Investigation on Design of the WWTP Control Structure

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Abstract: *Worldwide, a lot of wastewater is produced every day from home and industrial sources, creating problems like a water shortage and deteriorating the environment. As a possible solution to this issue, the creation of environmentally friendly and energy-efficient wastewater treatment technologies is sought after. In the event of the usage of conventional PI type controllers at the fundamental level, the goals pursued in this research were methodological aspects of the design of the WWTP control structure. A comparative qualitative examination of the potential strategies inside this control structure can currently be carried out thanks to the models and numerical simulation tools employed in the paper.*

Keywords: *Control strategies, PI controller, feedback control, and waste water treatment plants*

I. Introduction

vital to comprehend how earthquakes affect man-made structures before looking at the characteristics of earthquake-proof buildings. When an earthquake happens, it causes shockwaves to travel across the ground in brief, quick bursts that reach all directions. Buildings can typically withstand the vertical forces generated by their weight and gravity but not the side-to-side forces produced by earthquakes. Walls, floors, columns, beams, and the connectors that hold them together vibrate as a result of this horizontal movement. Buildings' bottom and top movements diverge, putting significant stress on the supporting frame and ultimately leading to the collapse of the entire structure.

Earthquakes are naturally occurring occurrences that cause the ground to shake and shift. Buildings in certain locations are thought to be somewhat seismically vulnerable. Ani et al. (2020) [1] noted that high-rise, or multi-story buildings, frequently retain a comparable greater degree of seismic susceptibility. Thus, a distinct branch of structural engineering called as earthquake or seismic engineering has been formed in order to comprehend and reduce the seismic susceptibility. According to Godwin (2007) [2], the structural load-bearing framework of most high-rise, or multi-story buildings, is comprised of either reinforced concrete (RC) or structural steel (SS), with some type of non-bearing infill wall or panel. One of the most widely used structural technologies in use today is infilled framing. Since in-fill walls are regarded as non-load bearing components, it is customary to exclude them from numerical models used for practical structural analysis and design when constructing such structural systems against seismic actions. By doing thus, their contribution to stiffness and strength as well as their interaction with the frame's load-bearing components (i.e., beams, columns, and walls) are completely disregarded. According to Asteris et al. (2013)[3,] the influence of infill walls is typically only taken into account by applying additional loads and masses that are properly distributed along the interfaces between the surrounding frame and the infill walls.

The most modern and potent FE analysis packages now implement predictive models, which are also continuously updated. The majority of studies conducted during this time period on the behavior of infilled frames have emphasized the importance of the in-plane (IP) interaction to the reaction as a whole. When compared to the stiffness of the bare structures, infills provide a significant increase in stiffness and significantly alter dynamic responsiveness. The collapse modes involving the entire structural complex have significantly changed along with the concurrent increase in strength, which is also observed.(Asteris et al., 2013, 2017; Kheyroddin et al., 2017) [3–5].

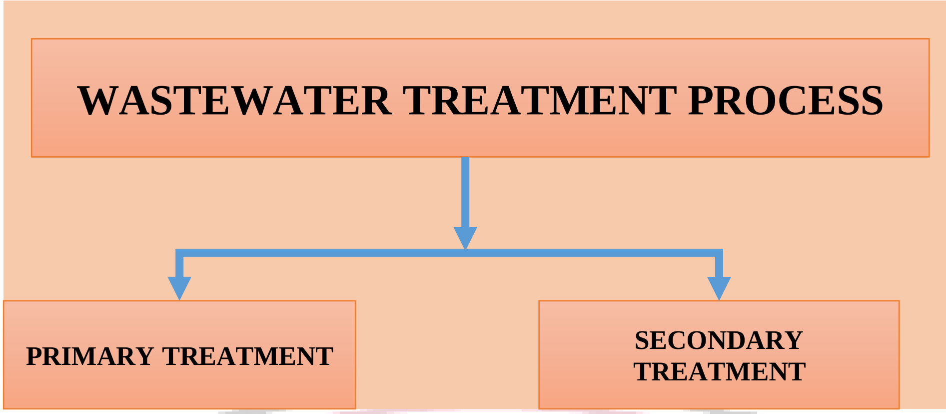

Figure 1: Treatment procedure of waste water

Activated sludge in wastewater applications is now controlled using a range of control systems with varied degrees of complexity. Compliance with effluent requirements and cost savings are the main drivers for the control and automation of wastewater treatment plants. The trend toward autonomous process control has been hastened by recent advancements in control technology. At this time, various levels of automation are being used.

Automatic control using SCADA and online measurements is the next level of control. The process is disturbed by changing wastewater properties. The process reacts to the disturbance by changing the concentration of dissolved oxygen (DO), for example, which can be measured. A controller receives the measurement and responds by sending an actuator a control signal in order to close the gap between the measurement and the intended set point.

