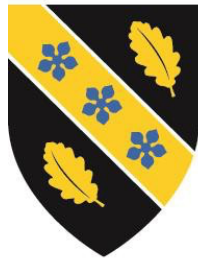


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Application of Automation in Wastewater Treatment

ACMA5001 – Control & Automation

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Executive Summary

This report will study the application of automation in wastewater treatment plant. This will involve scrutinizing the specific duties and roles that sensors, process controllers, and actuators play in the optimising of process conditions at wastewater treatment plants.

The report will analyse the relationship between sensors, control programs, and actuators in a closed loop system. This will detail the specific types of sensors and variables measured across the plant in a fully autonomous working environment.

The nature and impact of the management of wastewater on the environment will also be analysed, exploring regulations and standards that must be met to ensure operator and public safety.

The report will finally investigate further development and implementation of new technology. Continuous improvement is vital to provide the most effective methods of wastewater treatment throughout the industry.

Introduction

The treatment of wastewater is a crucial process for modern day living, ensuring that wastewater produced both industrially and domestically is treated sufficiently before entering any natural water way in the country. Its treatment ensures the safety and sustainability of public health, natural water sources, and the ecosystems that live in those natural water ways.

The treatment of the wastewater, whilst necessary, is often a far more difficult and demanding task than imagined. Wastewater treatment plants must have the technology and set up to ensure that processing of the wastewater is done continuously, and the standard of the treatment remains as effective throughout time. The parameters ensure effective processes that all suspended solids, organic matter, and harmful organisms are all removed.

To support the demand that is put on these key services, ensuring that a sustainable system is available is vital. The use of Instrumentation, Control and Automation (ICA) is fundamental to the operation of a modern-day facility. Its use ensures that plant activity is constantly monitored with a plethora of sensors and gauges to ensure that input variables are recorded and then analysed to provide the necessary output actions from actuators across the site.

As technology develops in the field of automation, further analysis is required to understand the benefits and limitations of ICA and control automation to provide more effective and efficient methods of wastewater management.

Wastewater Treatment Process Overview

The entire process involves a high-level sequence of processes, consisting of preliminary , primary, secondary and tertiary procedures. The stages aid in providing a fully functioning and effective system.

Prior to specific and targeted treatment of wastewater, the removal of large debris acts as the preliminary stage of the treatment process. This includes the removal of plastics, grit, and other large contaminants. Grit chambers and screening systems act as the main equipment in aiding this process. The aim of the preliminary system is to ensure reduced damage to equipment in the further stages of the process. (*Revollar et al., 2020*).

Settling tanks are the next equipment used for the Primary treatment. This involves the sedimentation of solids from wastewater. Heavier particles will separate from the wastewater and sink to the bottom, to form sludge at the bottom of the settling tanks. The water that remains above the sludge is then removed. (*Sundstrom and Klei, 1979*).

The secondary treatment process adopts the use of biological agents to break down dissolved organic matter. Whilst several methods can be used for this process, by far the most common is the activated sludge process. This is the use of microorganisms to metabolise organic pollutants. This is done with the use of aeration tanks, where the constant monitoring of dissolved oxygen levels is required to ensure that microbial activity is effective. (*Revollar et al., 2020*).

The final treatment process relies on purification of wastewater with the use of filtration systems, nutrient removal and disinfection. This final process is heavily scrutinised to ensure that the wastewater that is discharged meets the required environmental discharge safety standards.

