TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
PULCHOWK CAMPUS

Final Project Report On
Instrumentation Case Study

Visit Undertaken At
Aqua world,
Gokaneswor

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Learning transcends beyond books and text-related activities. Particularly in engineering, where innovation and technical expertise are highly valued, hands-on practical experience proves to be far more enriching than studying in isolation. It provides exposure to real-world working environments. Our learning journey was greatly facilitated by various individuals. With the dedication of numerous teaching and non-teaching staff, our case study reached fruition, and we extend our heartfelt acknowledgement to them. It is a privilege to use the pages of this study to express our gratitude and respect to all those who contributed to the success of this project, despite their busy schedules.

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INTRODUCTION

Overview of the Case Study

This case study examines the Aqua World water purification plant, focusing on the processes, technologies, and methodologies employed in water purification. Through an on-site visit, we gained insights into the practical applications of theoretical knowledge in the field of water treatment. The case study aims to provide a detailed account of the plant's operations, the challenges faced, and the solutions implemented to ensure the delivery of clean and safe water. Furthermore, this study identifies specific issues within the current system and proposes enhancements to improve efficiency and effectiveness.

Importance of Water Purification

Water purification is a critical process that ensures the availability of clean and safe water for consumption, industrial use, and environmental sustainability. Contaminated water poses significant health risks, including waterborne diseases, and can have detrimental effects on ecosystems. Efficient water purification systems are essential to remove impurities, pathogens, and harmful chemicals, thereby safeguarding public health and promoting overall well-being. In the context of increasing environmental pollution and water scarcity, advanced water treatment solutions have become more crucial than ever.

Purpose and Objective of the Visit

The primary purpose of our visit to Aqua World was to observe and understand the practical aspects of water purification processes. The specific objectives were to:

- Gain first-hand experience of the operations within a water purification plant.
- Understand the different stages of water treatment and the technologies used.
- Learn about the quality control measures and testing procedures in place.
- Identify the environmental and social impacts of water purification practices.
- Engage with professionals to discuss the challenges and innovations in the field.
- Study the existing system and propose improvements to address identified issues.

This visit not only enhanced our understanding of water purification but also provided valuable insights into the integration of theoretical knowledge with real-world applications and highlighted opportunities for system improvements.

Company Profile

History and Background of Aqua World

Aqua World is a leading jar water processing company that has been providing its services for over a decade. Established with the aim of ensuring the availability of pure and safe drinking water, Aqua World has become a trusted name in the Kathmandu Valley. The company specializes in delivering jar water directly to customers' doorsteps, a service that has been highly appreciated by the local community. Aqua World has made it convenient for customers to order water through their website and mobile apps, enhancing accessibility and customer satisfaction. As a Nepalese company registered under the Company Act of the Nepal Government, Aqua World operates in compliance with regulations set by the Department of Food Technology and Quality Control and the Department of Cottage Industries.

Mission and Vision of the Plant

Aqua World's mission is to provide the highest quality jar water to its customers, ensuring that every drop is pure and safe for consumption. By leveraging advanced purification technologies and adhering to stringent quality standards, Aqua World aims to be the foremost provider of clean drinking water in the Kathmandu Valley.

Aqua World envisions a future where every household in the Kathmandu Valley has access to pure and safe drinking water. With a commitment to innovation and customer service, the company strives to expand its reach and continue delivering on its motto: "Make sure, Drink Pure." Aqua World aims to set the benchmark for excellence in water purification and distribution, fostering a healthier community.

Key Personnel and Organizational Structure

Aqua World's organizational structure is designed to ensure efficient operations and high-quality service delivery. The key personnel include:

- Chief Executive Officer (CEO): The CEO oversees the overall management and strategic direction of the company, ensuring that Aqua World's mission and vision are realized.
- Operations Manager: Responsible for overseeing the day-to-day operations of the water purification plant, ensuring that all processes meet the required standards.
- Quality Control Manager: Ensures that the water meets stringent quality and safety standards before it is distributed to customers. This role involves regular testing and monitoring of the purification processes.
- Logistics Manager: Manages the distribution network, ensuring timely and efficient delivery of jar water to customers across the Kathmandu Valley.
- Customer Service Manager: Handles customer inquiries, orders, and feedback, ensuring a high level of customer satisfaction and engagement.
- IT Manager: Maintains the company's website and mobile apps, ensuring a seamless and user-friendly experience for customers placing orders online.

