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DESIGN GET UP SYSTEM REACTOR CONTROL AND MONITORING PHOTOCATALYST ZnO / TiO ₂- CuKA ARDUINO BASED

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Abstract

Photocatalysis process generally Still operated manually , so that duration radiation intersample No uniforms and operators at risk exposed ultraviolet (UV) radiation . Research This design and test system reactor control and monitoring photocatalyst ZnO / TiO ₂- CuKA Arduino Uno based system consists of on three knob input ; four relay module controlling channel pump filling , UV lamp , magnetic stirrer, and pump drainage ; as well as a 16×2 I2C LCD and buzzer as a media for monitoring status and process time . One cycle operation covering filling solution for 30 s, irradiation and stirring for 3600 s, and drainage for 17 s. Testing functional in 11 scenarios , including termination emergency at every stage , showing that all over relay, LCD, and buzzer responses are appropriate with design . Functional testing reactor use solution methylene blue 100 ppm produces efficiency 91% degradation in the 60th minute . System This standardize duration radiation every sample and eliminate contact directly to the operator solution and UV light during the process .

Keywords: *Arduino Uno; photocatalysis; methylene blue; UV reactor; monitoring system*

1. INTRODUCTION

Waste liquid industry textiles contain substance color difficult synthetic decomposed , decomposed toxic , and lowers quality of the receiving water body (Samsami et al., 2020; Wang et al., 2022). Photocatalysis based semiconductor like TiO_2 and ZnO be one of promising solution Because capable to describe compound organic complex into CO_2 and H_2O with help light (Chen et al., 2020). Merging ZnO / TiO_2 with carbon active reported increase capacity adsorption at a time separation charge on the catalyst (Taghizadeh -Lendeh et al., 2024). Apart from being determined by the catalyst material , the rate degradation is greatly influenced by conditions operations , especially duration and conditions irradiation (Enesca & Isac, 2020). Variation small in the duration of exposure intersample will shift mark efficiency and constant reported rate . Therefore that , control condition uniform operations is prerequisites for kinetic data can compared to .

In a number of study previously , reactor photocatalyst Still operated manually . Fathulhaq et al. (2020) used only a turbidity sensor measure turbidity solution . Nabiilah et al. (2023) used reactor "Calma" acrylic , while David & Nuraliyah (2024) used 60 W UV lamp equipped fan and magnetic stirrer. In a manual system , the ignition lights , stirring , and recording time depends on the operator. As a result , the duration radiation prone to No uniform , operator touch direct with solution , and eyes and operator's skin is at risk exposed UV radiation . Automation based microcontroller offer road go out from limitations Kubiak (2025) shows that that system controlled photocatalytic in a way electronic can applied to wastewater treatment real . For laboratory education vocational , Arduino Uno becomes the right choice Because cost low , easy programmed , and has ecosystem extensive modules . Study This aim design , realize , and test system reactor control and monitoring photocatalyst ZnO / TiO ₂- CuKA Arduino Uno based system automate order filling solution , UV irradiation with stirring , and drainage , as well as Displays the status and processing time on the LCD. System performance evaluated through testing functional based degradation scenarios and tests solution methylene blue .

2. RESEARCH METHOD

Study use method design building consisting of on three stage : design device hard , design device software , and testing system . Testing includes functional tests based degradation scenarios and tests methylene blue (MB) inside reactor .

2.1 Design Device Hard

System arranged top five groups functional , namely input , controller , output , actuator reactor and supply power (Figure 1). Input in the form of START, FILL WATER, and STOP buttons . Arduino Uno reads condition button , run timing , and determining output . Output consists of on a 16×2 I2C LCD and buzzer as monitoring media, as well four relay modules channel as switch electronic for four actuator reactor .

