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Real-Time Monitoring of Wastewater Treatment Facilities

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Contents

1. Introduction

In recent years, the wastewater treatment (WWT)'s narrative has transformed from regulatory-driven into proactive utility-driven planning. Such focuses on energy neutrality, less cost intensive operations, resource recovery, self-adaptation to variable parameters depending on population and weather, and finally sustainability. While regulations and guidelines still control the main infrastructure investments in this sector, facilities have taken the lead and initiative in developing the approaches that anticipate future challenges, potential new regulations, and population growth. By adopting a new vision, utilities can capitalize in sustainable methods with substantial profits. This whitepaper provides a summary of how Dension can facilitate such transition in the most effective and seamless way by analyzing the data collected from various processes of WWTs. At Dension, we specialize in systems analysis design. We understand that most wastewater treatment facilities cannot afford keeping full-time control system engineers on their staff to constantly monitor the system, collect data, analyze them, and design algorithms to detect faults or more importantly prevent them from happening in the future. Our monitoring and supervisory system will work with the newest technologies with expertise in multidisciplinary industries.

Our water and wastewater team of engineers will work closely with our team of electrical engineers who are experienced in power usage and quality, as well as with our data scientists who are experts in analyzing and modeling data to make proper recommendations to lower the cost of energy of your plant.

2. Upgrade procedure

2.1 Inspection of the current system:

A complete examination of the entire system will be performed to precisely establish the baseline state.

2.2 Develop and design a control plan:

The collected information will be used to design a plan to modify, upgrade, or replace the existing control system. This will also include the power supplies for the operating sections, as well as backup power for the control and radio links in case of power outage.

2.3 WWT process analysis:

The sensors and monitoring points of the wastewater treatment processes will be tested to ensure they are compatible with the new control system. These sensors will be upgraded to send notifications before critical points are reached. Additionally, they will offer a faster response time in unusual incidents, significantly effective to counter cyber-attacks.

3. Components of a real-time control system

There are four main categories for a real-time monitoring and control of wastewater treatment plants: 1) understanding of the current process; 2) sensors that provide real-time data; 3) suitable monitoring and control strategies and 4) actuators to execute the controller output. Considering that the expectations of water quality have become harsher, demanding more advanced treatment systems capable of compliance with stricter standards for both organic carbon and nutrient levels, the WWT systems have had to become more complex. The most essential barrier for a global acceptance of new sensors is that most of the existing wastewater treatment plants were designed and build for off-line control systems. This is evident in the absence of flexible and controllable actuators. Furthermore, these plants were built over-dimensioned to meet the effluent water quality without advanced control strategies (that depend on the new monitoring equipment). Therefore, their effluent streams meet criteria as they are and do not “feel” the need for upgrade. However, the implementation of new sensor technology seems inevitable as standards are becoming more tighter, increasing waste loads must be treated, or the need for cyber-attack protection now is getting more serious.

4. Features

From the concept, development, and execution, our team of expertise will provide a thorough assessment for the entire instrumentation and automation system.

- Plant-wide monitoring
- Dynamic response to each variable within various processes
- Project management
- Data logging and historian trends
- Network design
- Controls strategy across the plant
- Supervisory and data acquisition system design
- Remote access for operations personnel
- Proper equipment selection based on the obtained algorithms from collected data
- Integration of equipment supplier systems
- Training to keep the employees updated with the emerging technologies
- Continuous support contract

5. Wastewater treatment process

In general, an advanced wastewater treatment process consists of pre-treatment, primary treatment, secondary treatment, tertiary treatment, and disinfection. As shown in Figure 1, during the pretreatment process, solids, large particles, and rocks are separated from the raw sewage via screens and grit chambers to be sent out to landfills. The wastewater then will be sent out to the primary clarifiers where solid particles are settled out to the bottom using coagulation, flocculation, and sedimentation process and collected for reuse, while the fats and oils are skimmed off the surface and sent off to landfills. The primary clarifier’s effluent will flow into the secondary clarifiers where organic material is treated via the activated sludge process. The activated sludge process is an aerobic biological treatment which uses microorganisms to decompose fats, sugars, and carbohydrates as their food to grow. The activated sludge is an aerated process, since the oxygen content present in the air is a key requirement for the microbial activities. This is one of the most important stages of the WWT process which requires close monitoring, continuous checkups of the parameters, and careful maintenance. Once treatment is complete, a large portion of the microbes will be settled down during a secondary sedimentation process to be reused as biosolids by-product, while the rest will be recycled back into a freshly introduced wastewater to the secondary stage for treatment. The secondary effluent will enter another aerated biological process to oxidize ammonia to nitrate and nitrite using nitrifying microorganisms. In the next step, denitrifying microorganisms will convert nitrate and nitrite into nitrogen gas under an anoxic reduction. Since the microorganisms require a carbon source to perform the reaction, methanol will be added to the solution in this step. The tertiary effluent will enter a combined media filtration or nanofiltration process to remove the remaining micro- and nano-particles. The supernatant will be sent for disinfection including chlorination, ozonation, or UV. On the solids stream, all the collected solids will go through solid thickening and dewatering processes to be prepared for further applications such as gardening, farming, reclamation, etc.