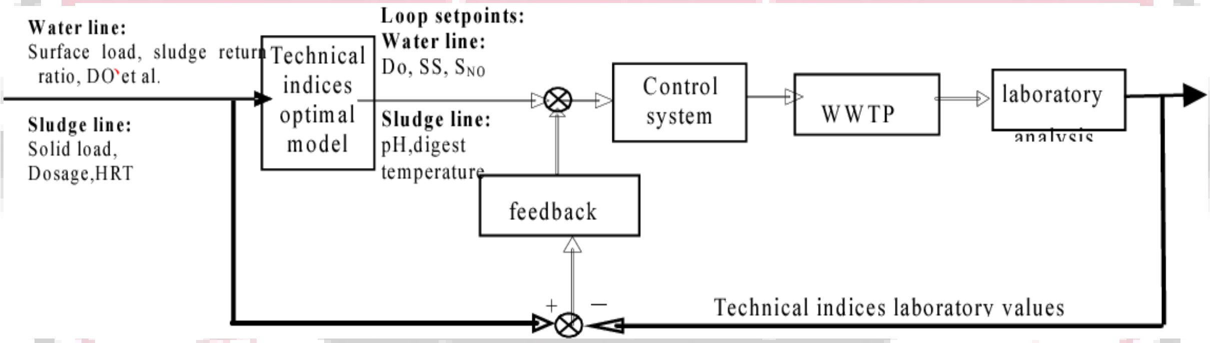

Figure 2: Feedback Control

On/off control is the most popular and affordable type of feedback control. Simple relays that start and stop machinery in response to a disturbance are used to control the operation. On/off control can be installed into existing facilities with little alteration, which is another advantage. Batch or semi-batch operations, such as blower control for cyclic activated sludge based on real-time measurements of DO, are where the application is most frequently used. Process instability and actuator degradation brought on by oscillation above and below the setpoint are the main downsides.

II. LITERATURE REVIEW

C. Cadet [1] designed the control technique with an eye on enhancing effluent quality. Singularperturbations techniques have been used to create a precise simplified model of the ASM1 model. A sensitivity analysis for the controller's choice of I/O variables uses this model.

B. Chachuat et al. [2] studies on the dynamic optimization of small wastewater treatment facilities The issue is presented as a hybrid dynamic optimisation problem, and a gradient-based approach is used to resolve it. The aeration policy that minimizes energy usage while satisfying discharge criteria is then developed, taking into account the provided restrictions (process and physical constraints).

S. Longo et al. [3] provides a summary of the literature on the effectiveness of WWTP energy use as well as current energy benchmarking techniques. The literature review found three basic benchmarking approaches: normalization, statistical methods, and programming methods. For each approach, benefits and drawbacks were noted.

Barancheshme and Munir [4] examines several methods of treatment for eradicating antibiotic-resistant organisms (AROs) and antibiotic-resistant genes (ARGs) in the wastewater environment. Due to the significant volume of antibiotics discharged into the wastewater, it is possible that some ARB and ARGs will be more likely to enter natural habitats. A major problem for global public health is the emergence of new microbial diseases and the rise of antibiotic resistance among them. It is a global environmental and public health issue that the propagation and dissemination of ARB and ARGs in the environment may lead to an increase in antibiotic-resistant microbial diseases.

By taking into account the sanitation procedure and the official household wastewater treatment start-up schedule permitted for the Metropolitan Region (MR) of Santiago, Chile, **M. Prendez and S. Lara-Gonzalez [5]** projected GHG emissions for the period 1990–2027. The methodology takes into account a few models developed by the Intergovernmental Panel on Climate Change (IPCC) as well as a few others that have been written by other authors and adapted for use in various country contexts, sanitary conditions, and temporal scenarios.

Bisinella de Faria et al. developed an integrated DM-LCA framework by comparing five wastewater treatment plant (WWTP) scenarios to a reference scenario using dynamic modeling (DM) and life cycle assessment (LCA) in order to quantify the energy and environmental benefits of urine source separation (USS) combined with various treatment processes in article **[6]**. In this regard, USS and EPC results showed that the coupled USS & EPC scenario and its combinations with agricultural N-rich effluent spreading and irrigation/anaerobic de-ammonification could present an energy-positive balance with, respectively, 27% and 33% lower energy requirements and an increase in biogas production of 23%, compared to thereference scenario.

Carlos Edo [7] investigated the presence of microplastics in a wastewater treatment plant's primary and secondary effluents, mixed sludge, processed heat-dried sludge, and soil amendment. Fragments and fibers, which were identified as having a cylindrical shape and a length to diameter ratio greater than three, were separated from the sampled microparticles. We demonstrated the existence of 12 different anthropogenic polymers or polymer groups, with a predominance of polyethylene, polypropylene, polyester, and acrylic fibers as well as a sizable proportion of synthetic natural fibers. In both primary and secondary effluents, the smaller sampled proportion, in the 25-10 m range, was by far the biggest. Less than one third of the anthropogenic particles in the studied effluents were fibers, which also revealed smaller sizes than fragments, but up to 84% of heat-dried sludge was fibers.

