DESIGNING AN ENVIRONMENTAL SYSTEM ANALYSIS LABORATORY FOR RESEARCH IN WATER QUALITY

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REFERENCE: Proceedings of the 1995 Georgia Water Resources Conference, held April 11 and 12, 1995, at the University of Georgia, Kathryn J. Hatcher, Editor, Vinson Institute of Government, The University of Georgia, Athens, Georgia.

Abstract. Research efforts in wastewater treatment plants are becoming less difficult because more automated on-line instrumentation for water quality research has become available. Instrumentation for water quality research may now be found by calling instrumentation, process control, and automation suppliers. Engineers then can integrate instruments from various manufacturers into a system which meets the monitoring needs of the research experiment. Recent advances in instrument technology, coupled with custom system integration have met the needs of contemporary WWTP research.

INTRODUCTION

Research of wastewater treatment plants' (WWTPs) processes requires instrumentation, laboratory equipment, and data collection devices to perform specific experiments. Quick, accurate, and reliable data collection requires continuous on-line monitoring instrumentation. This laboratory is to comprise an *integrated* package of instrumentation, sampling, equipment, and chemical analysis support to meet design specifications of (a) high mobility, (b) high reliability, and (c) minimal operating costs for on-site installation and off-site maintenance, and (d) will be devoted to tasks of research (as opposed to routine monitoring). In this program this means seeking out the appropriate instruments for the variables being monitored and designing the continuous on-line monitoring system for the specific research experiment.

Research into the process activities of an activated sludge bioreactor are limited by and depend on the ability to exercise control over the behavior of the system. One of the major factors is the capacity to observe how causes are related to effects. "In 1984, actual capacity to observe behavior in the activated sludge process on-line was limited essentially to the DO concentration in aerated bioreactors; otherwise observations were obtained through manual sampling on a routine basis at a relatively slow sampling frequency. The prospect then was of significant innovations in sensor technology. By 1994, some of this potential has been realized: substrates and products (ammonium-N, nitrate-N, phosphorus) is possible in actual practice" (Beck, 1994).

The Principal Investigator (PI) objectives are to: 1) increase his knowledge of the process through observation (monitoring the process), 2) create a simulation tool (computer model) for developing a knowledge base of how causes are related to effects, 3) explore the testing of automated control strategies and plant re-design options, and 4) create a basis for an interactive operator decision-support system and operator training. The need for quick, accurate, and reliable data collection with a minimum of laboratory service costs, makes automatic on-line instrumentation the equipment of choice for the researcher.

The Planned Wastewater Treatment Plant Research

The primary source of the research data will be through the monitoring of operating municipal WWTPs. The site monitoring will comprise intensive sampling campaigns lasting, for example, some five to ten days. However, longer and shorter-duration campaigns may also be necessary. These too will be intensive, but geared to monitoring process performance with differing time constants (response times).

The municipal plants used as sites for the research are, for the present, WWTPs which have a minimum size of 25 MGD and are within a two hour drive from Athens. The list of sites was developed from the "Major Municipal NPDES Facilities Inventory" obtained from the Municipal Permitting Office of the Georgia Environmental Protection Department. There are 121 municipal NPDES in the Georgia EPD inventory of June 15, 1993.

Of the eight plants having permitted effluent discharge of over 25 MGD, the six largest are located in the Atlanta Region. (Stevens 1993, Table 5). All the WWTPs in the cities of Atlanta, Athens, and Augusta have agreed to participate in the research activities.

Monitoring will initially be designed in a "dual-purpose" manner, i.e., using both automated on-line instruments and "classical" grab sampling with subsequent (wet chemical) analysis. The wet chemical analysis is intended to confirm sensor accuracy (comparing on-line instrument results with wet chemical analysis) and provide access to variables of water quality not currently amenable to automated on-line instruments.

Related Research

Previous research which showed greater use of on-line instrumentation was done at the Malmo Sewage Works in southern Sweden. The collaborative work with the Lund Institute of Technology required very special arrangements to monitor the wastewater treatment plant. A similar type of research program at a large WWTP would, it is expected, require specific collaboration with the WWTP staff and produce equally good results.

The work at Malmo will be emulated, where appropriate, hence the PI plans to use three categories of instrumentation: (i) on-line sensors; (ii) on-line data-logging facilities; and (iii) automatic samplers.