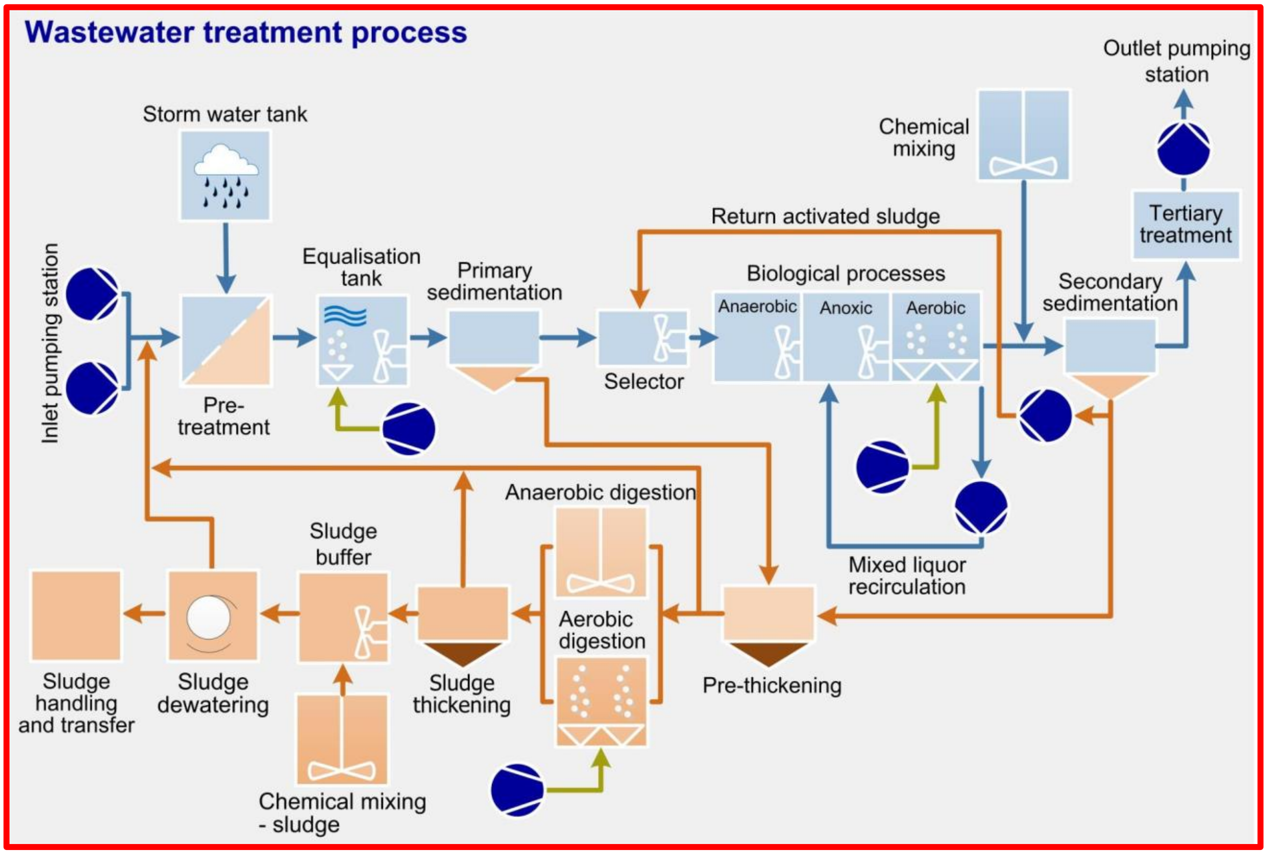

FIGURE 1- ADVANCED WASTEWATER TREATMENT PROCESS (HTTPS://WWW.SULZER.COM)

6. Sensors

There are three main applications for sensors: for monitoring, in automatic control systems, and for plant auditing/optimization/modelling. Sensors are classified as (1) simple and low maintenance, yet reliable which are used for the daily monitoring and control and (2) advanced and higher maintenance which are used for auditing, model development and optimization. In the following, the applications of these sensors in various wastewater treatment processes are discussed.

7. Sensors' applications

Water, solids and gases streams are the essence of all the wastewater treatment plants in the world and monitoring the properties of these phases is required. Because these sensors are shared among different processes, they are discussed independently here. Sensors measuring characteristics specific to certain processes will be discussed in the corresponding sections.

6.1. Environmental parameters (temperature and pressure)

Thermocouples and pressure transducers are used to collect data relevant to the temperature and pressure of the system, respectively. However, temperature is a rather vital parameter for anaerobic digesters where temperature control is often executed. Pressure measurements are especially important in aeration and anaerobic digesters where air and biogas are involved, respectively.

6.2. Flow rate of liquid and gas

There are different monitoring instruments for liquid/gas flow rate in WWT processes; venturi-based or electromagnetic sensors (for liquids) and rotameters or thermal mass flow meters (for gases) are some of the common examples.

Figure 2 illustrates a schematic view of how temperature, gas pressure, and flow rate in multi stages of a wastewater treatment plant can be monitored remotely, in real-time. Furthermore, the collected data will be used to develop a control and supervisory system to detect incidents, as well as preventing them from happening again in the future.

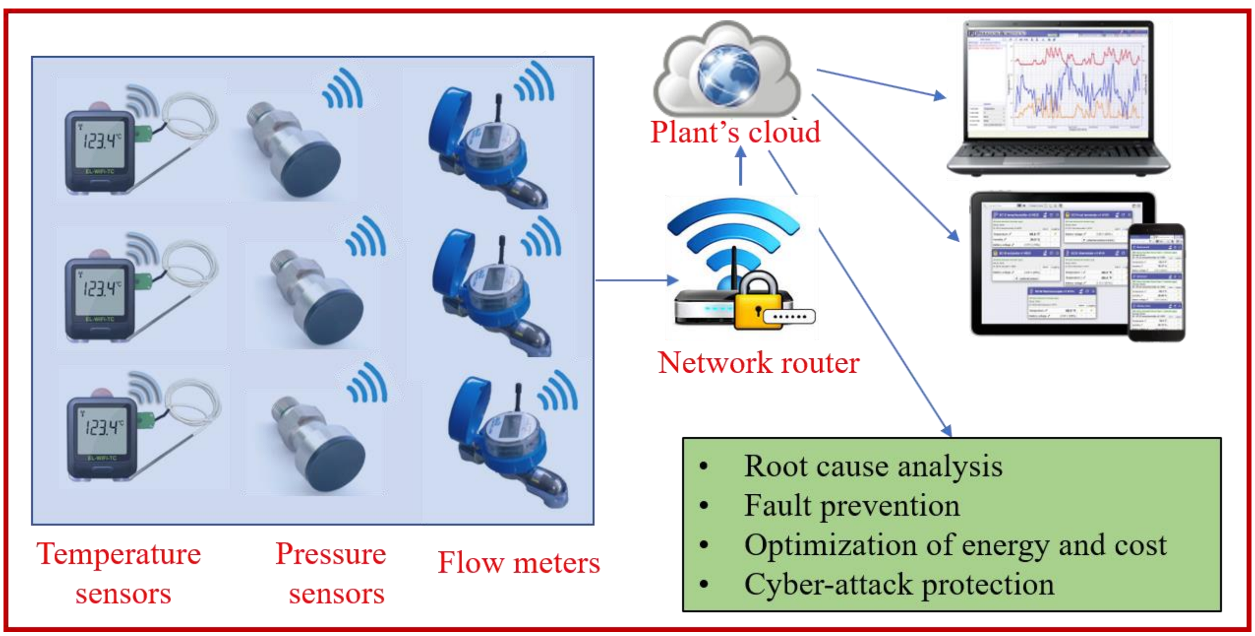

FIGURE 2- AN ON-LINE MONITORING OF ENVIRONMENTAL PARAMETERS OF A WWT PLANT.

6.3. Liquid level

The water levels can be monitored using floats with an internal electric switch; conductivity switches; differential pressure transducers; capacitance measurements and ultrasonic level detection. Floats and conductivity switches are used for on/off level detection and alarm functions, whereas differential pressure and ultrasonic equipment provide a continuous signal. Figure 3 demonstrates how the water level in various stages of wastewater treatment can be monitored remotely using appropriate sensors.