Q.H. Zhang [8] Urban China's wastewater treatment facilities (WWTPs) were examined in terms of treatment methods, pollutant removal, operating load, and effluent discharge regulations. China had established 3508 WWTPs by the end of 2013 with a total treatment capacity of 1.48 108 m3/d, distributed among 31 provinces and cities. China's east and west regions have had significantly varied economic development as a result of the uneven population distribution. Over 50% of the current WWTPs use AAO and oxidation ditch technologies, which are the most common ones. Statistics show that 656 WWTPs in 70 cities have good COD and NH3-N removal efficiency.

M. Garrido-Baserba et al [9] The significance of sewage sludge treatment within the context of wastewater treatment plants (WWTPs) introduces new analytical dimensions where the complexity of sludge management is rising due to the relevance of economic criteria paired with related environmental concerns. This study evaluates five potential configurations for sludge treatment, including mesophilic and thermophilic anaerobic digestion plus composting, incineration, gasification, and supercritical water oxidation, to aid in the decision-making process and for comparison purposes (SCWO).

Various home chemicals, biocides/pesticides, pharmaceutical residues, personal care items, and heavy metals are just a few of the compounds that can affect municipal wastewaters. Their outcome in wastewater treatment plants determines whether they are released into the environment, where they may have a negative impact on aquatic life (WWTPs). In order to evaluate surface water contamination, dangers for aquatic creatures, and to suggest ways to decrease their discharge into the environment, **Jonas Margot [10]** looked into the origins, usual concentrations, and fate of more than 160 micro pollutants of various classes in conventional WWTPs

III. Proposed Methodology

Plants that treat wastewater (WWTP) are intricate nonlinear systems. Due to the complexity of biochemical and biological processes and variations in input wastewater flow, it is difficult to regulate the effluent quality.

The MATLAB platform is utilized in this research project to demonstrate the implementation or simulation of the algorithm performance. There are measurement toolboxes utilized, as well as certain built-in routines for creating graphs. MATLAB routines are used to compute simulation results and a comparison of the performance of the developed model with certain others.

Genetic algorithm designing for Plant

The genetic algorithm approach uses two processes inside the general metaheuristic framework: I getting an initial set of solutions, and (ii) implementing an improved search that is guided by predetermined rules in order to produce new solution sets. The current state of an algorithm is represented by Sk S in each step k of a genetic algorithm, where Sk stands for the set of solutions in step k and S stands for the solution space.

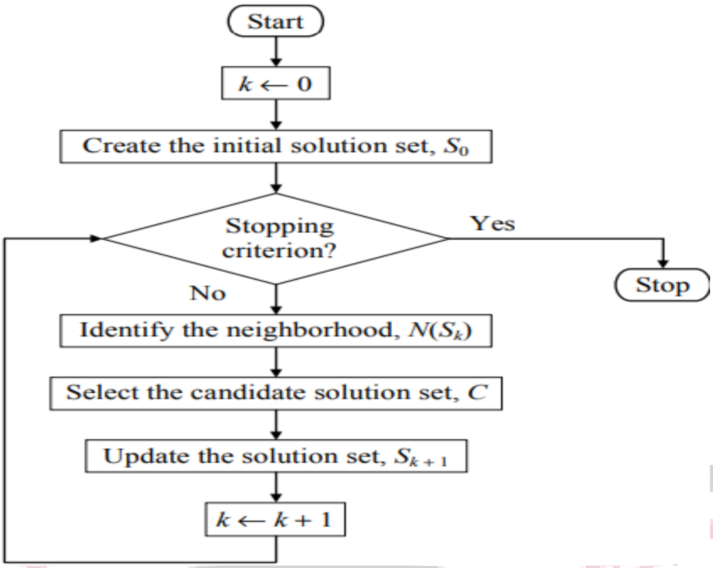

Figure 3: Genetic Algorithm performance flow chart

Every time the GA genetic algorithm is run, an ideal value of fiti is selected because it uses a random search procedure. These fiti ideal values are contrasted over the course of the implementation, up until the fiti optimal value stays the same. Finally, we determine the weights of W1 and W2. Table 1 lists these weights that are supplied in accordance with various meteorological conditions.

Table 1: Values of weighting factors

Weather	W1	W2
Dry	0.28	0.72
Rainy	0.33	0.67

IV. RESULTS AND DISCUSSION

Wastewater treatment processes (WWTPs) are typically nonlinear, multi-variable, unstable, and time-varying, which has an impact on how they are operated and managed. These tougher water quality regulations provide two significant challenges: energy conservation and emission reduction. The most effective control strategy for a WWTP that can efficiently minimize the annual total energy consumption while improving the water treatment process was developed using a generalized simplified supervisory control method.The result from the two models created in MATLAB/SIMULINK utilizing script is discussed and compared in this chapter. The first model used a streamlined supervisory control strategy, and the second one optimized plant characteristics using a genetic algorithm to get better results.The analysis has been separated into two sections to investigate the plant's performance under these two input scenarios:

Case 1: Using influent data and dry weather circumstances, the plant was fed.

