'Invest to Save' Opportunities at Smaller WwTWs

WATER WASTEWATER

John Moroney, HACH LANGE LTD Pacific Way, Salford, Machester M50 1DL
Tel: +44 (0) 161 872 1487 Fax: +44 (0) 161 848 7324 Email: info@hach-lange.co.uk

This article will address the major cost saving opportunities that now exist at smaller wastewater treatment works as a result of increased energy costs and reduced instrumentation costs (capital and maintenance).

Small WwTWs

Small and medium sized wastewater treatment plants have to handle greater fluctuations in influent concentrations and hydraulic loading than their larger counterparts (e.g. distinctive diurnal variations, storm surges, illegal agricultural discharges etc.). Furthermore, small plants have to function with ever fewer personnel, and as a result the case for instrumentation coupled with modern data transfer technology and, possibly, automation technology becomes even stronger. However, process measurement instruments for nutrient parameters are rarely employed in smaller plants (5000–20,000 pe or 'population equivalent'). In general, the only instruments used are oxygen sensors for aeration control or probes for recording outflow turbidity as a measure of plant efficiency.

So, despite the fact that smaller plants have, in some ways, a greater need for instrumentation and control, in the past it has not been provided for sound financial reasons. However, this article will demonstrate that the financial situation at these plants has changed dramatically in recent years.

Ammonium and Orthophosphate Monitoring

Traditionally, wastewater is monitored following the withdrawal and filtration of a representative sample, and the subsequent exposure of that sample to a series of sensors and analysers. These analysers have had to be housed in an analysis station, a container, or even a building, and as a result their cost has been high. Development activity has focused on improved sensor technology and more reliable sampling and filtration methods and in-tank process analysers for NH4-N and PO4-P (Figure 1a) have been available for a number of years. In addition, tank-side analysers (Figure 1 b) are becoming established as a cost-efficient alternative.

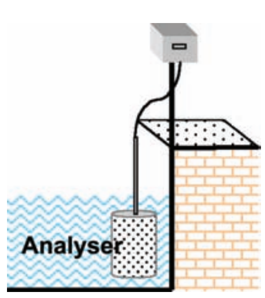

Figure 1a: In-tank process analyser

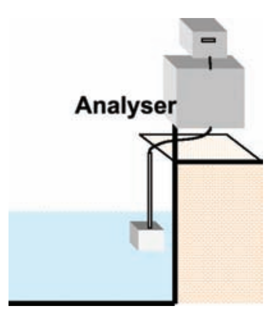

Figure 1b: Tank-side process analyser

These new analysers offer greater flexibility in the choice of monitoring locations, which is especially important for the optimisation of wastewater treatment plants. Another advantage is that, thanks to short distances between sampling and analysis, errors associated with longer transportation paths are eliminated.

Integrated Sample Preparation

In the early 1990s a breakthrough was made in the continuous measurement of nutrient parameters when it became possible to obtain a particle-free sample stream from active sludge by means of ultrafiltration. This type of sample preparation, which involves high operating and investment costs, was standard in wastewater treatment plants until the late 1990s.The investment costs included about £3,450 for a semi-automatic ultrafiltration system, a further £1,000 for a submersible motor-driven pump, and operating and energy costs of about £1,000/year. In the late 1990s this type of sample preparation was superseded by special membrane filtration systems designed for use with analytical instruments. Ion filters and membranes are now widely integrated in the analysers used with in-tank and tank-side measuring instruments, so that response times have been considerably shortened.

Miniaturised Analysis Systems

The advent of micromechanics for the exact dosage and mixing of liquid streams in process analysers has drastically reduced reagent consumption. At the same time, peristaltic pumps have been replaced by wear-free dispensing systems, thereby reducing frequency of maintenance.

As an example of this cost trend, Table 1 shows the progress of the operating and investment of NH4-N and PO4-P measurement (AMTAX/PHOSPHAX series, HACH-LANGE) purchased in 1995, 2000 and 2005. The investment costs of orthophosphate and NH4-N measurement have gone down by up to 41% and 45% respectively (Table 1). Moreover, operating costs have also been significantly reduced (PO4-P: 50%, NH4-N: 44%) (Table 1).

Ion-Selective Electrodes for Measuring NH4-N

Ion-selective electrodes for measuring NH4-N appear to be an especially attractive alternative to process analysers, not least because the initial investment is significantly lower. However, the operating costs vary considerably, depending on the wastewater profile (the membrane and sensor may need to be changed more frequently) and, under unfavourable circumstances, may exceed those of an analyser. The variable wastewater matrices that smaller wastewater treatment plants often have to deal with necessitate relatively frequent manual calibration and adaptation to interference ions.