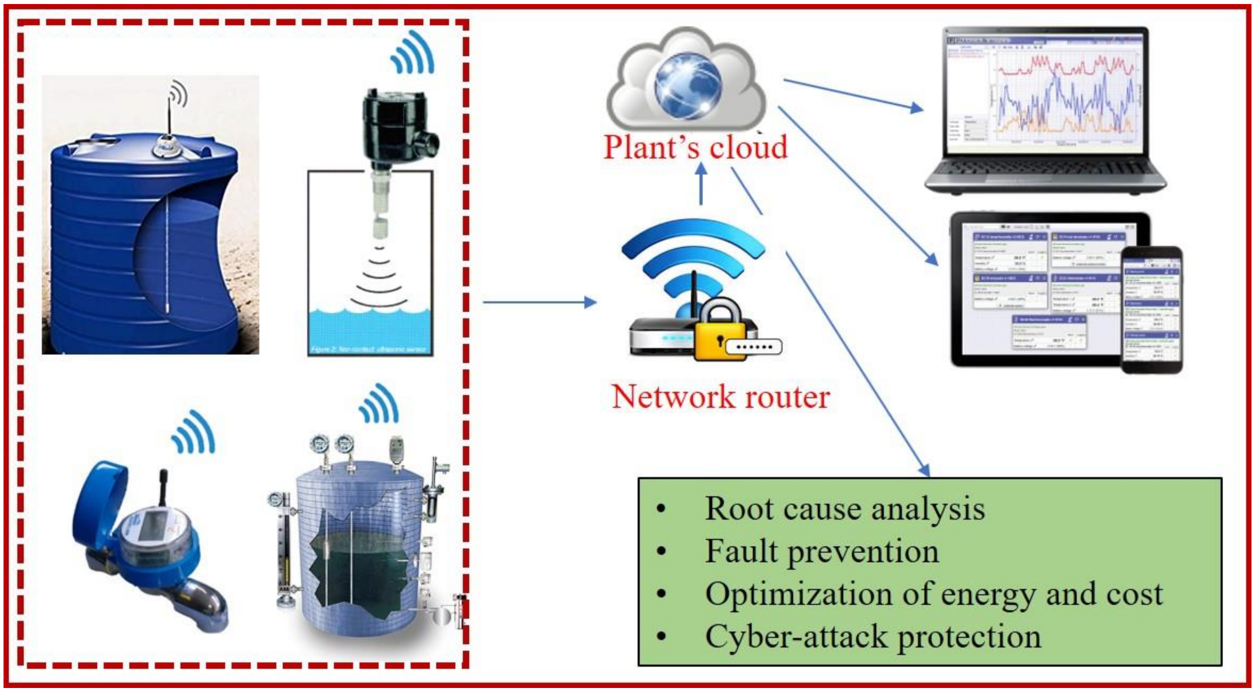

FIGURE 3- REAL-TIME MONITORING AND CONTROL OF LIQUID LEVEL IN VARIOUS PROCESSES OF WWT.

6.4. pH and conductivity

The most common sensors to measure pH is pH electrodes, which require frequent cleaning and calibration due to the direct contact they have with wastewater. Once these sensors are connected to the principle control system, automated cleaning strategies including hydraulic (water spray), mechanical (brush), chemical (rinsing with cleaning agent) or ultrasonic cleaning can be implemented. Some data verification strategies such as duplicate sensors to compare the readings and in advanced systems self-diagnosis systems have been integrated. In more complex systems, automated checks of the impedance of the diaphragm and the glass electrode, while tests are conducted over automatic calibration can identify potential deficiencies. pH measurements are specifically crucial in anaerobic digestion and nitrification where important quantities of protons are released, discussed separately in the relevant sections.

Influent composition variations are monitored with conductivity sensors, which are the foundation of control strategies for chemical phosphorus removal. Conductivity sensors also require frequent cleaning and an alternating current is critical to avoid electrode polarization

6.5. Biomass/suspended solids (SS)

Suspended solids concentration is the most important parameter in WWT which can be measured through (1) optical measurements, (2) ultrasound and (3) dielectric spectrometry. Suspended solids present in the water scatter and absorb the incident light detected by detectors. The existence of sensitive light detectors has made possible for developing sensors capable of automating the measurement of optical density (OD) of SS in an illuminated sample. The OD readings will be converted into real SS concentrations using appropriate calibration curves. Occasional interreference with air bubbles can be reduced by degassing the sample and filtering of the bubble-induced spiky data (Hatch and Veilleux, 1995). Additionally, integrating the sensors with a routinely conducted "air check" allows an automatic detection of a miniscule build-up of film at the tips of the sensors, preventing them from fouling or defect (Watts et al., 1990).

Ultrasound sensors are used for measuring the biomass content. It operates to measure the difference between the velocity of ultrasonic sound in the suspension and in the microorganism-free solution. Figure 4 demonstrates an on-line method to measure biomass content in wastewater in real-time.

Dielectric sensors are also used to determine the biomass concentrations (Davey et al., 1993; Spierings, 1998; November and Van Impe, 2001). Biomass caries negative charges and therefore is attracted towards positive ions, resulting in movement of ions in the solution and within the cells that will accomplish charge separation or polarization across the cell membrane.