In this instance, information about dry weather conditions has been integrated into the water treatment process. An efficient optimization control based on genetic algorithms is designed with the goal of resolving the conflict between multiple performance indicators in complex wastewater treatment processes (WWTPs). After that, influent data is analyzed by both algorithms, including data such as PH values in different reactors. Additionally, numerous plant factors are examined in the effluent data, and comparisons between the two methods are made.

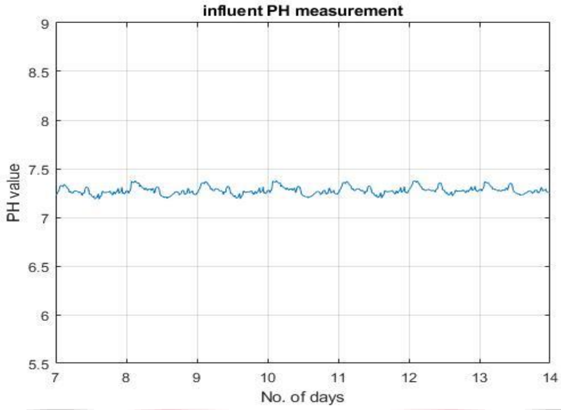

Figure 4: PH of the influent stream in case 1

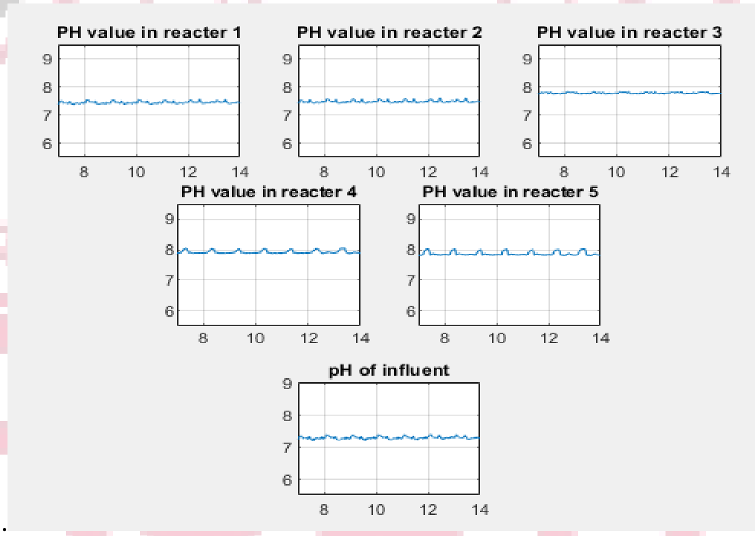

Figure 5: PH values at various stages of WWTP with simplified supervisory controller in case 1

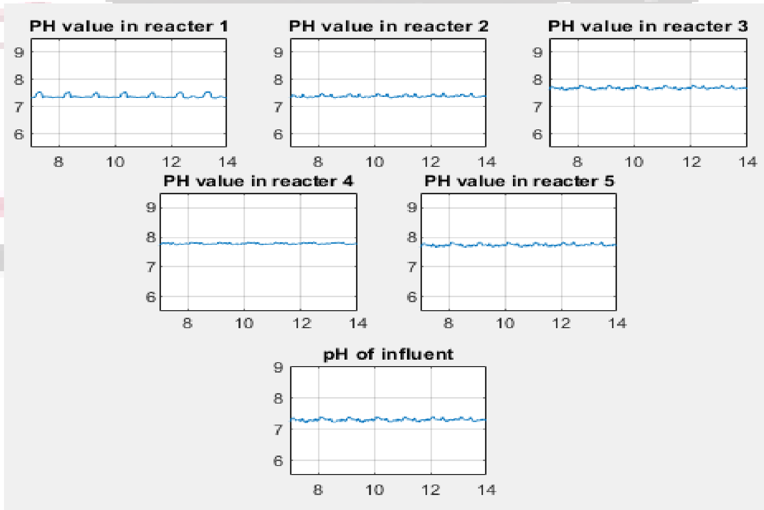

Figure 6: PH values at various stages of WWTP with proposed AI based controller in case1

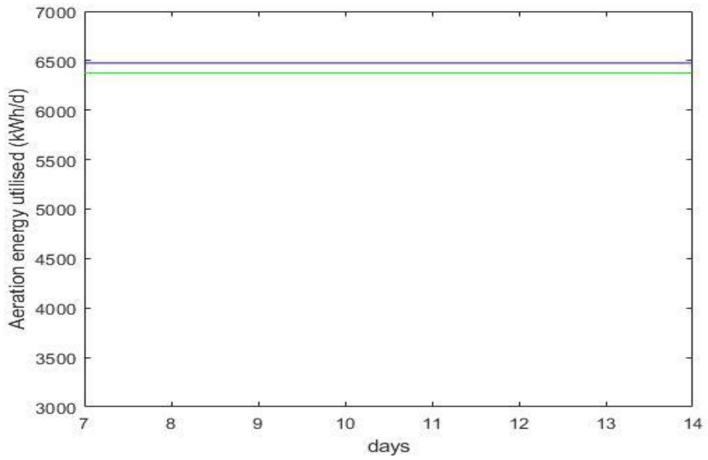

Figure 7: Comparative analysis of aeration energy used using two controllers in WWTP in case 1