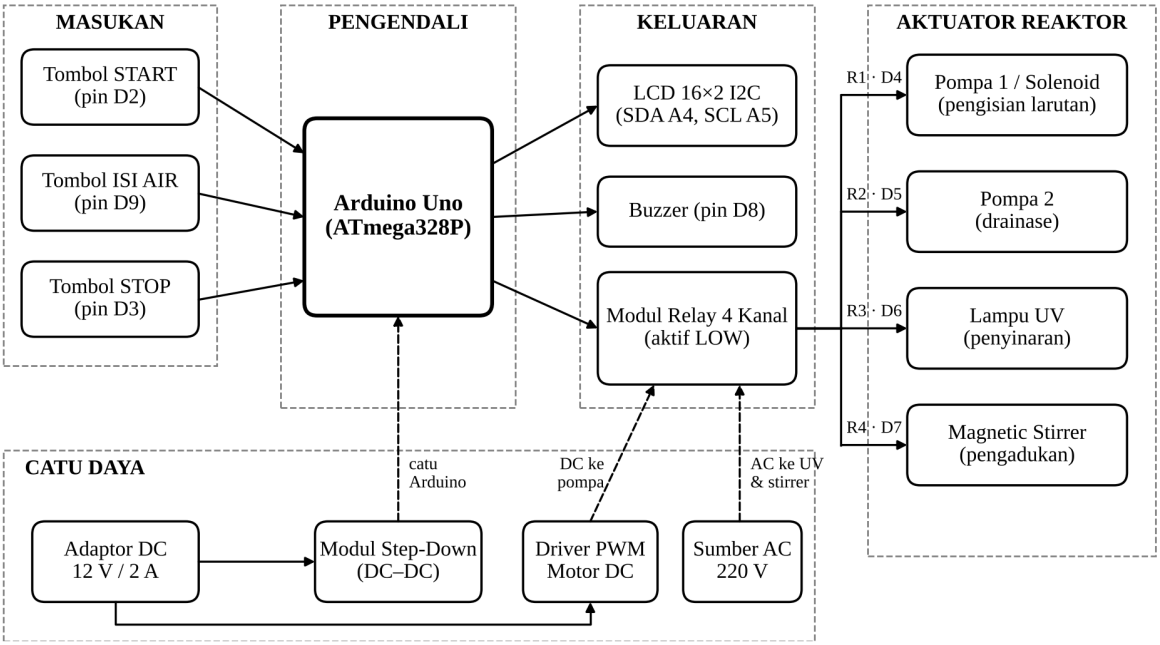


Figure 1. Block diagram system reactor control and monitoring photocatalyst

Specifications and functions each component summarized in Table 1, while Arduino Uno pin configuration is shown in Table 2.

Table 1. Components device hard system

Component	Specification	Function
Arduino Uno	ATmega328P, 5 V, 16 MHz	Controller main
channel relay module	10 A/250 VAC contact, input active LOW	Switch pump , UV lamp , and stirrer
16×2 LCD + I2C module	I2C address 0x27	Showing stages and process time
Buzzer	Active 5 V	Bait come back end of process button and alarm
Knob press (3 pieces)	Push button, INPUT_PULLUP	Enter START, FILL WATER, and STOP
Pump 1	DC pump	Stream solution to beaker
Pump 2	DC pump	Empty solution (drainage)
UV lamp	AC 220 V	Source photon For activation catalyst
Magnetic stirrer	AC 220 V	Stirring during radiation
DC adapter	12 V / 2 A	Power supply DC side
Step-down module	DC–DC converter	Arduino power supply
DC motor PWM driver	Regulator speed	Arrange rate flow pump

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Table 2. Arduino Uno pin configuration

Pin	Component	Mode	Active logic
D2	START button	INPUT_PULLUP	LOW
D3	STOP button	INPUT_PULLUP	LOW
D9	FILL WATER button	INPUT_PULLUP	LOW
D4	Relay 1 (pump filling)	OUTPUT	LOW
D5	Relay 2 (pump drainage)	OUTPUT	LOW
D6	Relay 3 (UV lamp)	OUTPUT	LOW
D7	Relay 4 (magnetic stirrer)	OUTPUT	LOW
D8	Buzzer	OUTPUT	HIGH
A4 / A5	I2C LCD	SDA / SCL	–

System applying two conventions logic . First , the button using an internal pull-up resistor, so that the pin is HIGH when knob released and LOW when pressed . Second , the relay is active LOW, so that all relay pins are initialized HIGH in the function setup( ) so that all burden dead moment system turned on . The AC load is supplied through relay contacts , so that side isolated 220 V power from side Arduino logic . Relay 3 and Relay 4 are enabled and disabled simultaneously , so that stirring always ongoing during irradiation .