Water Purification Process

Overview of the Entire Process

Aqua World's water purification process is a comprehensive multi-stage system designed to ensure the delivery of clean, safe, and high-quality drinking water. The process begins with the intake of ground water or spring water and includes various stages of treatment to remove impurities, pathogens, and contaminants. Each stage is carefully engineered to address specific types of pollutants and ensure that the final product meets the highest safety and quality standards. The purified water is then stored in a product water tank before being distributed to customers.

Stages in Water Purification

1. Intake (Ground Water/Spring Water)
2. Sedimentation
3. Chlorination
4. Sand Filtration
5. Carbon Filtration
6. Candle Filtration
7. Micron Cartridge Filtration
8. Reverse Osmosis (RO)
9. Ozonation
10. Polishing
11. UV Water Purifier
12. Product Water Tank

Technologies and Equipment Used

1. Sedimentation Tanks: For initial settling of larger particles and sediments.
2. Chlorine Injectors: For disinfection and microbial control.

3. Sand Filters: To remove suspended solids and particulate matter.
4. Activated Carbon Filters: For removing chlorine, organic compounds, and chemicals.
5. Ceramic Candle Filters: For trapping small particles and impurities.
6. Micron Cartridge Filters: For fine filtration of small particles and microorganisms.
7. Reverse Osmosis Membranes: For removing dissolved salts, heavy metals, and impurities.
8. Ozone Generators: For advanced disinfection and oxidation.
9. UV Lamps: For sterilizing the water by killing bacteria and viruses.
10. Product Water Tanks: For hygienic storage of the final purified water.

Existing System of the Water Processing and Treatment

Description of the Current Water Purification System

Aqua World's current water purification system is designed to ensure the provision of high-quality drinking water by utilizing a multi-stage treatment process. The system begins with sourcing water from ground or spring water, followed by a series of purification steps that address various contaminants and ensure the water meets stringent quality standards. This system has been operational for over a decade, consistently delivering safe and clean water to customers throughout the Kathmandu Valley.

Processing System Details

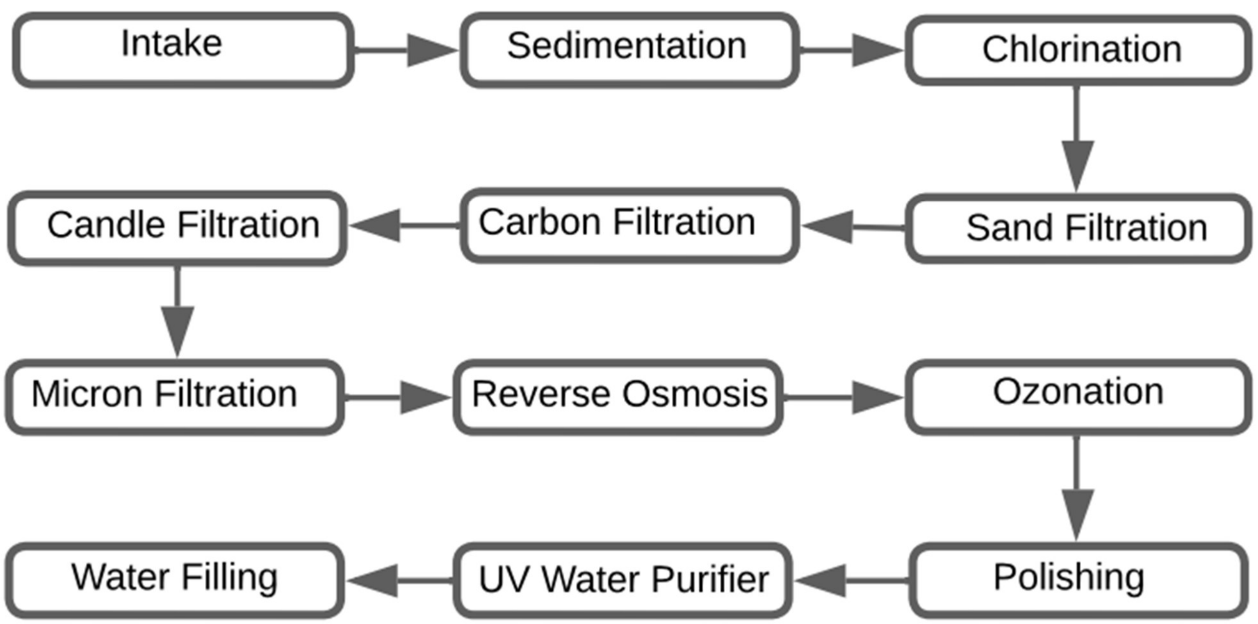
The existing water purification system at Aqua World follows a meticulously designed sequence of treatments, each aimed at removing specific impurities and enhancing the overall quality of the water. The stages are as follows:

1. Intake (Ground Water/Spring Water)
   - Description: Water is sourced from selected ground water or spring water sources. These sources are chosen for their initial quality and natural purity.
   - Purpose: To begin the purification process with water that has minimal initial contamination.
2. Sedimentation
   - Description: The water is directed into sedimentation tanks where it is allowed to sit undisturbed. Larger particles, sediments, and debris settle to the bottom of the tank.
   - Purpose: To remove larger solids and reduce the turbidity of the water, preparing it for further treatment.
3. Chlorination
   - Description: Chlorine is added to the water to kill bacteria, viruses, and other microorganisms. This step is crucial for microbial disinfection.
   - Purpose: To ensure that the water is free from harmful pathogens that could pose health risks.
4. Sand Filtration
   - Description: Water passes through layers of sand in sand filters. The sand traps and removes suspended solids and particulate matter.
   - Purpose: To further clarify the water by removing finer particles not captured during sedimentation.
5. Carbon Filtration
   - Description: The water flows through activated carbon filters, which adsorb chlorine, organic compounds, and other chemicals that can affect the taste and odor of the water.
   - Purpose: To improve the taste, odor, and overall quality of the water by removing chemical contaminants.
6. Candle Filtration
   - Description: Water is filtered through ceramic candle filters, which have a porous structure to capture smaller particles and impurities.

- Purpose: To provide additional filtration and remove fine particles that may have passed through previous stages.

7. Micron Cartridge Filtration
   - Description: The water is passed through micron cartridges that filter out very small particles and microorganisms.
   - Purpose: To achieve a higher level of clarity and purity by removing microscopic contaminants.
8. Reverse Osmosis (RO)
   - Description: Water is forced through a semi-permeable membrane in the RO process, which removes dissolved salts, heavy metals, and other impurities.
   - Purpose: To significantly reduce the total dissolved solids (TDS) and enhance the purity of the water.
9. Ozonation
   - Description: Ozone is injected into the water to further disinfect and oxidize organic and inorganic substances.
   - Purpose: To provide an additional layer of disinfection and remove any remaining contaminants without leaving harmful residues.
10. Polishing
    - Description: The water undergoes final polishing treatments, which may include additional carbon filtration or other fine filtration methods.
    - Purpose: To ensure the water reaches the highest standards of purity and taste before storage.
11. UV Water Purifier
    - Description: Ultraviolet (UV) light is used to sterilize the water, destroying any remaining bacteria and viruses.
    - Purpose: To provide final disinfection and ensure microbiological safety of the water.

Illustrative Representation of the Existing Model



Quality Control and Testing

Water Quality Standards and Regulations

Aqua World adheres to stringent water quality standards and regulations to ensure the safety and purity of its drinking water. The company complies with national and international guidelines, including those set by the Department of Food Technology and Quality Control and the Department of Cottage Industries of Nepal. These standards dictate the permissible levels of various contaminants and ensure that the water is safe for human consumption. Aqua World's commitment to quality is reflected in its rigorous testing protocols and adherence to these regulations.