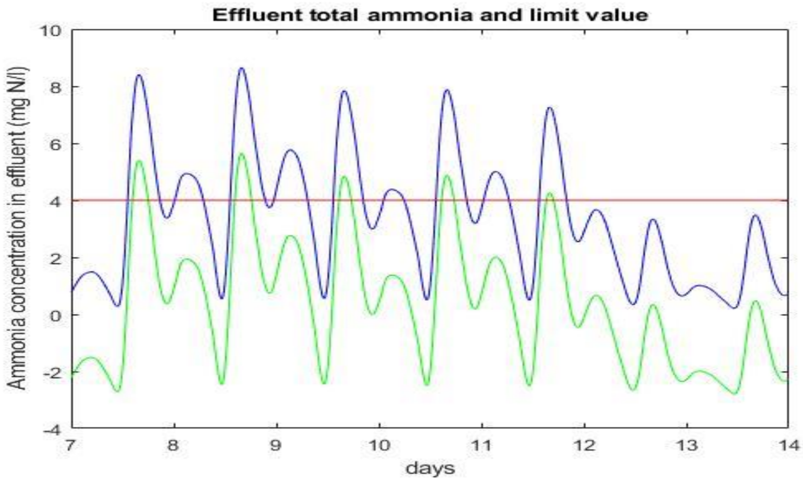

Figure 8: Comparative analysis of Ammonia in effluent using two controllers in WWTP in case 1

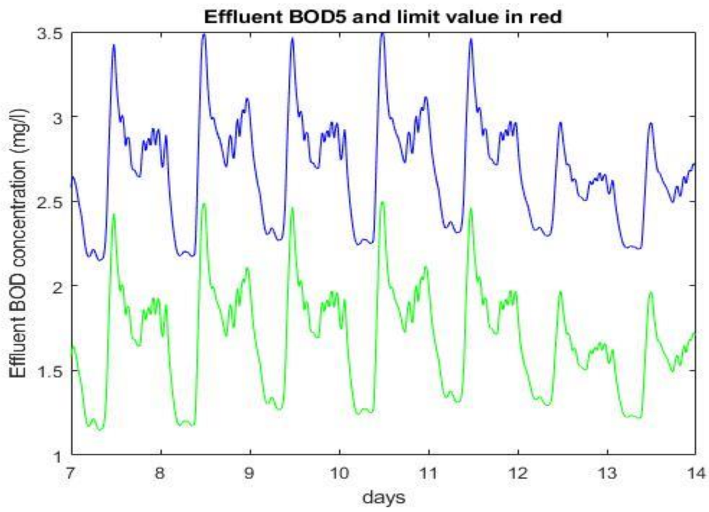

Figure 9: Comparative analysis BOD in effluent using two controllers in WWTP in case 1

