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Development of an Automated Compact Wastewater Treament Facility in Mapua University Canteen Area with Ph and Dissolved Oxygen Monitoring

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Abstract. The lack of proper monitoring of wastewater parameters may result to non-conformance to effluent regulatory standards. The aim of this study was to fully automate a compact wastewater treatment with pH and Dissolved Oxygen Concentration monitoring for Mapúa University's canteen. The wastewater parameters that were considered were BOD, COD, TSS, and pH level. The prototype was built through the characterization of the canteen's effluent by which unit treatment operations performed were formulated. Furthermore, automation was applied using Programmable Logic Controller (PLC) and was monitored using Open Platform Communications (OPC)-based Graphical User Interface (GUI). Using t–test on the prototype's effluent parameters, it was found that -7.77, -7.74, -8.78 were the resulting t-values for BOD, COD, and TSS respectively compared to the -1.76 critical value. It was proven in these findings that the effluent's wastewater parameters were less than that of the DENR's effluent standards under DAO 2016-08 pursuant to RA 9275 (Philippine Clean Water Act of 2004). Thus, the prototype was proven capable of treating the canteen's wastewater

.**Keywords:** Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Hydraulic Detention Time (HDT), Wastewater, Programmable Logic Controller (PLC), Open Platform Communications (OPC), Graphical User Interface (GUI).

1. Introduction

Establishments are instructed to acquire discharge permits and Environmental Compliance Certificates (ECC) to allow the discharging of waste to adherent bodies of water subsequently avoiding penalties. Meanwhile, most of establishments dispose and monitor their wastewater without conforming to government regulations. In Metro Manila, approximately 2,000 m3 of solvent wastes, 22,000 tons of heavy metals, infectious wastes, biological sludge, lubricants, intractable wastes, and 25,000,000 m3 of acid/alkaline liquid wastes are incorrectly discharged per annum [1]. Poor water quality may consequently yield to potential risks to human life as per diseases relevant to water pollution. Having poor sanitation and water pollution may cause 6,000 premature deaths [2].

There have already been wastewater treatment facilities constructed in some areas in Bulacan, Davao Del Sur, Baguio, San Mateo, Dumaguete, and University of the Philippines, Diliman [1]. However, multiple establishments and corresponding treatment facilities still lack proper control and monitoring due to increasing population and infrastructures. While these existing facilities do treat their wastewater, they also require large land areas and equipment.

The main objective of this study was to develop an automated compact wastewater treatment for the canteen area of Mapúa University with pH and Dissolved Oxygen (DO) monitoring. The specific objectives

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of the study were the following: (1) to create a prototype of the design, (2) to determine hydraulic detention time, (3) to implement controls, monitoring and data acquisition, and (4) to apply statistical analysis for effluent wastewater parameters compared to the DENR effluent standards for wastewater parameters to be discharged in class C bodies of water under DAO 2016-08 pursuant to RA 9275 (Philippine Clean Water Act of 2004). Compact wastewater treatment for areas that have limited space while monitoring the treatment operations and effluent effectively was promoted in this study.

This study was intended to cover the design and automation of the compact wastewater treatment for Mapúa University Canteen. It also covered the comparison of the treatment's effluent wastewater parameters namely the biochemical oxygen demand (BOD), chemical oxygen Demand (COD), total suspended solids (TSS), and pH level to DENR's effluent standards (DAO 2016-08).

2. Methodology

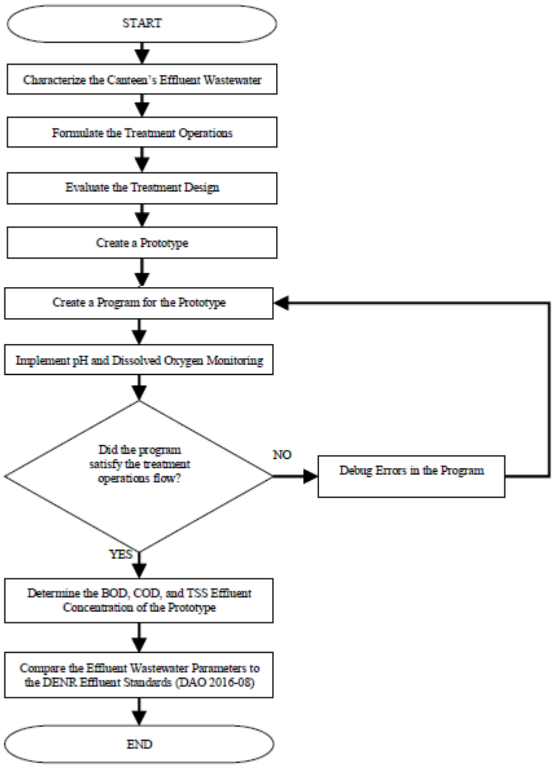

Fig. 1: Research Flowchart.