Table 1: Price development of process analysers, as illustrated by the HACH LANGE PHOSPHAX and AMTAX series (1995, 2000 and 2005)

Years	**1995**	**2000**	**2005**	**1995**	**2000**	**2005**
Cost for measurement and control technology	PHOSPHAX	PHOSPHAX compact	PHOSPHAX sc *	AMTAX inter	AMTAX compact	AMTAX sc *
Analyser (£)	9,300	7,000	8,900	10,600	7,000	8,900
Housing (container)	3,450	3,450		3,450	3,450	
Ultrafiltration	3,450			3,450		
Pump	1,000			1,000		
Filtration		3,250	1,800		3,250	1,800
Sample Preparation	4,450	3,250	1,800	4,450	3,250	1,800
Controller	1,000	1,000		1,000	1,000	
Total investment costs	18,200	14,700	10,700	19,500	14,700	10,700
Investment costs relative to 1993	100%	81%	59%	100%	75%	55%
Depreciation (linear) Years	8	8	8	8	8	8
Depreciation/year £/year	2,275	1,838	1,338	2,438	1,838	1,338
Running costs						
Ultrafiltration (Energy / Modules)	1,000			1,000		
Sample preparation (service contract) £/Year		310	310		310	310
Sample preparation spare parts £/Year		200			200	
Analyser (Service contract) £/Year	670	340	340	680	340	340
Annual requirement (10 min. meas. Int.) £/Year	960	470	470	1,300	870	1,000
Total	2,630	1,320	1,120	2,980	1,720	1,650
Personnel requirement Hrs/Wk	2.0	1.5	0.8	2.0	1.5	0.8
Personnel costs/hr £/h	28	35	42	28	35	42
Personnel costs per year £/Year	2,912	2,730	1,638	2,912	2,730	1,638
Operating costs £/Year	5,542	4,050	2,758	5,892	4,450	3,288
Operating costs for 8 years	44,336	32,400	22,064	47,136	35,600	26,304
Operating costs for 8 years relative to 1993	100%	73%	50%	100%	76%	56%
Total costs £/Year	7,817	5,888	4,096	8,330	6,288	4,626

* Further cost reduction if one transducer is used for several sc analysers

Intelligent (smart) Sensors

Following the advent of digital signal processing, traditional measuring instruments have given way to digital sensors, often referred to as smart sensors. Smart sensors transmit a digital signal consisting of numerical value in addition to status signals. As a result, different sensors can be connected to a single, multi-channel controller thereby providing significant cost savings.

Network Capability

The network capability of modern controllers enables distributed measurement points to be cost-effectively linked to each other to form a network. Figure 2 shows the basic structure of such a network. Each measurement point is equipped with a probe module, which is linked to the measurement point's sensors. All probe modules are connected together on a bus cable and the whole network is operated via a display screen connected to any one of the probe modules.

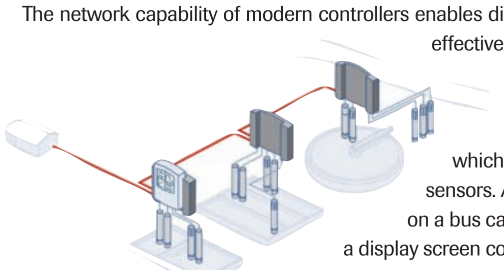

Figure 2: Network capability of modern controllers

Remote Communications

The Ethernet capability of modern controllers means that, if a WLAN is installed at a plant, all sensor and status signals of the network can be called up at any time from any part of the plant from a conventional mobile device or a pocket PC. With the help of GSM modules, measurement and status signals can be transmitted over long distances, all connected sensors can be remotely configured, and new software can be uploaded from a distance. Results can be sent by SMS or email.

Open Systems/Automation Modules

Traditional transducers have 0/4–20 mA current output cards for measurement signal transmission and relays that transmit high-value or low-value alerts and error messages. New-generation controllers also enable analogue and/or digital measurement and status signals to be accommodated. These can be mathematically linked with the measured values of the connected sensors to generate more signals or controlled variables (in much the same way as in a programmable controller, but more conveniently and without any programming knowledge). For example, a controller can register flow signals and quality measurements and use them to calculate the loading; if necessary, it can then trigger actuators via digital or analogue outputs. PID controllers designed specially for wastewater treatment processes are of particular importance for small plants. For example, it is now possible to manage a control program for intermittent denitrification, based on an oxygen sensor and a NO3-N probe, conveniently and cost-efficiently on a controller.