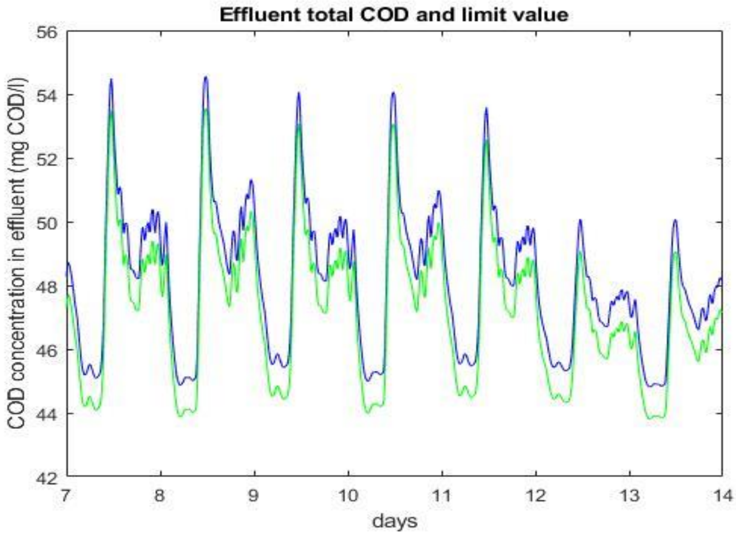

Figure 10: Comparative analysis of COD using two controllers in WWTP in case 1

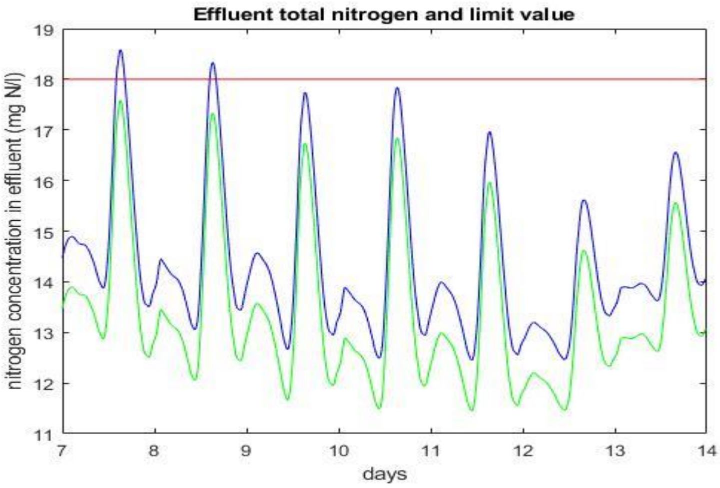

Figure 11: Comparative analysis of nitrogen concentration of effluent using two controllers in WWTP in case 1

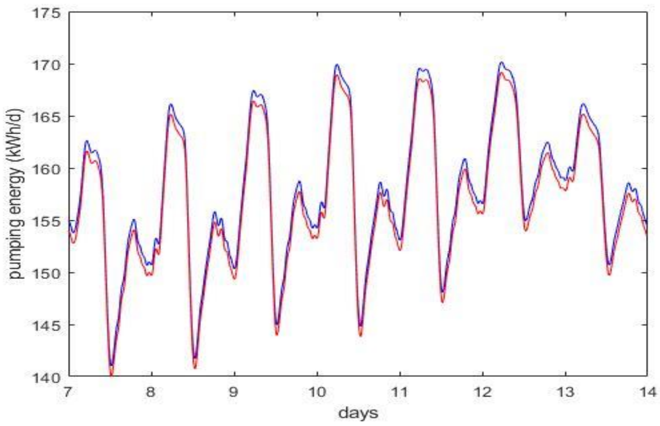

Figure 12: Comparative analysis of pumping energy in system using two controllers in WWTP in case 1

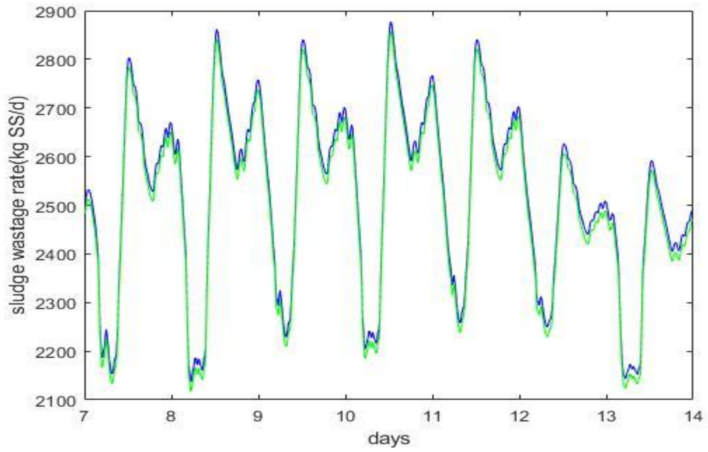

Figure 13: Comparative analysis of sludge waste rate in system using two controllers in WWTP in case 1

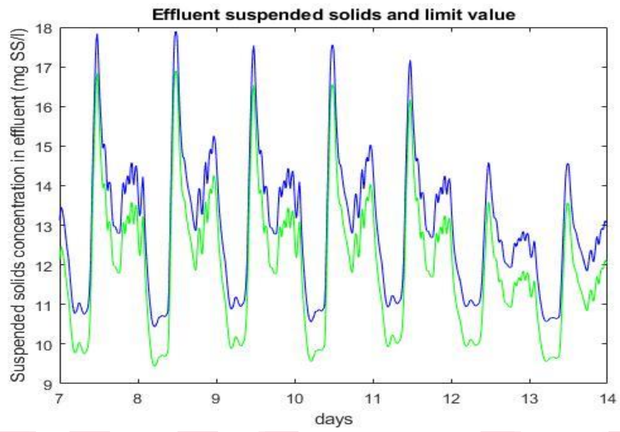

Figure 14: Comparative analysis of suspended solid concentration using two controllers in WWTP in case 1

Case 2: Rainy weather conditions and influent data were used to feed the plant.

In this instance, information about wet weather conditions has been supplied into the water treatment process. An efficient optimization control based on genetic algorithms is designed with the goal of resolving the conflict between multiple performance indicators in complex wastewater treatment processes (WWTPs). After that, influent data is analyzed by both algorithms, including data such as PH values in different reactors. Additionally, numerous plant factors are examined in the effluent data, and the results of the two algorithms are compared. To alter the PH level of the input water, rainy water influent data is introduced at 8.5.