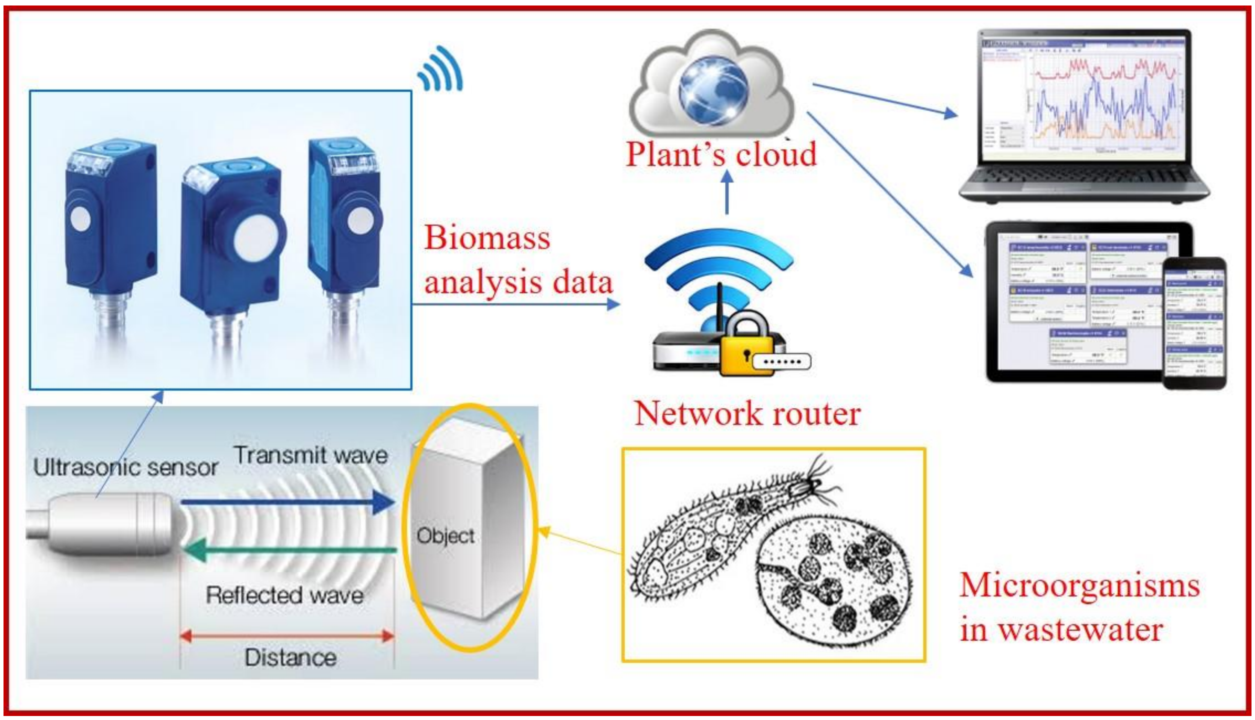

FIGURE 4- ANALYZING BIOMASS IN WASTEWATER USING ULTRASOUND SENSORS.

6.6. Screening and grit removal

Through the initial screening, wastewater is pumped up from the ground to the treatment plant. The pump can be automatically run and controlled by the main control system of the plant and adjusted based on the desired flow rate for the sewage. After the screening is complete, the wastewater is transported to the primary clarifiers, where solid particles settle out to the bottom of the clarifier. The pumping system at clarifier inlet, again, can be controlled remotely and adjusted based on the targeted flow rate. The detention time of the primary clarifier can be controlled using sensors located at the influent and effluent streams of the clarifier. Total Suspended Solids (TSS) concentration of the effluent can be analyzed using the same methods used for biomass content. Once TSS content reaches the targeted level, a command will be sent to the outlet sensors from the control system to allow the wastewater discharge to the secondary reactors and sedimentation.

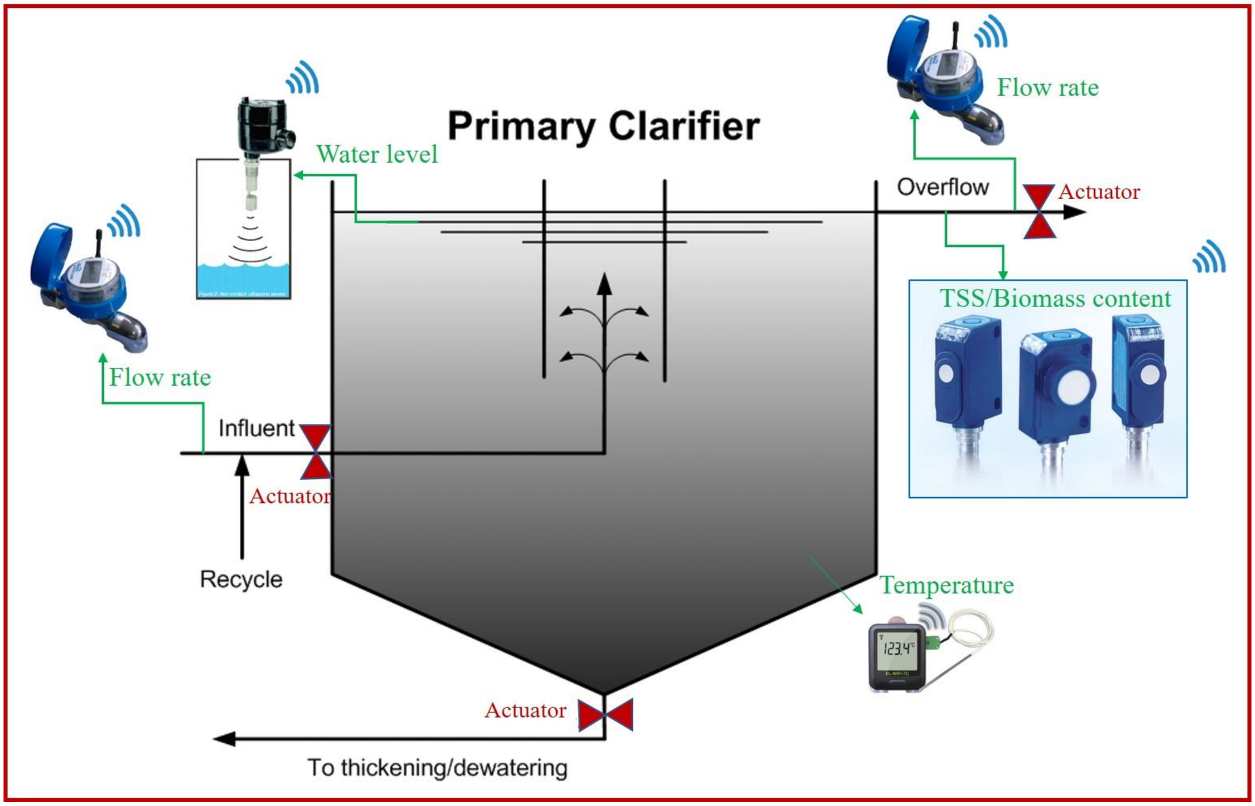

FIGURE 5- REAL-TIME MONITORING AND CONTROLLING A PRIMARY CLARIFIER.

6.7. Secondary reactors and sedimentation (biological process)

Secondary treatment of WWT consists of removing nutrients from wastewater using biological methods. Phosphorus in wastewater is present in different forms of orthophosphates, polyphosphates and organic phosphates. Due to potential eutrophication that presence of phosphorus can cause in natural waters, phosphorus removal is highly regulated. Enhanced biological phosphorus removal (EBPR) is one of the techniques used in activated sludge systems for phosphate removal (Korving et al., 2019). Through EBPR, within the activated sludge, a group of heterotrophic bacteria, called polyphosphate-accumulating organisms (PAO), are selectively enriched in the bacterial community that collect large quantities of polyphosphate within their cells to enhance the removal of phosphorus (Qiu et al., 2019). Over the second approach occurring in sequencing batch reactors (SBR), which is a fill-and-draw activated sludge system, the sludge containing PAO is enriched. Though off-line measurements (such as volatile fatty acids and phosphorus measurements) are often performed for these methods, an off-line monitoring of the SBR cycle is slow as there is a delay between sampling and availability of the results. Hence, a real-time monitoring system is required for establishing effective control strategies. This on-line monitoring system can improve the overall process management, in addition to enabling real-time detection of abnormal situations and the new control strategies execution. More importantly, it is essential to design an adaptive control system that can adjust the processes based on varied operational parameters.