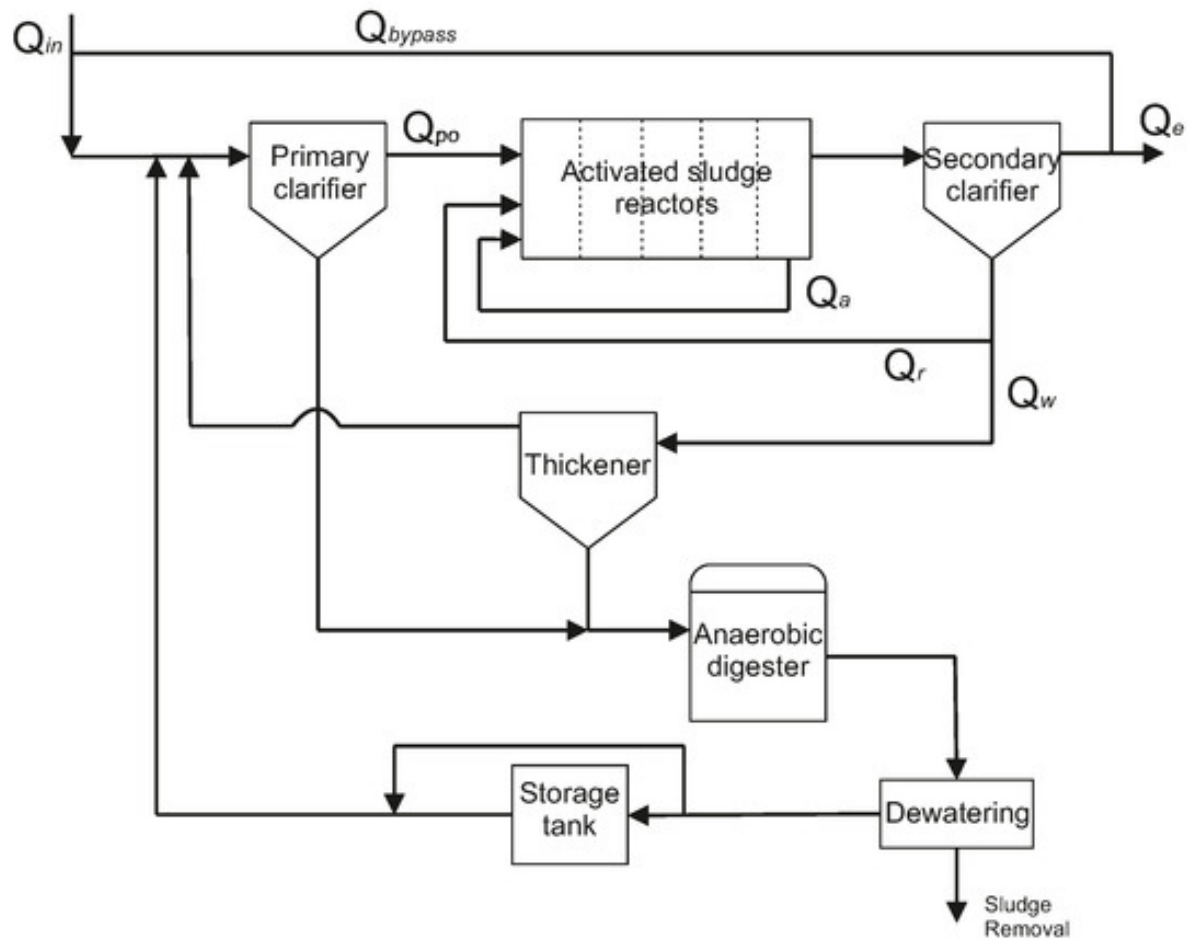


Figure 1 - Basic Process Diagram of Wastewater Treatment. <https://www.mdpi.com/2071-1050/12/3/768>

Instrumentation and Sensors

The implementation and continuous use of instrumentation and sensors in wastewater treatment is vital in providing an efficient and effective service. Physical and Chemical properties of the wastewater at several different stages can act as key data for interpreting into control actions.

A key property to measure is the flow volume of the wastewater in and out of the treatment plant, the exact role of a flow meter. The rate of wastewater flow can be measured using electromagnetic flow meters, which are especially useful in wastewater processes to avoid clogging in the system. Conductive fluids make this type of flow meter the most applicable.

The secondary process involving aeration requires the use of dissolved oxygen sensors. These are vital for controlling aeration systems by maintain the most effective levels of oxygen to ensure that the breakdown of organic pollutants is efficiently completed. The ability to manage the oxygen levels with automated control drastically reduced energy consumption in this process. (*Institution Of Electrical Engineers, Group and Institution of Electrical Engineers. Computing & Control Division, 1991*).

During biological treatment procedures, the acidity or alkalinity of the wastewater acts as a key variable and ensures sufficient treatment of the water. pH sensors are used for this, ensures that the treated wastewater is at the correct pH for the processes to work effectively, whilst also in ensuring that when the post treated wastewater is removed, that the pH is not damaging to the environment of which it enters.

Further sensors are required around the facility to ensure that data driven variables can be used for automated changes and adjustments. This includes turbidity sensors, used to measure the clarity of treated water following the treatment stages. Level gauges are key to ensure that the facilities tanks and other equipment is within the failure limits, to avoid damage to site equipment or leakage from the treatment plant. (*Webster and Eren, 2014*).