Methods of Testing

To maintain the highest standards of water quality, Aqua World employs a comprehensive testing regimen that includes both in-house and third-party laboratory analyses. The methods used for testing water quality include:

- Physical Testing: Measures properties such as turbidity, color, odor, and taste.
- Chemical Testing: Analyzes the presence of chemical contaminants, including heavy metals, nitrates, and chlorine levels.
- Microbiological Testing: Detects bacteria, viruses, and other pathogens to ensure microbiological safety.
- Organoleptic Testing: Assesses the sensory qualities of water, such as taste and smell, to ensure consumer satisfaction.

Frequency of Testing:

- Daily Testing: Routine checks are performed daily to monitor key parameters such as chlorine levels, pH, and turbidity.
- Weekly Testing: Comprehensive chemical and microbiological tests are conducted weekly to ensure ongoing compliance with quality standards.
- Monthly Testing: Detailed analyses, including tests for trace contaminants and comprehensive microbiological assessments, are performed monthly.
- Annual Testing: Extensive testing by accredited third-party laboratories to validate in-house testing results and ensure compliance with national and international standards.

Common Contaminants Tested and Their Allowable Limits

Aqua World tests for a variety of contaminants to ensure the water meets all safety and quality standards. Some common contaminants tested and their allowable limits include:

1. Microbiological Contaminants:
    - Coliform Bacteria: Must be absent in 100 ml of water.
    - E. Coli: Must be absent in 100 ml of water.
    - Total Plate Count: Should be less than 500 CFU/ml.
2. Chemical Contaminants:
    - Chlorine: Residual chlorine levels should be between 0.2 to 0.5 mg/L.
    - Nitrates: Should not exceed 50 mg/L.
    - Fluoride: Should be within 0.5 to 1.5 mg/L.
3. Heavy Metals:
    - Lead: Should not exceed 0.01 mg/L.
    - Arsenic: Should not exceed 0.01 mg/L.
    - Mercury: Should not exceed 0.001 mg/L.

4. Physical Parameters:
    - pH: Should be between 6.5 and 8.5.
    - Turbidity: Should be less than 1 NTU.
    - Color: Should be less than 15 color units.

By adhering to these rigorous testing protocols and maintaining compliance with established standards, Aqua World ensures that the water delivered to customers is of the highest quality, safe for consumption, and free from harmful contaminants. The commitment to quality control and continuous testing underscores Aqua World's dedication to public health and customer satisfaction.

Dispatch and Delivery of Water Jars

Overview of the Dispatch and Delivery Process

After completing the first phase of water purification, Aqua World prepares the jars for refilling with purified drinking water. This phase, while heavily reliant on manpower, also involves automation and micro-controller technology to enhance efficiency and effectiveness. The sub-processes involved in this phase include receiving, rinsing, bottling and labeling, storage, and dispatch. Each sub-process is critical in ensuring the jars are delivered safely and efficiently to customers.

Logistics and Distribution Network

Aqua World's logistics and distribution network is designed to handle the receipt, processing, and delivery of water jars throughout the Kathmandu Valley. The network ensures timely and efficient delivery, maintaining the quality and integrity of the water during transit. The process involves several key steps:

1. Receiving of Jars
   Jars are received from various parts of Kathmandu via jeeps and other vehicles. The unloading is done manually, which can lead to wear and tear of the jar bases over time. To mitigate this, introducing compartments for bulk unloading can prevent damage and improve efficiency.
2. Rinsing of Jars
   Jars are rinsed using a compact and economical machine. The empty jars are placed in an inverted position on the rinsing jacket manually, and the process is initiated via a control panel. Rinsing occurs in three sections with minimally treated raw water from a nearby source.This machine is easy to operate, maintenance-free, and ensures the jars are clean before filling.
3. Bottling and Labeling
   After rinsing, the jars are filled manually, maintaining high hygiene standards. Six outlets operate simultaneously, refilling around 3,000 jars daily. The bottles, caps, and company logos are sourced from an external plastic factory.
4. Storage of Jars
   The sequential nature of refilling and delivery minimizes the need for extensive storage. During exceptions like curfew days, jars are stored in cool, shaded areas to prevent deterioration. Jars should be stored horizontally on the ground without stacking to avoid damage.
5. Dispatch
   Once vehicles arrive, jars are loaded manually, a process that can be time-consuming. Automation could streamline this process, reducing labor costs and enhancing efficiency despite higher initial investments.
6. Quality Checks
   Skilled personnel monitor each process, ensuring the quality of work. Water samples undergo physical, chemical, and bacteriological tests to maintain quality standards.