Fig. 1 shows the research process flowchart. The first step was to create a prototype based from the characterized canteen effluent wastewater, formulated treatment operations, and evaluated treatment design. Next, a PLC program with pH and Dissolved Oxygen monitoring was created to work in concurrence with the formulated treatment operations. Then, the program was tested to check if it satisfied the treatment operations sequence. Otherwise, errors were debugged before finalization. Lastly, the effluent wastewater parameters were compared to the DENR effluent standards (DAO 2016-08) if it met the set standard values for each parameter.

2.1. Characterization of the Canteen's Effluent Wastewater

Two factors considered in characterizing the canteen's effluent wastewater were the average wastewater flow rate and the influent wastewater parameters. The average wastewater flow rate was computed as the wastewater generated over time.

It was determined from the records of the Mapúa Campus Development and Maintenance Office (CDMO) that the wastewater generated from 2012 up to 2018 was equal to 6,190 m3 [3]. In the same period, the canteen's operation time was equal to 1,088 days [3]. A flow rate of 6 m3/d was determined using (1). Based on the results of laboratory testing, the influent wastewater parameter concentrations were determined to be 1,132 ppm for Biochemical Oxygen Demand – the amount of Dissolved Oxygen that must be present in water in order for microorganisms to decompose the organic matter in the water, 2,811 ppm for Chemical Oxygen Demand – measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals, 540 ppm for Total Suspended Solids – dry-weight of suspended particles, that are not dissolved, in a sample of water, and 4.83 for pH level or acidity level.

2.2. Maintaining the Integrity of the Specifications

The operations involved in treating wastewater as per physical, chemical, and biological treatment requirements involved screening, ph neutralization, coagulation, flocculation, sedimentation and aeration [4]. First, the large solid particles are to be screened from the wastewater. Next, the water's pH is to be adjusted using the alkaline Sodium Hydroxide as per the untreated water being acidic. Then, the wastewater is to be subjected to coagulation by having Aluminum Sulfate dosed and mixed into the wastewater to have floc settling occur. Lastly, the clarified wastewater was to be aerated which follows four phases: filling, aeration, settling, and decanting. Aeration reduces Biochemical Oxygen Demand and increases Dissolved Oxygen thus making the effluent viable for sustaining marine life when discharged.

2.3. Creation of the Prototype

The treatment design prototype was created based from the computed parameters shown in table I and II. Fig. 2 shows the actual prototype.

Table 1. Treatment's Tank Specification

Description	Symbol	Result	
Average Daily Wastewater Flow Rate	Q_{ww}	6	m^3/d
Equalization Tank	V_E	0.25	m^3
Neutralization Tank	V_N	0.25	m^3
Clarifier Tank	V_C	0.25	m^3
Aeration Tank	V_A	0.25	m^3
Total Volume	V_T	1.00	m^3

Table 2. Treatment's Mechanical Equipment Specification

Description	Symbol	Result	
Average Daily Wastewater Flow Rate	Q_{ww}	6	m3/d
Sodium Hydroxide Dosing Pump Flow Rating	Q_{NaOH}	0.18	m3/d
Aluminum Sulphate Dosing Pump Flow Rating	Q_{Alum}	0.0406 2	m3/d
Aerator Air Flow Rate	Q_{Air}	420	m^3
Neutralization Mixer Speed	ω_s	630	rev/min
Flocculator Speed	ω_f	13.66	rev/min

Fig. 2: Compact Wastewater Prototype.

The operating sequence of valves, motors, and pumps, shown on Fig. 2 were controlled by the PLC by means of monitoring sensor readings A ladder program that followed the automation process was uploaded to the PLC using the GX-Developer Software. Also, an Open Platform Communications (OPC) -based GUI was created for the monitoring of the electrical devices using the CX-Supervisor application for the construction of the GUI and the KepserverEx application for the OPC server, which connected the PLC to the GUI. Fig. 5 below shows the actual Graphical User Interface,

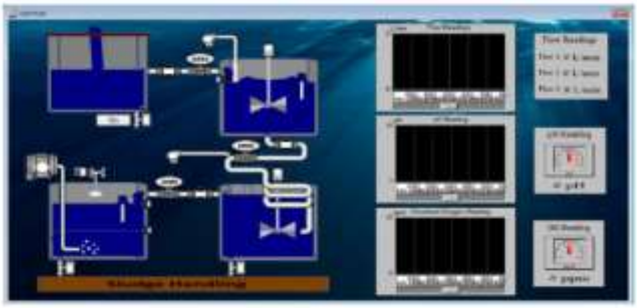

Fig. 3 Graphical User Interface

2.4. Results and Discussion

From the DENR effluent standard (DAO 2016-08) and aeration standard, pH level and Dissolved Oxygen concentration should be within the range of 6.0-9.0, and 2-3ppm, respectively. The effluent standards for BOD, COD, and TSS effluent parameters based on the DENR Administrative Order 2016-08 are 50ppm, 100ppm and 100ppm, respectively.