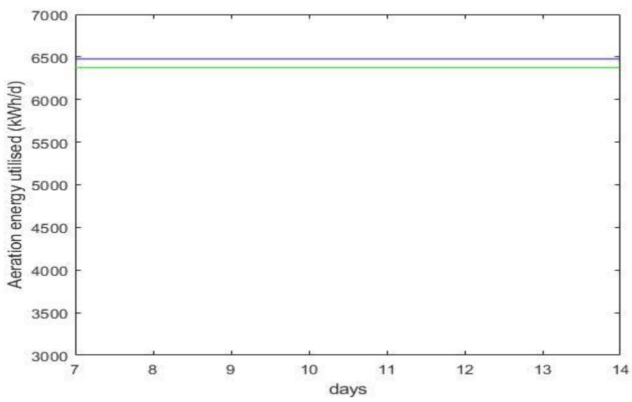

Figure 15: Comparative analysis of aeration energy in system using two controllers in WWTP in case 2

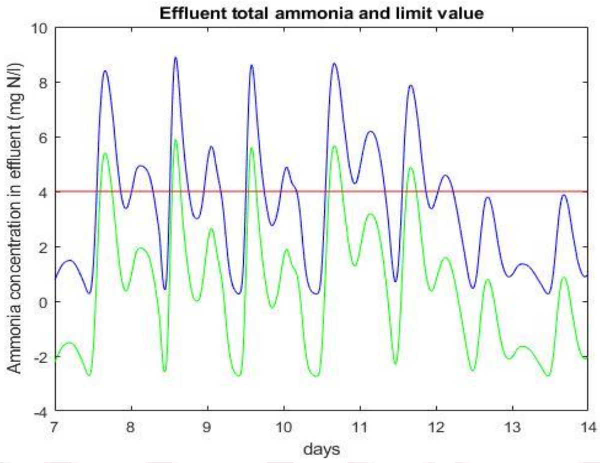

Figure 16: Comparative analysis of effluent ammonia concentration using two controllers in WWTP in case 2

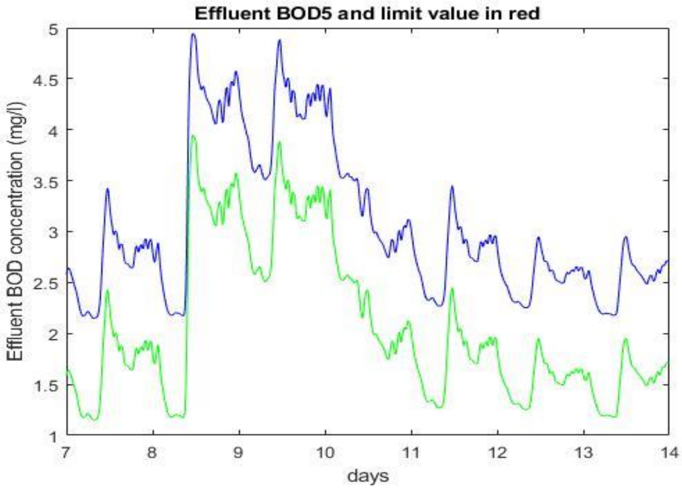

Figure 17: Comparative analysis of BOD in effluent using two controllers in WWTP in case 2

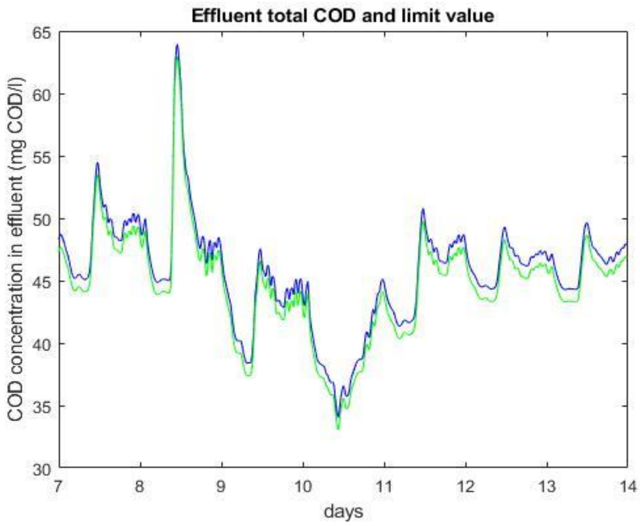

Figure 18: Comparative analysis of COD in effluent using two controllers in WWTP in case 2

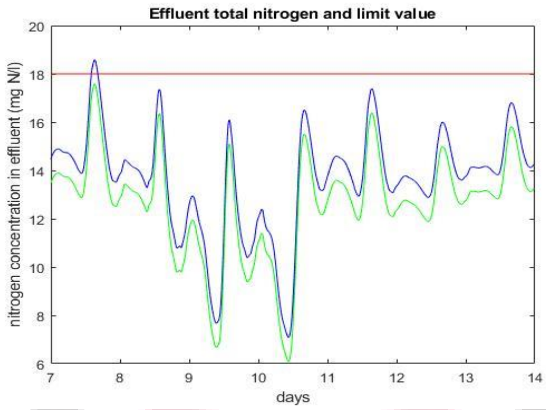

Figure 19: Comparative analysis of nitrogen level effluent using two controllers in WWTP in case 2