2.2 Design Software

The program is written in the Arduino IDE using library Wire.h and LiquidCrystal_I2C.h. The program consists of over five functions , namely setup( ), loop( ), buzz( ), the irradiation process function , and stopSystem ( ). Three variables boolean set system status : isSystemActive (system has enabled), isWaterFilling (filling has started), and processCompleted (cycle finished or stopped).

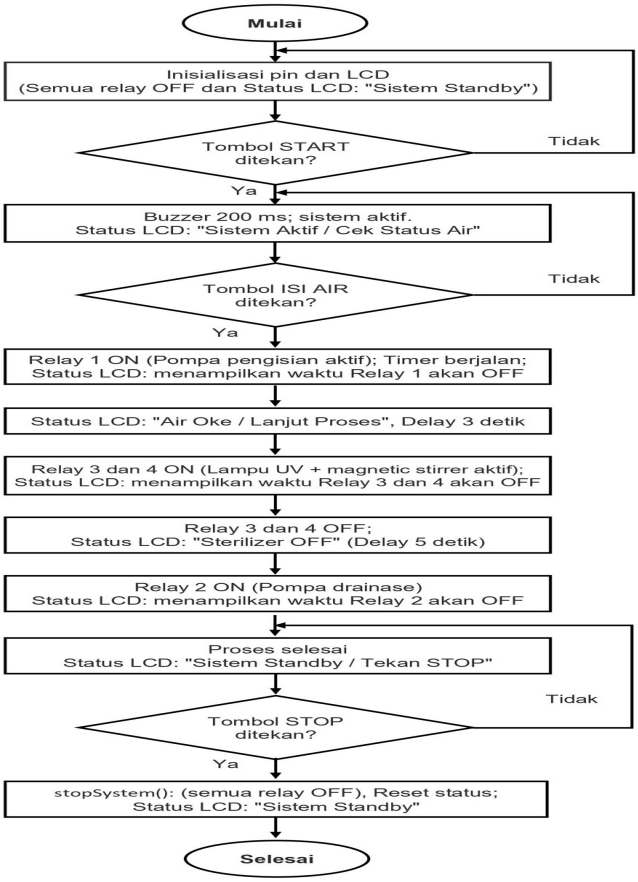


Figure 2. System program flowchart control reactor photocatalyst

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The program flow in Figure 2 runs in a way sequential . After The START button is pressed , the operator presses FILL WATER to operate pump charging system Then operate irradiation and stirring , drainage , then return to condition standby . The STOP button is read on every stage , so that all over actuator can turned off When just .

2.3 Procedure Testing

Functional test done with give input buttons on each condition system , then observe relay, LCD, and buzzer response . scenario tested , including normal operation and shutdown emergency at the stage filling , lighting , and drainage . Scenario stated succeed if response current The same with designed response .

Degradation test done with 40 mL of 100 ppm MB solution and catalyst ZnO / TiO ₂- CuKA as much as 1 gram. Absorbance measured with UV-Vis spectrophotometer in the range of 200–1000 nm with 1 nm intervals. The 0 minute sample was diluted 10 times because absorbance beyond linear range of the detector .

Efficiency degradation (η) is calculated from absorbance at length wave maximum MB, which is 664 nm, using Equation (1).

$$\eta\,(\%) = \frac{A_0 - A_t}{A_0} \times 100\% \qquad (1)$$

3. RESULTS AND DISCUSSION

3.1 Realization Prototype

Prototype reactor succeed realized in form room metal closed with UV lamp and magnetic stirrer inside (Figure 3). Control box contains Arduino Uno, relay module , and wall - mounted LCD outside reactor . Tank bait and container container connected to reactor through hose that is fed by the pump .



Figure 3. Prototype reactor photocatalyst with system Arduino Uno based control and monitoring

Closed space obstruct light outside enter to solution , so that source photon only originate from UV lamp . Construction this also holds UV radiation inside reactor . Because the LCD is outside reactor , the operator can monitor the way process without open room irradiation .