The most common forms of on-line monitoring and control of SBRs are direct sensors such as dissolved oxygen (DO), oxidation-reduction potential (ORP) and pH probes. The biological parameters of nitrogen and phosphorus removal in SBR directly associate with the DO, ORP and pH variations, which can be used to evaluate and control various stages of the process as the following; phosphate release by the ORP and pH breakpoints; assessment of influent ammonia load under constant aeration nitrification (will be discussed in the next section of this paper); phosphate uptake by the pH breakpoint; and residual organic carbon oxidation by the DO and ORP carbon elbows. Therefore, the principal control system can automatically monitor and control all the operations to achieve an efficient nitrogen and phosphorus removal.

In addition to the abovementioned direct sensors, phosphorus can also be detected using a photo sensor that measures the wavelength of a distinct color (e.g. blue or yellow). The color is the result of a chemical reaction between phosphorus and a special reagent. Photo sensors are used in two P detection methods; molybdenum blue and Vanadate / molydate yellow methods. In both methods, the dye intensity by using a photometric sensor measures the concentration of phosphorus in the solution.

Potentiometric sensors are also used for phosphorus detection in wastewater, called the phosphate microelectrode. Like all other potentiometric methods, in phosphate microelectrode the voltage output (mV) is measured and converted to phosphate concentrations. Potentiometric sensors can communicate with the control system to send out data and receive commands within the secondary treatment processes.

Microwave cavity resonators are the other options to be installed in WWT facilitates for nutrient detection. They can detect phosphorus P as phosphate (PO_4) using a microwave Vector Network Analyser (VNA) and a cylindrical microwave cavity. Microwave cavity resonators are proved to be sensitive to P concentrations as low as 25 ppm (Al-Dasoqi et al, 2009). These resonators can be used as alternative or secondary sensors for any of the direct, photo, or potentiometric sensors in the system, and can be connected to the control network to send and receive data from the control system.

The other parameter affecting the secondary treatment process is the biochemical oxygen demand (BOD). The biodegradable substances of wastewater can be measured by the standard and off-line method of BOD_5. The BOD_5 measures the amount of dissolved oxygen needed for the biochemical oxidation of the organic solutes over 5 days (Goffin et al., 2018). Figure 6 illustrates a schematic of how the secondary treatment process can be monitored and controlled in real time. Each sensor will send data to the plant control system simultaneously. The collected data will help with supervising the process as well as modeling the system for optimization, energy saving, and cost reduction.

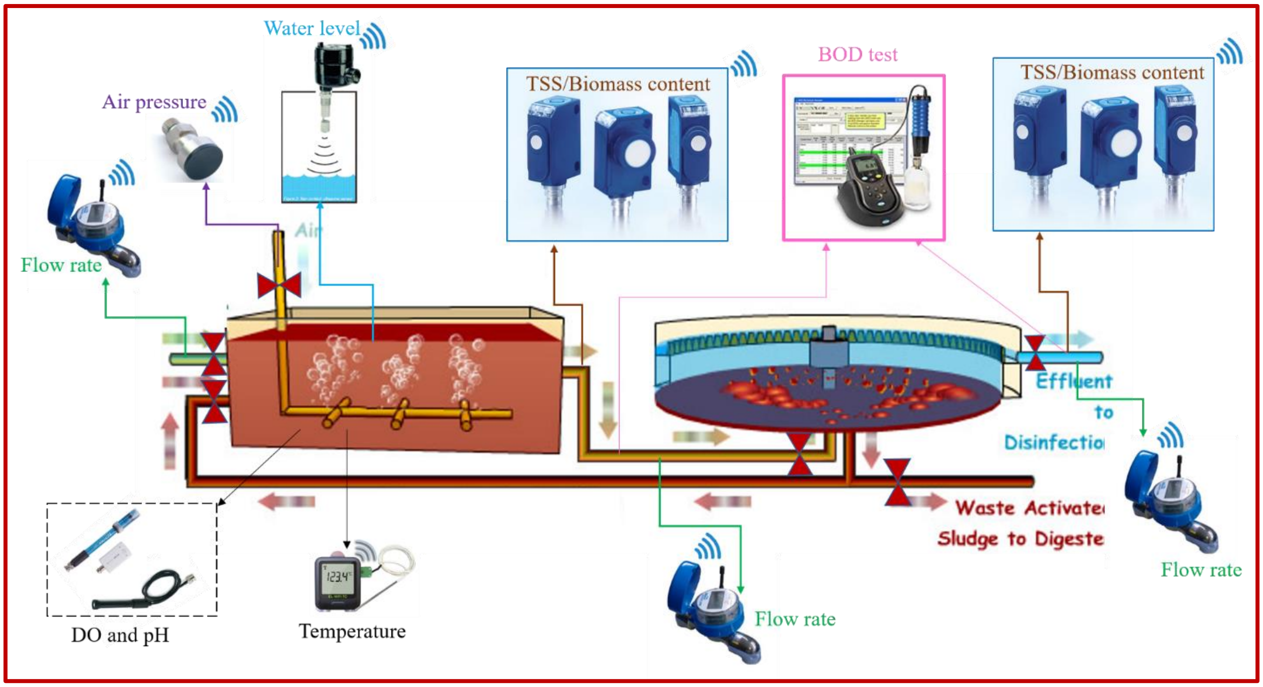

FIGURE 6- ONLINE MONITORING AND CONTROL OF THE SECONDARY TREATMENT PROCESS.

6.8 Tertiary treatment

Biological nitrogen removal (BNR) is one of the most crucial wastewater treatment processes. In fact, BNR is one of the most cost-effective methods of nitrogen reduction in wastewater (EPA, 1993). Biological nitrogen removal consists of two steps; nitrification and denitrification. During nitrification, the aerobic phase, ammonium is converted into nitrite and nitrate. During denitrification, under an anoxic phase, the oxidized nitrogen species are utilized as electron acceptor, in the presence of enough biodegradable chemical oxygen demand (COD), to convert nitrate and nitrite into dinitrogen gas that escapes to the atmosphere. To handle the daily, weekly and seasonal influent load variations to the treatment plant, on-line monitoring of relevant process parameters such as dissolved oxygen (DO), pH, NH^{4+}-N or NO_3^--N concentration, and oxidation-reduction potential (ORP) in the mixed solution is necessary.

All the sensors used for monitoring nitrogen removal processes including direct probes (DO, pH and ORP electrodes), indirect probes (on-line $NH4^+$ -N and NO_3^- -N analyzers), and biosensors can be connected to the overall control system of the plant to send data and receive commands.

Figure 7 demonstrates how nitrification, denitrification, aeration, and sedimentation processes involved in the advanced nutrient removal (tertiary treatment processes) can be monitored on-line and remotely. Any potential fault will be detected within the shortest amount of time, while the collected data will be analyzed for design a preventive and control system. The sensors implemented for each process are explained in the following.