The overflow analysis was based on the hourly operation of the canteen (see table III). The “influent” refers to the hourly period readings of the sub meters from the canteen. Next, the “average influent” column was recorded by converting the wastewater flow rate to cubic meter per hour which was determined to be at 0.250 m3/h. Next, the fourth column was obtained from computing the difference of the two columns preceding it. Lastly, the “cumulative difference” column was determined by adding the preceding value in the fourth column to the current value in the same column. The highest overflow in the fifth column happened in the 11-hour period which was determined to be 0.248 m3. Thus, to prevent overflow, a 0.250 cubic meter equalization tank was designed. The hydraulic detention time (HDT) was patterned to the hour period set in the overflow analysis. Thus, the Hydraulic detention time of each tank was set at 1 hour each. The pH level and Dissolved Oxygen were tested and monitored to determine whether or not the created program satisfies the treatment operation sequence. The test was conducted using pH and DO sensors.

Table 3. Overflow Analysis

Time	Influent	Average Influent	Difference Between Influent and Average Influent	Cumulative Difference
10 h	0.388 m^3	0.250 m^3	0.138 m^3	0.221 m^3
11 h	0.277 m^3	0.250 m^3	0.027 m^3	0.248 m^3
12 h	0.027 m^3	0.250 m^3	-0.223 m^3	0.025 m^3

From table IV, it was observed that the values in the table were within the range as required by the DENR. Thus, the prototype satisfied the treatment operation. In comparing the prototype’s effluent parameters to the DENR’s effluent standards (DAO 2016-08), the capability of the prototype to treat wastewater was proven.

Table 4. pH Level and Dissolved Oxygen(DO) Concentration Monitored by pH and DO Sensor

Set	pH Level	Set	Dissolved Oxygen Concentration
1	7.02	1	2.40 ppm
2	7.10	2	2.43 ppm
3	7.00	3	2.56 ppm

From table V, it was observed that the values in the table were less than values required by DENR.

Table 5 Effluent Wastewater Parameters Concentrations

Samples	BOD	COD	TSS
1	28 ppm	60 ppm	45 ppm
2	35 ppm	70 ppm	44 ppm
3	43 ppm	86 ppm	45 ppm

The researchers conducted a one tailed t-test to support the claim that the effluent concentrations were less than the DENR's effluent standard (DAO 2016-08) values upon being treated by the prototype. The analysis was done by comparing t-value to the critical value. From table VI, it was observed that the t-values were less than the critical value. Thus, the claim was accepted.

Table 6. Statistical Analysis

Wastewater Parameter	Critical Value	t-value
BOD	-1.761	-7.77
COD	-1.761	-7.74
TSS	-1.761	-8.78

2.5. Conclusion

The researchers were also able to create and develop a PLC-automated yet compact wastewater treatment prototype capable of improving wastewater quality parameters. They also were able to statistically analyze important water quality parameters in comparison to the DENR's effluent standards for Class C bodies of water. In characterizing the canteen's wastewater discharge, a flow rate of 6 m3/d was determined through data from the Mapúa CDMO. Next, concentrations of 1,132 ppm for BOD, 2,811 ppm for COD, 540 ppm for TSS, and 4.83 for pH level were attained from laboratory results; where, these values were not conforming to effluent standards set by DAO 2016-08 pursuant to RA 9275 (Philippine Clean Water Act of 2004). Lastly, screening, pH neutralization, coagulation, flocculation, sedimentation, and aeration operations were selected and studied to be used as treatment operations in treating the canteen's wastewater. It was concluded from this evaluation that the Mapúa University Canteen's wastewater is in need of treatment, and the canteen space and data proved that research and development of a prototype was viable.

The researchers determined the hydraulic detention time. A 1-hour period was given to each tank in the design compact wastewater treatment as per dosage, filling, and decanting times studied per unit operation. Also, flow rate was considered in determining HDT. It was determined that upon computing for the HDT, the prototype was capable of preventing overflow and backflow.

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