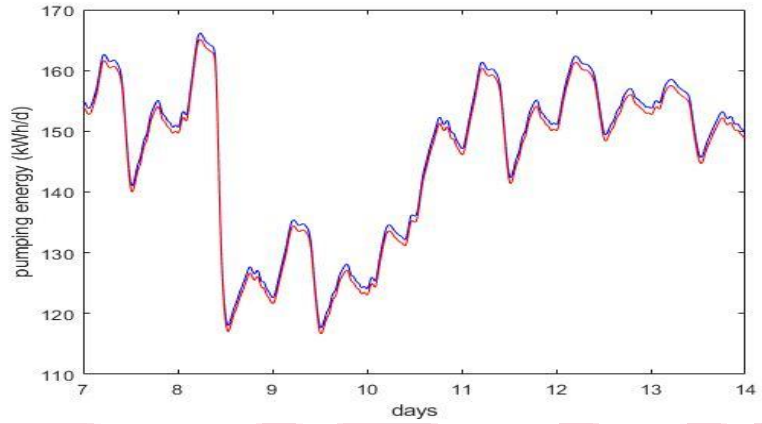

Figure 20: Comparative analysis of pumping using two controllers in WWTP in case 2

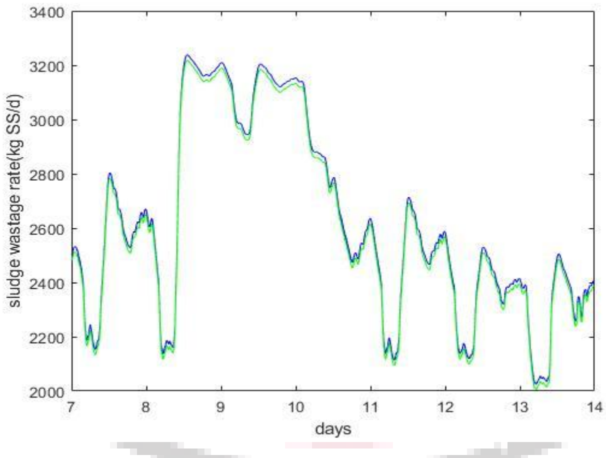

Figure 21: Comparative analysis of sludge waste rate effluent using two controllers in WWTP in case 2

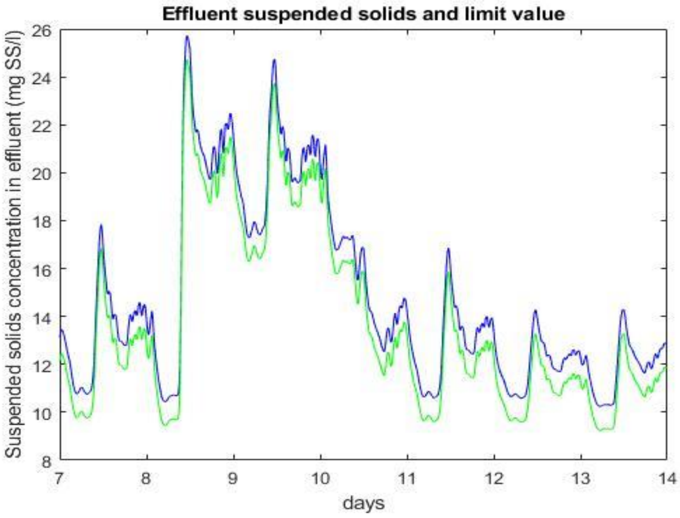

Figure 22: Comparative analysis of suspended solid concentration in effluent using two controllers in WWTP in case 2

The blue graph of figures above depicts theaeration energy in system, BOD, COD, effluent ammonia concentration,nitrogen level effluent,sludge waste rate effluent andsuspended solid concentration (SSC) in the effluent using standard supervisory controller and the green graphs depicts theaeration energy in system, BOD, COD, effluent ammonia concentration,nitrogen level effluent,sludge waste rate effluent andSSC in the effluent from the proposed controller which is reduced.

Conclusion

In the event of the usage of conventional PI type controllers at the fundamental level, the goals pursued in this research were methodological aspects of the design of the WWTP control structure. A comparative qualitative examination of the potential strategies inside this control structure can currently be carried out thanks to the models and numerical simulation tools employed in the paper. The outcomes of the two control systems have been analyzed, and the important outcomes are as follows.

- The outcomes from using a higher-level control are encouraging. In other words, whether in dry weather and in wet weather, the total operating cost of the system OCI or/and the output effluent quality index EQI are greatly lowered.
- The green graphs show the effluent's suspended solid concentration (SSC), which is lower in both types of weather circumstances, when the proposed controller is used instead of the usual supervisory controller.
- At each stage of the treatment process, the PH level of the influent has increased.
- When compared, the BOD concentration in the effluent from the suggested controller is lower, indicating that the amount of organic compounds in the water is reduced while maintaining a similar requirement for pumping energy in both situations.
- The suggested controller's nitrogen concentration is below the maximum allowable level for the WWTP.

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