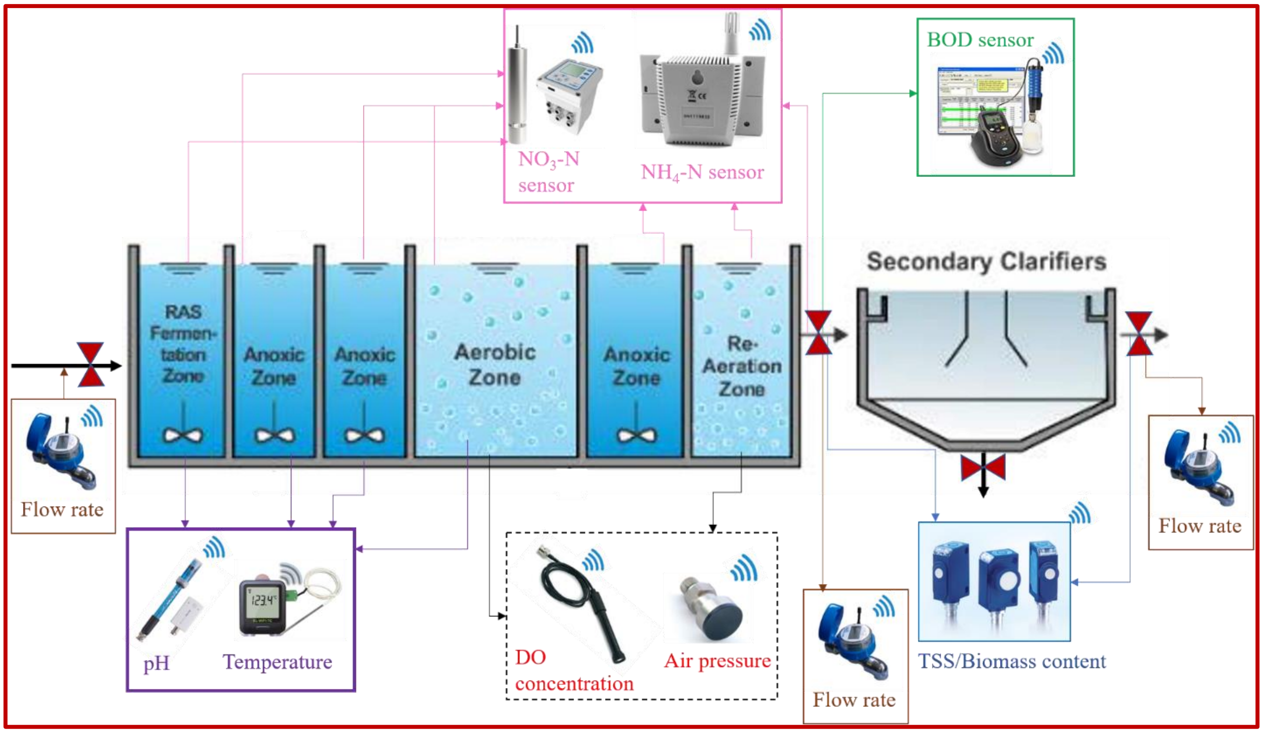

Figure 7- Real-time monitoring and control of the tertiary treatment processes.

6.8.1 DO sensors

To avoid electrode fouling and to ensure of the data sent for control purposes, DO probes require frequent cleaning and calibration. The collected data from these sensors are used to develop appropriate time intervals based on which the principal control system will send commands for automatic cleaning and calibration of the electrode. More importantly, DO sensors are used to maintain a fixed DO setpoint in the aeration tank to minimize the costs of aeration. Aeration is the most energy intensive process in wastewater treatment and thus it is critical to precisely control the DO at its minimum level required for an effective aeration. A simultaneous on-line estimation of both oxygen mass transfer characteristics and biological oxygen uptake in the aeration tank will allow a successful optimization.

6.8.2. pH

The common measurement in every process of WWT is pH measurements. Like DO sensors, electrode fouling is also a problem with pH probes. This can be handled by sending proper commends from the principal control system to the sensors obtaining longer periods without maintenance of the electrode through an automated hydraulic, mechanical, chemical or ultrasonic cleaning system. pH sensors play a critical role in nitrification/denitrification process. The proton release can result in acidification and subsequent process failure. In addition, the proton production or consumption is used to characterize nitrifying and denitrifying populations, respectively. When the buffer capacity of the mixed solution is too low or too high to lever the proton production/consumption due to nitrification/denitrification, a pH analysis system along with a dosing system can be used to adjust pH in the nitrifying activated sludge and denitrifying units. The integrated system will include a sensor that communicates with the plant control system, sending out data to and receiving commands from the control system.

6.8.3. Oxidation reduction potential (ORP)

In any monitored system, ORP electrodes provide a general indication of the oxidative status of the system. In addition, ORP electrodes provide data about the biological processes happening under anoxic and anaerobic phases. Similar to acid/base titration graphs, the breakpoints in ORP profiles indicate the appearance or disappearance of a redox buffer system, among which the DO and the NO_3^- breakpoints are well-known. Figure 1 demonstrates an ORP profile example including both DO and NO_3^- breakpoints ("knees") recorded during subsequent anoxic and aerobic conditions in a sequencing batch reactor. The breakpoint acquired after about 35 minutes agreed with the disappearance of nitrate from the mixed solution (Demuynck et al., 1994). In nitrification process, the DO breakpoint represents the complete conversion of ammonia (end of nitrification), while in denitrification, NO_3^- breakpoint specifies the disappearance of NO_3^- which is the end of denitrification. From a practical point of view, the DO and NO_3^- breakpoints are hints to when the aeration must be stopped and started again, respectively. Once the ORP sensors are in place, these commands will be generated automatically based on the developed ORP models verified with the collected data from the ORP profiles of nitrification and denitrification processes.

