigured to describe the given plant and the software to simulate the resulting treatment processes. This would improve the cost effectiveness of the basic trainer. It also could expand its usefulness into the basic area of design where "what if" conditions and failure/reliability modes of operation could be analyzed.

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