With respect to the first of these, the PI has culled from presentations at the recent IAWQ (Hamilton; 1993) Workshop on "Instrumentation, Control, and Automation," the following: "Vassos (1993) indicated that the following sensor/variables: Cl_2 residual, SS, DO, Flow, NH_4-N, $N0_3$-N, OUR (respirom), ORP and NADH all showed great promise for being measured with on-line instruments." "Briggs and Grattan (1992) states that (for a similar list of variables, but including "organic matter" and TOC as well): Instruments and support systems which measure, with varying degrees of precision and reliability, a substantial number of the variables listed above, are already installed and in many cases have been in operation for several years."

THE PROTYPE EXPERIMENT

The PI has determined that monitoring the biological nutrient removal (BNR) system in the activated sludge bioreactor of the WWTP will be the focus of the primary experiment. In order to determine the availability of automatic on-line instrumentation, all potential suppliers were sent the chart showing the generic system (Figure 1). The instrument requirements for monitoring the process variables is shown for point C only.

Research Experiment Objective

- To observe the Biological Nutrient Removal (BNR) dynamics, including settling/compaction behavior of biological flocs and bio-mass — substrate interactions in the secondary settler and recycle line.
- To develop a dynamic model of BNR behavior and further understand that behavior.
- To use the model in simulations of possible design modifications and to evaluate the responses to "What if?" queries; and to improve the energy efficiency, reliability, decision making abilities, and operational characteristics of the plant.

The Data Collection Criteria for this Prototype Experiment

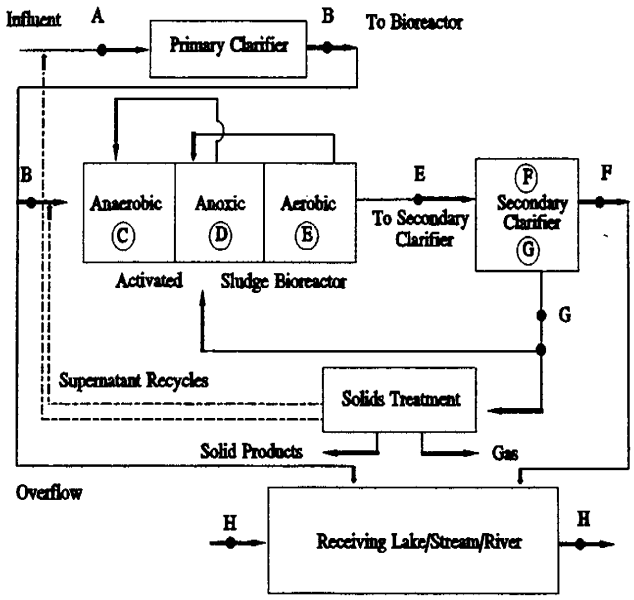
(1) Experiment duration: 10 days; (2) Sampling frequency of instruments: as continuous as possible; and (3) On-line computer monitoring and signal transmission: continuous.

Variables to be Measured are Shown in Figure 1

Based on the data collection, on-line monitoring and signal transmission criteria, the following equipment characteristics are most important: reliability, repeatability, accuracy, tolerance/sensitivity, and maintainability.

THE INSTRUMENT SUPPLIERS

The nine instrument suppliers, of the over 28 suppliers originally contacted, who responded to our initial information requests for their products and showed interest in the program were given a complete specification for the work. They were



Anaerobic Zone of Activated Sludge Bioreactor
Point C

	Milligrams per liter (mg/l)
Suspended Solids (SS):	1,500-10,000
Volatile Suspended Solids (VSS):	1,200-8,000
Total Chemical Oxygen Demand (COD_T):	1,500-12,000
Soluble Chemical Oxygen Demand (COD_S):	0-500
Ammonium - N (NH_4-N):	5-75
Nitrate - N (NO_3-N):	0-40(50), 0-5 (good capability → 0.0)
Total Phosphorus (TP):	
Orthophosphorus - P (PO_4-P):	0.0-5.0
Dissolved Oxygen (DO):	= 0
pH:	

Figure 1. The generic system (showing process relationships and monitoring points).

supplied a seven page document describing the prototype experiment, with the generic system (Figure 1), and monitoring points A-H with the process characteristics and range of measurement required at each point.

Of these nine, only three at the present time are proposing a concept using their system and/or integrating their and others' equipment to do all the on-line monitoring that was specified. Some advances in instrument technology which provides these instruments with continuous on-line monitoring capability are: (1) Ultra filters provide continuous flow of ultrafiltered process liquid to on-line measuring instruments; (2) Filters which prevent fouling of the sensors by use of an automatic cleaner and filter backwash; (3) The use of ion-selective techniques to measure the variable; and (4) Using sensors with proprietary optical devices with electronic compensation for component variations and fouling of the sensor.