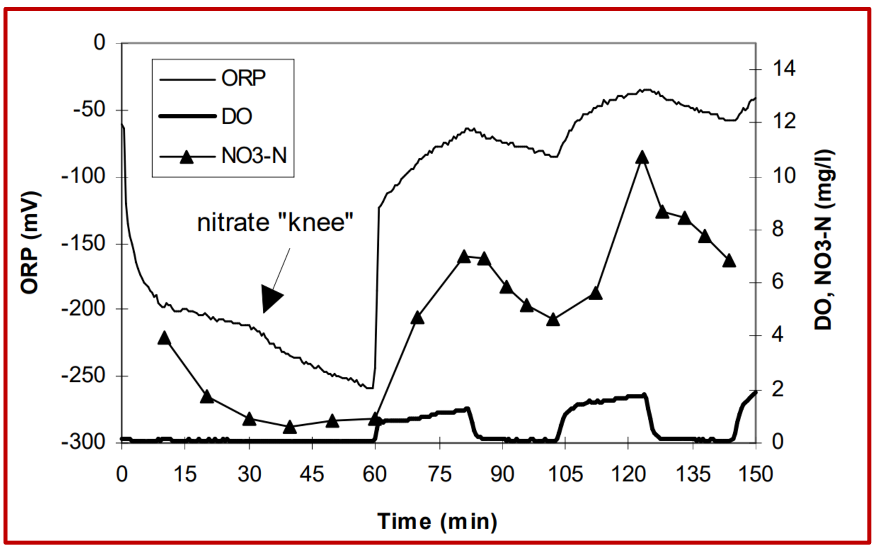

FIGURE 8 A SAMPLE ORP PROFILE DEMONSTRATED DO AND NITRATE BREAKPOINTS (DEMUYNCK ET AL., 1994).

6.8.4. NO_3^- and NH_4^+ analyzers

Most on-line NO_3^- and NH_4^+ NH_4^+ analyzers function based on ion-selective electrodes (ISE) or colorimetric reactions. The endpoint of nitrification can be detected using an NH_4^+ analyzer installed on activated sludge tanks in alternating activated sludge processes. The analyzer determines if an increase of the DO setpoint is required in the aeration tank at increased NH_4^+ concentrations. Given that oxygen is a limiting factor for nitrification under normal operating conditions, the increase in the DO setpoint will lead to a higher nitrification rate in the aeration tank. In alternating activated sludge processes, the endpoint detection with an NH_4^+ analyzer offers slightly higher overall process rates compared to ORP or DO measurements. Such is because the on-line analyzers allow to stop the aerated phase prior a complete oxidization of NH_4^+, resulting in both a low effluent NH_4^+ level and consequently an optimal usage of the available reactor volume. ISEs are preferred as NH_4^+ due to no usage of reagents (mostly generate hazardous wastes), no chemical interferences, the short response time of the analyzer (less than 10 minutes) (Thomsen and Nielsen, 1992; Wacheux et al., 1995), and the possibility of connecting them to the main control network of the plant. However, the system is sensitive to contamination of the electrode. This problem can be controlled by pretreatment of the samples, frequent automatic calibration and availability of a spare electrode, yet negatively impacts the response time of the system, increases the operational costs and restricts the real measuring time of the analyzer. These issues will be alleviated by sending calculated commands from the plant control system to the analyzers (which are connected to the control network).

6.8.5. Biosensors

Wherever a biological process is involved in WWT, the characterization of substrate and biomass is a key to a desired result. Such offers crucial information about the biodegradability of a matter, the process kinetic rates (nitrification, denitrification, and carbon oxidation), and the toxicity of a stream or a chemical substance. A biosensor can deliver this information from a certain process to the principal control system of the plant to make appropriate decisions, take timely actions, or send operational commands (Ejeian et al., 2018). Two forms of biosensors specific for nitrification-denitrification monitoring are respirometric and titrometric biosensors.

6.8.5.1. Respirometric biosensors

During the aerobic stage of activated sludge plants, respirometry measures the oxygen uptake rate (OUR) or the respiration rate of activated sludge, and the device used for these measurements is called a respirometer. Pressure transducers and CO_2 stripping can detect the oxygen consumption volumetrically. Specific oxygen sensing devices also can be applied in the aquatic phase, i.e. DO probes, or in the gas phase using fuel cells or paramagnetic oxygen analyzers. There are two respirometric modes; batch and continuous (Spanjers, 1993; Spanjers et al, 2002). In closed batch respirometers an activated sludge sample is transferred into a small vessel and then its decline of DO concentration with time is monitored following a short-aerated phase. While the usage of the closed batch respirometers is limited due to the potential danger for oxygen limitations, open respirometers are often used continuously aerated. The open respirometers offer higher sludge concentrations usage, since oxygen is continuously introduced into the system and therefore the oxygen limitation is unlikely. In this case, the respiration rate is calculated considering the oxygen transfer coefficient and the saturation DO concentration. Once the respirometers are connected to the plant control system and enough data is gathered for a proper model development, batch respirometers can be operated in a semi-continuous way, under which the respirometer carries out a repeated batch experiment.

Continuous flow-through respirometers measure both the inlet and outlet DO concentrations of a closed respiration chamber, while aerated sludge is continuously pumped through the chamber. In this case, the OUR is measured via an oxygen mass balance over the respiration chamber including the input and output DO concentrations and the chamber residence.

Respirometric sensors are used frequently for on-line influent toxicity detection in wastewater treatment plants, in which nitrifying bacteria are used as indicator organisms for toxicity. The sensors communicate with the principal control system, sending real-time data. A preventive algorithm can be developed using the collected data to avoid any fault or incidents with toxins in the WWT processes.

6.8.5.2. Titrometric biosensors

A titration unit can serve as a pH controller and verify the amount of base required to neutralize the protons produced in a mixed liquor sample. This is done through the stoichiometric relation between the amount of oxidized $NH_4{}^+$-N and the number of protons generated during nitrification. Compared to pH probes, these biosensors are more accurate and compatible with the control system.

Two forms of titrometric biosensors used in nitrification/denitrification processes are Biological Residual Ammonium Monitor (BRAM) and Denitrification Carbon Source Dosage System (DECADOS). BRAM considers the stoichiometric conversion of $NH_4{}^+$ to 2 H^+ to calculate the residual $NH_4{}^+$ -N concentration in the mixed liquor samples. DECADOS biosensor is used for denitrification control in activated sludge plants. DECADOS operates based on simple and “robust” probes (pH and ORP). It delivers the information relevant to the kinetics and the stoichiometry of the denitrification process and, in some instances, the concentration of nitrate.

6.9 Multimedia filtration and disinfection

UV lights, chlorination, and ozonation sensors used for disinfection can be easily connected to the control system to receive start/stop commands, as well as for varying the intensity level and flow rate. For chlorination, ozonation, and multimedia filtration, different control strategies such as forward, feed-back loop, and adaptive control systems can be developed and implemented. The flow rate of the influent and contact time to the filtration unit can be adjusted automatically based on the characteristics of the tertiary effluent measured and delivered by the relevant sensors to the control system. As can be seen in Figure 9, the last process performed on wastewater, multimedia filtration (tertiary filtration) and disinfection, can also be controlled remotely and in real time. Similar to any other pump in the plant, the pumps associated with this process (not shown in the figure) will be set up to work automatically within the main network.