Aeration

Energy costs can account for up to 65% of total plant costs and it has been estimated that a reduction in DO from the usually encountered 2 mg/l to 1 mg/l during times of low loading would achieve savings of 15%. In addition, numerous studies carried out in the 1990s, showed that energy savings of 10-20% could be achieved with a control system that regulates the oxygen input on the basis of NH4-N. If an oxygen demand of approximately 70 g/pe/day is assumed and the efficiency of the aeration system is 1.5 kgO2/kWh, the annual energy requirement is 17 kWh/pe and the annual potential saving is approx. 2.5 kWh/pe or 17p/pe/year at 6.7p/kWh. This compares with the ammonium measurement costs shown in Table 1 of about £3,000/year (this takes no account of possible additional personnel costs). Therefore, a NH4-N analyser would today be economically worthwhile (in terms of energy savings alone) for a plant with a capacity of about 17,650 pe.

The predicted annual costs of a NH4-N analyser in 2010 are £2,200/year, at which point the analyser would be justifiable from 13,000 pe. Given that energy prices can be expected to rise considerably anyway, the threshold may very well fall below 10,000 pe before 2010.

The use of ion-selective sensors reduces the annual costs of the analysis to about £1,400/year. However, the use of these sensors in a control circuit with ammonium as the primary controlled variable and oxygen as the secondary controlled variable is not advisable in view of the high level of measurement uncertainty.

Phosphate Removal

The costs of chemicals and sludge disposal are the key factors in a cost-benefit calculation.
At Burnley WwTW a sophisticated monitoring and dosing scheme has been developed in order to achieve the required levels of phosphate reduction. This includes an influent Ortho Phosphate measurement to inform a chemical dosing control system. The complete monitoring and dosing control system including tanks, pipework, lines, instrumentation, bunds, hard landscaping etc cost around £1.5m.

In excess of 3000 tonnes of ferric sulphate is used in one year in addition to almost 1000 tonnes of caustic soda. Without the monitoring system, dosing levels would have to be either fixed rate or regulated by an influent flow measurement and United Utilities estimates that, when compared with a fixed dose rate system, the monitoring/dosing system is saving approximately 37% of the ferric sulphate and 57% of the caustic chemical costs.

The Future

Political, economic and environmental developments will further advance the cause for online measuring instruments in wastewater treatment plants.

In recent decades, numerous laws, directives and regulations have been enacted to protect water and the environment by replacing an emissions-based regime with an impact-oriented approach. This will increase demands on the efficiency of wastewater treatment plants, because such plants often discharge into waters with poor biodegradation characteristics.

Integrated Measurement and Control Strategies

If wastewater treatment infrastructure is to be used more efficiently, measurement and control strategies will be needed that go further than the optimisation of local plant components and are designed to optimise the whole plant or the entire system.
In Germany, for example, the Messel Sewage Treatment Plant Project shows that such measurement and control strategies can improve the economic and environmental efficiency of wastewater treatment facilities to such an extent that the use of extensive measurement technology can be economically justified for plants designed for 5000 pe.

Satellite Plants

As a result of the economic pressures on plant operators and the rapid progress in telecommunications and automation, the visits of qualified personnel to small WwTWs will be infrequent. The plants will be connected to a central system via communications technology and routine visits will be replaced by event-oriented visits (e.g. when malfunctions occur).

Conclusions

In recent years, technological advances have boosted the efficiency of analysers for measuring ammonium and orthophosphate and investment costs for NH4-N and PO4-P analysers have fallen by about 50% and operating costs have fallen by a similar amount. If the increasing costs of energy and sludge disposal are taken into account, the use of the analysers would be economically worthwhile in a much larger proportion of small and medium sized wastewater treatment plants.

Remote data transmission and telediagnosis also open up new possibilities. In future, they can be used to develop completely new service arrangements, which will reduce the personnel costs of supervising and maintaining the instruments to a minimum. These possibilities will become increasingly important for small and medium sized plants as the number of qualified on-site personnel is reduced.

The use of online measurement technology in wastewater treatment plants can be expected to gain in importance and in view of the fact that about 45,000 of the 51,000 wastewater treatment plants in Western Europe are designed for less than 15,000 pe (and 15,000 of them for 2000 to 15,000 pe), the only potential hindrance to exploitation of the cost savings outlined above will be the readiness of Water Companies to invest in the equipment that makes it possible.