Table 1 below shows the distribution of the suppliers who are proposing equipment for evaluation based on their stated competencies.

Table 1. Supplying Companies

Variables Measured	Company A	B	C	D	E	F	G	H*	I
Suspended Solids (SS):		x	x	x	x	x		x	
Volatile Suspended Solids (VSS:)				x				x	
Total Chemical Oxygen Demand (COD_T):				x				x	x
Soluble Chemical Oxygen Demand (COD_S):				x				x	
Ammonium - N (NH_4-N):		x		x		x	x	x	x
Nitrate - N (NO_3-N):		x		x		x	x	x	x
Total Phosphorus (TP):		x		x				x	x
Orthophosphate - P (PO_4-P):		x		x				x	x
Dissolved Oxygen (DO):	x	x	x	x	x	x	x	x	x
pH:	x	x	x	x	x	x	x	x	x

*This is a supplier of all laboratory backup equipment

LABORATORY FACILITIES

While monitoring will be by automated on-line instruments where possible, it will also be designed in a "dual-purpose" manner, i.e., using both automated instruments and contemporary sampling techniques with subsequent wet chemical laboratory analysis. The wet chemical analysis is intended to confirm sensor accuracy (comparing on-line instrument results with wet chemical analysis) and to provide additional information on variables of water quality not capable of being monitored with currently available on-line instruments. The laboratory will be a complete backup for all tests being planned in this research program. When sample collection is used, analysis will no doubt be performed in an automated, water chemistry analyzer. All the wet chemical laboratory analysis equipment has been available and successfully used for years.

Because of the effort not to duplicate facilities available at the University of Georgia and the unique use of the equipment (i.e., for example, two intensive 10-day surveys per annum), the PI is planning to share the laboratory with other interested faculty.

CONCLUSIONS

An integrated, continuous, on-line analysis and monitoring system will be used for these research experiments. Various suppliers' equipment will be integrated into a customized monitoring system designed by the organization's engineering and technical staff or by a consulting engineering firm.

In the past it was found that "The factors which limit the ability to meet performance objectives are directly related to limitations in existing instrumentation, control, and automation (ICA) capabilities. The need to optimize plant performance and meet increasingly stringent effluent standards are two key factors which will influence the development of ICA technologies in the future." (VASSOS 1993). The major problem in continuous on-line analysis in wastewater samples is that high solids and particulate matter prevent proper operation. This concern was handled by operating, maintenance, and instrumentation personnel at a high cost.

However, the Nyberg, et al. (1993) experiments at the Klagshamn WWTP used on-line equipment which proved successful. The equipment was European. Researching domestic manufacturers has uncovered suppliers who claim similar performance from their equipment. These instruments can provide continuous sampling, on-line computer monitoring, and signal transmission. These are microprocessor-based instruments which are reliable, accurate, and with low maintenance.

These instruments, using the latest technology enhancements, can monitor most of the variables in the prototype experiment.

For this experiment there will be an integrated system using instruments to monitor dissolved oxygen, pH, ammonium, nitrate, phosphorus, orthophosphate, suspended solids and sludge blanket depth. A sampling method with automated wet chemistry analysis will be used for volatile suspended solids and total and soluble chemical oxygen demand, to meet the PI's total needs. The integration of different manufacturers' equipment into a complete monitoring system for this and other research experiments will require a custom integrated system design.

There also needs to be a complete strategy related to the use of this laboratory. Project management techniques will have to be developed supporting each protype research case that the PI proposes to implement. These projects (research cases) will include all tasks: (1) Engineering/technical staffing — planning, project management, staff training and required equipment procurement, receipt, evaluation and system integration; (2) Laboratory staffing — preparing sampling equipment, analysis and data management; and (3) Field staffing — onsite mechanical installation, operational support, decommissioning and return of equipment to laboratory.

RECOMMENDATIONS

Engineers involved in research of complex processes such as wastewater treatment plants (WWTPs) must recognize that the preponderance of equipment available in the market today may be adequate for operational, process control, and plant automation, but not for research projects. In a research program this means finding the appropriate instruments for the variables being monitored and designing the continuous on-line monitoring system for the specific research experiment. The designing of an integrated continuous on-line monitoring system may require the services of a consulting firm specializing in WWTP engineering.

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