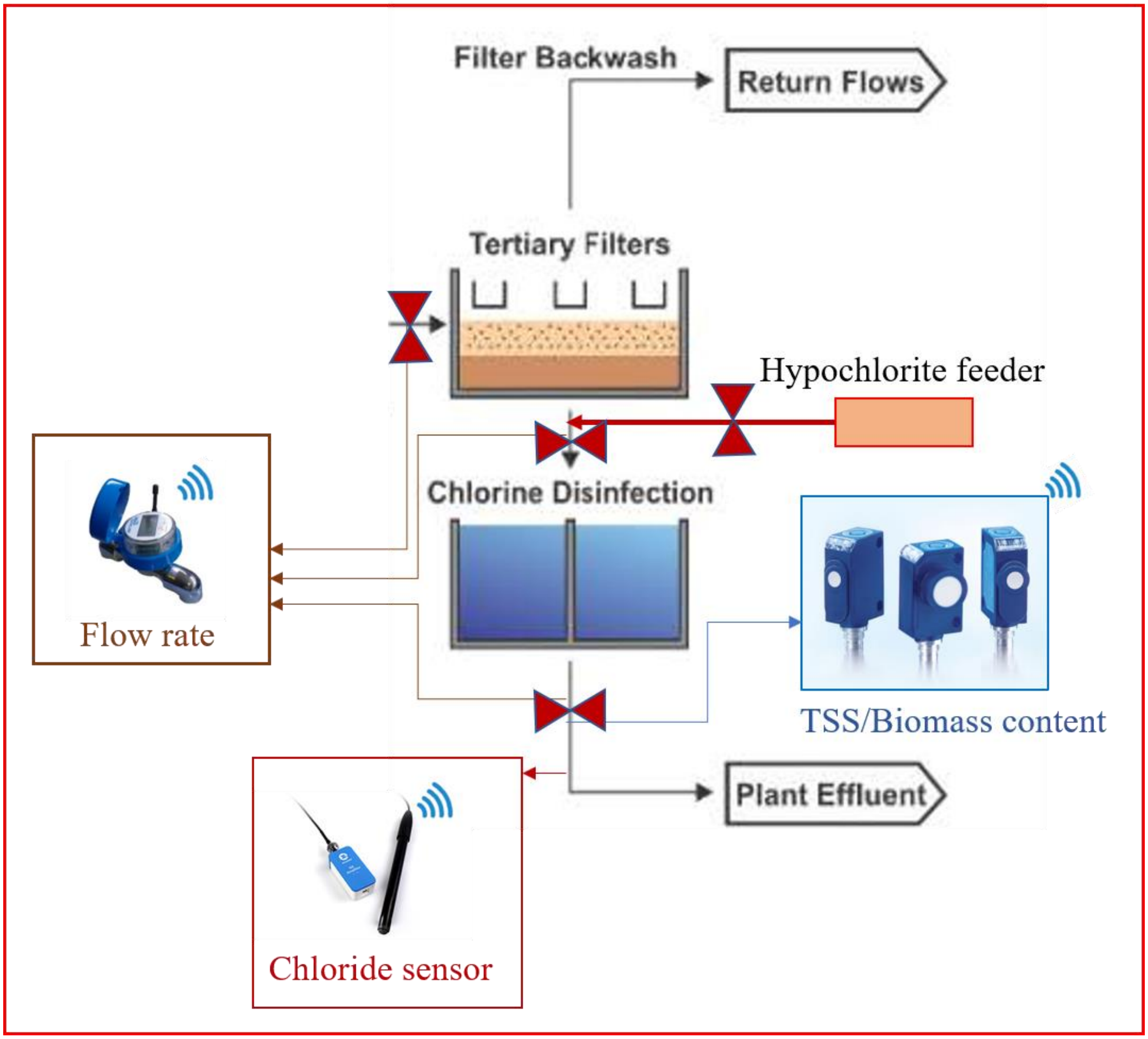

FIGURE 9- REAL-TIME MONITORING AND CONTROL OF THE DISINFECTION PROCESS.

6.10 Solids thickening and dewatering

The anaerobic digestion process involves a complete mineralization of organic material into gaseous products (H_2, CH_4, CO_2 and H_2S). The biogas generation happens within a two-step process in which methanogenesis relies on the intermediates produced in the previous acidification stage. Since the two processes depend on each other, they must be synched properly to prevent the accumulation of the volatile fatty acids generated in the first step. Therefore, in anaerobic digesters control strategies, careful measurements must be conducted on the intermediates and the gaseous effluents.

An infrared absorption sensor can measure carbon dioxide and methane. Specific hydrogen analyzers operating based on electrochemical cells can measure hydrogen gas. H_2S can be quantified using automatic colorimetry.

Volatile fatty acids (VFA) can be detected using an advanced instrumentation consisting a gas chromatograph (GC) or high-pressure liquid chromatograph (HPLC) coupled with a sample preparation unit, or a Fourier Transform Infra-Red (FT-IR) spectrometer. A simpler technique would be titrimetry which can provide information on both the bicarbonate and VFA content of the sample.

8. Energy efficiency

About 25–40% of operating costs of a wastewater treatment plant is associated with its energy consumption, which can vary within the range of about 0.3–2.1 kW h/m3 of treated wastewater (Metcalf and Eddy Inc, 2006; Elías-Maxil et al., 2014; Venkatesh and Brattebø, 2011; Liu et al., 2004). The main energy intensive sectors are the aeration process (55–70%), primary and secondary sedimentation along with sludge pumping (15.6%) and sludge dewatering (7%) (Panepinto et al 2016). These processes can be optimized using the collected data from each stage which will result in consuming the minimum amount of energy required for an efficient performance. Other parameters responsible for an increase in energy consumption such as poor maintenance of electro-mechanic devices, the rainwater infiltration, and any imbalanced hydrodynamic behavior of the reactors can also be prevented by a real-time monitoring system.

9. Renewable energy sources applications

Considering the large amount of power that is consumed in any wastewater treatment facility (energy consumption in wastewater treatment is 10 times the energy needed for water treatment, referring to a report from water environment research foundation) and raising concerns about climate change and global warming issues necessitate the application of clean energy sources to provide the electricity needs of WWT plant instead of fossil fuel-based thermal power plants. As an example, application of energy recovery methods such as offsetting the onsite renewable generated power (such as biogas) can lower the carbon footprint at a WWT plant up to 40%. Application of microgrids, which are localized small-scale power generation systems based on renewable energy sources, justifies localized WWT plants that are powered by pure renewable energy sources within a microgrid (e.g., solar photovoltaic, combined heat and power generator (CHP), and wind turbines) along with energy storage technologies can reduce the cost of wastewater treatment process and significantly improve the reliability of WWT plants. To optimize the performance of such integration, collaborative research and development between industry and academia in multidisciplinary fields are needed.

10. Conclusion

Implementing sensors and connect them to a secure network in order to monitor the plant and collect useful data from each process will allow for establishing root cause analysis, fault detection and prevention procedures, as well as optimizing the operating parameters which will result in a significant energy consumption reduction.

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