The standard and quality of the instrumentation is directly adjacent to the overall effectiveness of the treatment processes. Effective automation allows for accurate processors with limited opportunity for human factor to present an issue to the procedures. Effective sensors are those that are regularly maintained, calibrated, and replaced to provide the most accurate readings and measurements possible.

Control Systems and Controllers

The implementation of control systems in wastewater treatment plants have provided the ability to analyse sensor data throughout all of the processes to then adjust process operations. This then maintains the desired conditions for ideal treatment. Programmable Logic Controllers (PLCs) are the most common way on automating process controls in wastewater plants.

The principle of how the PLCs work it simple; there is an input, a control algorithm, and an output. The input signal is delivered from the sensors around the treatment facility, from the likes of level gauges, turbidity sensors, to provide data to the PLC. The reading is compared and read in line with the algorithm set, where the PLC will then generate an output signal. The signal is used to control actuators such as valves, aeration systems, and pumps around the site. (*Lewis and Institution of Electrical Engineers, 1998*).

Proportional-integral-derivative (PID) control is one of the most commonly used control strategies in wastewater treatment. A set point is established for a particular process variable, such as temperature, where the sensor and PID work simultaneously to read and adjust the output variable to bring it back to the desired set point.

Whilst PID control is adopted for single or specific process controls, the use of Supervisory Control and Data Acquisition (SCADA) systems provides entire treatment plant control. This centralised from of monitoring and control ensures that site operators are able to visualise plant performance through digital interfaces and remotely adjust operating output. The continuous monitoring of plant-wide activity ensures that readings and data is current and effective in providing information to make process decisions. It is also crucial to identify discrepancies in plant performance and efficiency. This is especially crucial in identifying broken equipment, inaccurate gauges, or potential safety issues that would not be identified through physical inspection. The long-term benefits of having this system in place include succession planning for replacement of sensors and equipment, along with long term performance analysis. (*Lewis and Institution of Electrical Engineers, 1998*).

Actuators and Process Equipment

The process input and sensor use is ultimately communicated with actuators and equipment to physically implement the desired process conditions. The conditions determined with the use of gauges and sensors is based compares with the algorithm set up to provide the ideal process conditions. The output signal is then sent to several different actuators which includes pumps, aeration blowers, valves, and mechanical mixers.

Control valves are used to regulate wastewater flow, along with chemicals or air in particular processes. With the automated system preferred across the facility, the valves are electrically or pneumatically operated. The remain a key actuator in several treatment process such as dosing systems and aeration control.

The transportation of wastewater is produced by pumps. Along the wastewater, pumps will transport sludge and chemicals between treatment processes. Continuous pump monitoring is required to reduce dry running or overloaded conditions. As part of an automated system, pumps will align its output pressure with the demands and requirements of the wastewater processes. This is effective in maximising process efficiency, along with protecting components in the system when required. (*Revollar et al., 2020*).

One of the most energy dependant actuators in the plant are the Aeration blowers used in the biological treatment process. They are required to supply oxygen to the microorganisms required to process and treat the wastewater. This stage cannot limit its energy consumption due the requirement for the process. It can, however, monitor and communicate effectively with its PLC to ensure that no wasted energy is created. Continuously measuring oxygen levels and adjusting the output of the actuator is the most effective method of accuracy control and cost management.

The relationship between sensors, controllers, and actuators from a closed loop control system, ensuring that the treatment plant runs as efficient and constant system.

Historical Development of Automation

The development of automated systems and programming was highly beneficial to several key industries across the Country and the world. In any manufacturing, energy, or waste management setting, automation played a key role in digitising and influencing effective change across industries for automation.

The most significant evolution in wastewater treatment plants is the implementation of automated systems in the last century. Prior to its introduction to automation, the facilities relied on manual operation. Process conditions and equipment use was solely down to operator responsibility.

Relay based mechanical control systems were introduced in the mid-twentieth century, allowing the automation of basic functions such as valve control and pump operation. In relation to the closed loop connection system discussed, the actuators were the first autonomous element of the system. Whilst the initial use of this system was inflexible and difficult to modify, it lay the groundwork for what would be seen now as an element of a vast set of automated components and processes that aid in the treatment of the wastewater.

PLCs were introduced in the 70's, representing another development in automated systems technology. This technology marked the implementation of flexible digital systems able to control highly technical process activities.

As of now, the use of SCADA systems is the most adopted technology in the wastewater treatment industry. The ability to supply the requirements of the facilities with continuous monitoring and detection, digital control, and data logging means that an accurate and autonomous facility is run.