Illustration Showing Receiving and Dispatch of Water Jars

An illustrative representation of the receiving and dispatch process helps visualize the workflow and identify areas for potential improvement:

1. Receiving
    - Vehicles arrive at the plant.
    - Jars are manually unloaded into designated compartments to prevent damage.
2. Processing
    - Jars undergo rinsing, filling, and labeling.
    - Quality checks are performed at each stage.
3. Storage
    - Jars are stored in cool, shaded areas during exceptional circumstances.
    - Proper storage techniques are employed to maintain jar integrity.
4. Dispatch
    - Vehicles are loaded with jars for delivery.
    - Manual loading is done with care to avoid damage.
5. Delivery
    - Jars are delivered to retailers and customers throughout the Kathmandu Valley.
    - Continuous quality checks ensure the water remains pure and safe.

Environmental Impact

Efforts to Minimize Environmental Footprint

Aqua World is committed to minimizing its environmental footprint through a variety of sustainable practices and initiatives. The company recognizes the importance of protecting the environment while providing clean and safe drinking water. Key efforts include:

- Solid Waste Management: Aqua World manages solid waste effectively by recycling used jars and ensuring that waste materials are properly sorted and processed. The company runs awareness programs to educate customers and staff on the importance of jar protection and promotes the reuse of jars to minimize waste.
- Energy Consumption: The Company utilizes solar panels to harness renewable energy, reducing its reliance on conventional power sources and lowering its carbon footprint.
- Effluent Treatment: Aqua World treats wastewater generated during the purification process in an effluent treatment plant. This ensures that any residual contaminants are removed before the water is discharged, meeting environmental quality standards.
- Chemical Use: The Company prioritizes the use of environmentally friendly chemicals and continuously seeks to reduce the use of harmful substances in its purification processes. By adopting advanced filtration technologies, Aqua World ensures high-quality water with minimal chemical discharge.

Proposed System for Improvement

Purpose of Proposing a New System

The primary purpose of proposing this new system is to automate the processes of washing and filling water jars to enhance operational efficiency, reduce human error, and ensure consistent quality. The current manual processes for washing and filling jars are labor-intensive, time-consuming, and prone to inconsistencies. By automating these processes, Aqua World can achieve greater hygiene, improved accuracy, and reduced operational costs.

Description of the Proposed System

The proposed system includes two major updates:

1. Automated Jar Washing System
2. Sensor-Based Automated Jar Filling System

Automated Jar Washing System

Existing System:

- Jar washing is done by inverting the jar inside a water nozzle.
- Manual intervention is required for thorough cleaning.
- Jars are prone to contamination due to insufficient cleaning.

Proposed System:

- Three motors fitted with rotating brushes: one inserted inside the jar and two for cleaning the outer surface.
- Automated control using an Arduino microcontroller.
- Enhanced cleaning efficiency and hygiene.