3.2 Monitoring Status and Processing Time

One cycle operation ongoing approximately 3655 s or ±61 minutes and divided on nine stages (Table 3). At each stage , the LCD displays the stage name on the first line and the time walking on the second line .

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Table 3. Stages process , relay status, and LCD display

No	Stage	Relay active	LCD display	Duration
1	Standby	–	Lecturer Standby / Research System	Until START is pressed
2	System active	–	System Active / Check Water Status	Until the WATER FILL is pressed
3	Charging solution	R1	Filling Water / Time: n seconds	30 s
4	Confirmation	–	Water OK / Continue Process	3 s
5	Irradiation and stirring	R3, R4	Degradation / Time: n seconds	3600 s
6	Pause	–	OFF Degradation	1 s
7	Drainage	R2	Drainage ON / Time: n seconds	17 s
8	Finished	–	System / Press STOP	4 s
9	Stop	All OFF	PTI Standby / Research System	2 s

Monitoring implemented status and time . Information This give know which stage operator is on walking and the rest the time , while the buzzer marks emphasis buttons and ends irradiation . Thus , the operator does not need be near reactor for 60 minutes irradiation . Duration 3600 s irradiation is determined by the program, not by manual recording , so that every sample accept time the same irradiation .

3.3 Functional Test Results

All 11 test scenarios resulted in appropriate response with design , so that level functional test success reached 100% (Table 4).

Table 4. Functional test scenarios and results

No	Scenario	Response current	Results
1	System turned on	All relays OFF; LCD " System Standby"	In accordance
2	START is pressed moment standby	Buzzer 200 ms ; LCD " System Active / Check Water Status"	In accordance
3	AIR CONTENT pressed moment system active	Relay 1 ON; LCD counts 30 s	In accordance
4	Charging finished	Relay 1 OFF; LCD "Water OK / Continue Process"	In accordance
5	START is pressed return without filling	Direct to stage radiation without pump	In accordance
6	Stage radiation	Relay 3 and 4 ON; LCD counts 3600 s	In accordance
7	Stage drainage	Relay 2 ON; LCD counts 17 s	In accordance
8	Cycle finished	All relays OFF; LCD " System Standby / Press STOP"	In accordance
9	STOP when filling	Relay 1 OFF immediately ; LCD " System Standby"	In accordance
10	STOP when radiation	Relay 3 and 4 OFF immediately ; LCD " System Standby"	In accordance
11	STOP when drainage	Relay 2 OFF immediately ; LCD " System Standby"	In accordance

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Scenario 9–11 shows that STOP button can cut off actuator on each stage . Function This important as safety , for example when happen leakage hose or door reactor need opened . Scenario 5 allows reactor executed repeat with the solution that has been be inside beaker without lid filling addition .

3.4 Degradation Test Methylene Blue

Controlled reactor system This degrades 100ppm in 60 minutes achieved 91% degradation . Efficiency This more tall than decline 21% turbidity in the system ZnO:KA (Fathulhaq et al., 2020) and 53.64% degradation in the reactor TiO_2 with concentration of 6 ppm (Nabiilah et al., 2023). Comparison This need read with Be careful Because catalyst , source light and concentration initially different . However , the results the show that reactor automatic This capable running the photocatalysis process in a way effective . Because carbon active own Power adsorption high , contribution adsorption to decline color need separated through dark tests in research continued . System moment This Work based time . Filling volume determined by the duration of the pump lights up , so that depends on stability rate flow . The system is also not yet measure intensity light , temperature solution , as well as concentration substance color in a way directly , and not yet save data.

4. CONCLUSION

System reactor control and monitoring photocatalyst ZnO / TiO_2- CuKA based on Arduino Uno has succeed designed and realized . The system automate order charging 30 s, irradiation and stirring 3600 s, and drainage 17 s, and displays the status and time every stages on a 16×2 LCD. functional test scenario successful , including termination emergency at every stage . Functional test reactor produce degradation of MB 100 ppm by 91% System This standardize duration irradiation and eliminating contact directly to the operator solution and UV radiation . Research advanced recommended add height sensor solution , UV intensity , and temperature , as well as database - based data recording time .

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