Modern Automation Technologies

Further development in digital technology in the wastewater industry has enhanced automation. Technologies developed in similar industries have been adopted into wastewater treatment, ensuring that the industry is effective in finding further efficiencies in its use.

Smart sensors are an example of the advancement of ICA in industry. This technology uses integrated diagnostics to identify measurement errors and automatically compensate for them and also adjust for a common industry issue with lifespan of sensors known as sensor drift. This is important to ensure that the input data being provided is recorded and identified accurately to avoid an incorrect output measure.

A further modern technology used is the Internet of Things (IoT). This allows for remote monitoring of the entire site infrastructure, providing a network for all of the connected sensors and devices. The efficiency and performance of the facility is continuously monitored, meaning that small faults or defects are identified and acted on prior to actuator or system failure.

Not only can algorithms be set for specific parameters and variables but also be set up as Machine Learning algorithms. A predictive control system has the capability of adjusting output from various actuators, such as aeration rates for secondary process, based on predicted flow and wastewater volume. This means that the system is able to react to the characteristics of the current wastewater prior to the flow reaching certain areas of site. A reduction in actuator usage and energy consumption is two of the advantages of this, along with the treatment facility being far more effective in its application.

A further advancement in automation is the Digital twin technology. This is set up a digital replica of the wastewater treatment facility, where the operators are able to simulate plant operations to have prior knowledge in process outputs and variables before implementing them in the real plant. This removes the 'trial and error' method of thinking and shows reliable data to make site operating decisions.

Regulations and Standards

Wastewater treatment facilities are subject to rigorous regulation and inspection to ensure that the plants are safe and effective in their aim of providing a thorough process in treating its wastewater product. High pressure systems, along with large equipment and hazardous product creates an environment that, if below regulation standard, could cause harm to operators and the general public.

The Health and Safety at Work Act (HASAWA) 1974 provides a general overview of the safe standards of work to uphold. More specific regulations include OSHA confined space regulations, pressurised systems regulations, manual handling, along with Control of Substances Hazardous to Health (COSHH) regulation. (*Great Britain. Health And Safety Executive, 2005*).

The wastewater itself is a hazardous substance, along with the biological agents used. The use of autonomous systems limits operator exposure to all of these potential hazards.

The discharged water from the facility must be to a standard that is safe enough to be released to the local environment. The Environmental Agency in the UK ensure that the treatment facilities are operating to an acceptable level of competency and effectiveness to release the water following its treatment. (*A and Ageros, 2010*).

There are limits and procedures that must be followed across all plants including biological oxygen demand, ammonia concentration, and suspended solids. The sensors and gauges across site ensure that these limits are adhered to.

Critical Analysis and Future Improvements

Whilst the implementation of autonomous systems in ICA have improved accuracy and efficiency, their use creates new considerations and potential issues. The constant exposure to fouling, corrosion, and measurement drift are a few of the challenges that having the automated control set-up creates. In an application where the human input is being reduced, the sensors replacing this have to be able to cope with the conditions.

The initial cost of implementing such advanced systems is significant. Not only to wastewater treatment plants, but to any plant that requires the addition of control. With new treatment facilities costing tens of millions to build, the automation as part of the plant is a large part of this.

The benefit of the system is not at the very start but with the future savings made by having such an efficient system. Energy and products used by the plant are optimised to ensure that little to no excess cost is incurred. The system allows the operator to have all available data and input variables to ensure maximum efficiency. The long-term benefits of cost saving and efficiency outweigh the initial cost of investment in the technology.

With the development of artificial intelligence and its application in Electrical systems and control systems, future investment may be required to incorporate its usage into the control system network. This could be paired with predictive maintenance, and advanced sensor technology to further improve the safety and efficiency of the wastewater treatment plant.

Conclusion

Automation plays a major role in treatment plants, ensuring that a continuous monitoring system is available for precise control of the treatment processes. Sensors provide input data and variables about the process conditions, allows for the controllers and actuators to interpret the data given, and adjust process controls to maintain optimised conditions.

The advancement of technologies for controlling process conditions such as IoT and AI allow for more automated actuators and output actions, providing efficient performance and reduced human factor.

Whilst initial investment and maintenance of sensors and programming technology seem excessive and costly, the effect of having the closed loop system in place provides the optimal conditions for a safe, and reliable facility.

In an industry that has such a severe impact of environment and general public, the investment of resource and research into further improving the conditions of operating these facilities is just and should therefore continue to develop further technologies and infrastructure.

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