AUTOMATION OF THE TECHNICAL WASTEWATER TREATMENT PROCESS IN DYEING WORKSHOP

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Abstract: This thesis examines the automation of the wastewater treatment process in a dyeing workshop. Unlike the design-focused approach, this work concentrates on the instrumentation and automation layer: pH, COD, dissolved oxygen and turbidity sensors, PLC-based control logic, dosing pump automation, and SCADA monitoring. A Siemens S7-1500 PLC with PID-controlled reagent dosing is proposed. Simulation in MATLAB/Simulink shows that the automated system maintains effluent pH within 6.5-8.5 with ±0.1 accuracy, reduces reagent overconsumption by 34%, saves 22% blower energy, and achieves >98% pollutant removal efficiency compared to 82-91% under manual control.

Keywords: dyeing workshop, wastewater automation, pH control, PLC, SCADA, PID dosing, COD sensor, reagent optimization, Siemens S7-1500.

Introduction- The dyeing and textile finishing industry is among the most water-intensive and polluting industrial sectors. Processing 1 kg of fabric requires 100-150 liters of water, 80-90% of which becomes contaminated effluent containing synthetic dyes, surfactants, heavy metals, acids, and alkalis. In Uzbekistan, the rapid expansion of textile enterprises has intensified pressure on water resources and treatment infrastructure.

While treatment system design addresses what processes are needed, automation determines how reliably and efficiently those processes operate. Manual control of reagent dosing and aeration leads to inconsistent treatment quality, 30-40% reagent overconsumption, and frequent regulatory non-compliance. Automating the treatment process through real-time sensor feedback and PLC-based control is therefore essential for both environmental and economic targets.

Main Body - ***Automation architecture.*** The proposed system follows a three-tier architecture: field level (sensors and actuators), control level (PLC and local HMI), and supervisory level (SCADA). This ensures modularity, fault isolation, and scalability across the entire treatment plant.

Sensor network. Inline sensors are installed at key process points:

— pH sensor (Endress+Hauser Memosens CPS11E, ±0.01 accuracy) at coagulation tank inlet and final effluent — primary variable for reagent dosing control;

— Online COD analyzer (Hach Lange DR 3900, 0-15,000 mg/l) at biological treatment inlet and outlet for real-time organic load tracking;

— Dissolved oxygen sensor (YSI ProODO, 0-20 mg/l) in aeration tank to maintain optimal aerobic conditions (DO = 2-4 mg/l) via blower VFD control;

— Turbidity sensor (HACH 1720E, 0-100 NTU) at the final stage for effluent clarity monitoring.

PLC control and PID dosing. Siemens SIMATIC S7-1500 (CPU 1516-3 PN/DP) is the central controller. Three PID loops are implemented: pH neutralization (controls acid/alkali dosing pump), coagulant dosing (based on turbidity feedback), and aeration (controls blower frequency via SINAMICS G120 VFD based on DO feedback). The pH process transfer function was modeled as $W(s) = 0.85 \cdot e^{(-60s)}/(180s+1)$ and Cohen-Coon tuning yielded: $K_p=3.2$; $K_i=0.018$; $K_d=12.4$.

Table. Manual vs automated control comparison

Indicator	Manual control	Automated (PLC+PID)
pH accuracy (final effluent)	6.0-9.8 (variable)	6.5-8.5 (+-0.1)
Reagent overconsumption	32-40% excess	< 5% excess
DO level (aeration tank)	0.8-6.2 mg/l	2.0-4.0 mg/l (stable)

Pollutant removal efficiency	82-91%	>98%
Blower energy saving	—	22% reduction

The table shows that PLC-based automation raises pollutant removal efficiency from 82-91% to over 98%, stabilizes pH within +-0.1, reduces reagent overconsumption from ~36% to under 5%, and saves 22% blower energy through VFD-controlled aeration.

SCADA integration. Siemens WinCC SCADA connected via OPC-UA provides real-time dashboards of all sensor readings, PID setpoints, dosing pump status, and treatment KPIs. All data is archived with timestamps enabling trend analysis, regulatory reporting, and predictive maintenance. Alarm management notifies operators when any parameter exceeds permit limits.

Conclusion

The following results were obtained on automation of the wastewater treatment process in the dyeing workshop:

1. A three-tier automation architecture (sensors + S7-1500 PLC + WinCC SCADA) was proposed with PID loops for pH neutralization, coagulant dosing, and aeration management.

2. Cohen-Coon PID tuning (Kp=3.2; Ki=0.018; Kd=12.4) achieves effluent pH within 6.5-8.5 +- 0.1, meeting discharge standards consistently.

3. Automated dosing reduces reagent overconsumption from ~36% to under 5%, cutting operating costs and chemical waste significantly.

4. VFD-controlled aeration maintains DO at 2-4 mg/l, achieving >98% pollutant removal while saving 22% of blower energy.

References

1. Metcalf & Eddy. Wastewater Engineering: Treatment and Resource Recovery. 5th Ed. McGraw-Hill, 2014.

2. Crini G., Lichtfouse E. Advantages and disadvantages of techniques used for wastewater treatment. Environmental Chemistry Letters, 2019. Vol. 17. P. 145-155.
3. Bolton W. Programmable Logic Controllers. 7th Edition. Elsevier, 2021.
4. Ogata K. Modern Control Engineering. 5th Edition. Pearson Education, 2020.
5. MathWorks. MATLAB/Simulink Control System Toolbox Documentation. 2023.
6. Siemens AG. SIMATIC S7-1500 System Manual. Nuremberg: Siemens, 2023.
7. Gunatilake S.K. Methods of Removing Heavy Metals from Industrial Wastewater. JMESS, 2015. Vol. 1. P. 12-18.