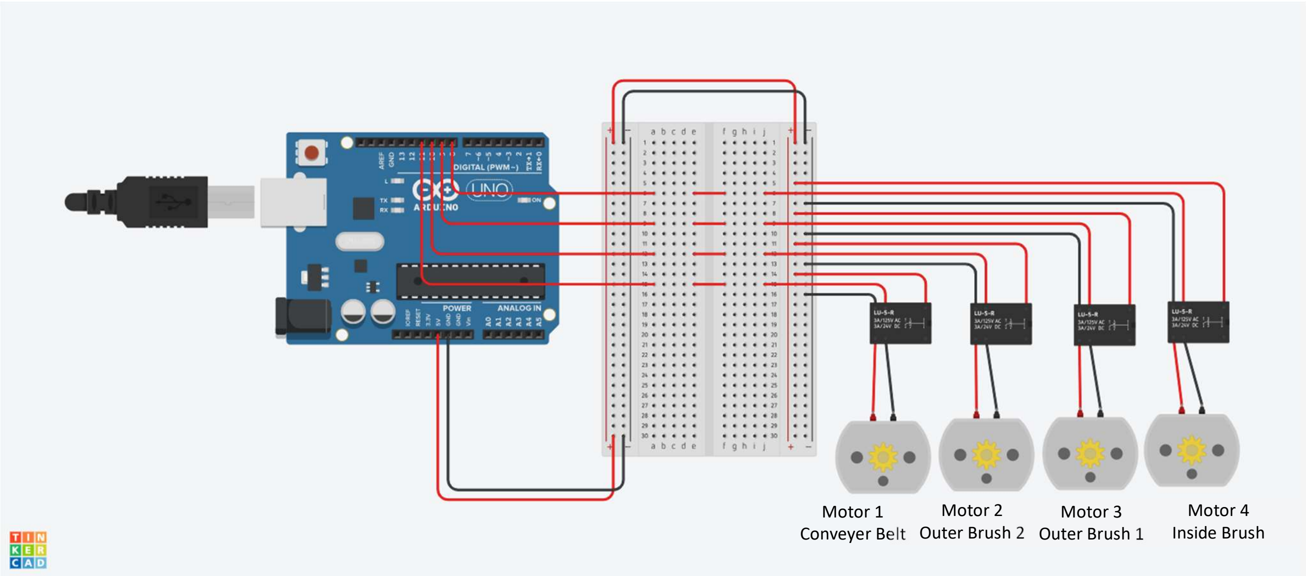
Hardware Used:

- DC Motors: Three motors to drive the rotating brushes.
- Arduino UNO: Microcontroller to control the motor operations.
- Relay Module (LU-5-R): Used to switch the motors on and off.
- Conveyor Belt Motor: To move jars to the next stage after washing.
- Power Supply: Provides necessary power for motors and Arduino.

How It Works:

- The jars are placed into the washing station.
- The motors rotate the brushes for 30 seconds, thoroughly cleaning both the inside and outside of the jars.
- After 30 seconds, the motors stop, and the conveyor belt motor activates for 3 seconds, moving the cleaned jar to the next stage.

Circuit Diagram for Automated Jar Washing System:



Arduino Code for Controlling Automated Jar Washing System:

```
const int motor1RelayPin = 8;  // Relay for motor 1 (inside brush)
const int motor2RelayPin = 9;  // Relay for motor 2 (outer brush 1)
const int motor3RelayPin = 10; // Relay for motor 3 (outer brush 2)
const int conveyorRelayPin = 11; // Relay for conveyor belt

void setup() {
  pinMode(motor1RelayPin, OUTPUT);
  pinMode(motor2RelayPin, OUTPUT);
  pinMode(motor3RelayPin, OUTPUT);
  pinMode(conveyorRelayPin, OUTPUT);

  // Initially all motors and conveyor are OFF
  digitalWrite(motor1RelayPin, HIGH);
  digitalWrite(motor2RelayPin, HIGH);
  digitalWrite(motor3RelayPin, HIGH);
  digitalWrite(conveyorRelayPin, HIGH);
}

void loop() {
  // Some delay before starting
  delay(3000);

  // Turning ON washing motors
  digitalWrite(motor1RelayPin, LOW);
  digitalWrite(motor2RelayPin, LOW);
  digitalWrite(motor3RelayPin, LOW);

  // Washing jars for 30 seconds
  delay(30000);

  //Turning OFF washing motors
  digitalWrite(motor1RelayPin, HIGH);
  digitalWrite(motor2RelayPin, HIGH);
  digitalWrite(motor3RelayPin, HIGH);

  // Starting the conveyor belt to move jars for 3 seconds
  digitalWrite(conveyorRelayPin, LOW);

  // Moving conveyer for 3 seconds
  delay(3000);

  // Turning OFF the conveyor belt
  digitalWrite(conveyorRelayPin, HIGH);
}
```

Sensor-Based Automated Jar Filling System

Existing System:

- Jars are manually placed under the clean water filling nozzle.
- Supports only five jars at a time.
- Human intervention is required to remove the filled jar, turn off the nozzle, and place another jar.

Proposed System:

- Introduce a conveyor belt system to automate the placement of jars under the filling nozzles.
- Fit sensors in the jars that recognize the water level and stop the nozzle automatically.
- The conveyor belt moves the jars to the next stage without human intervention.

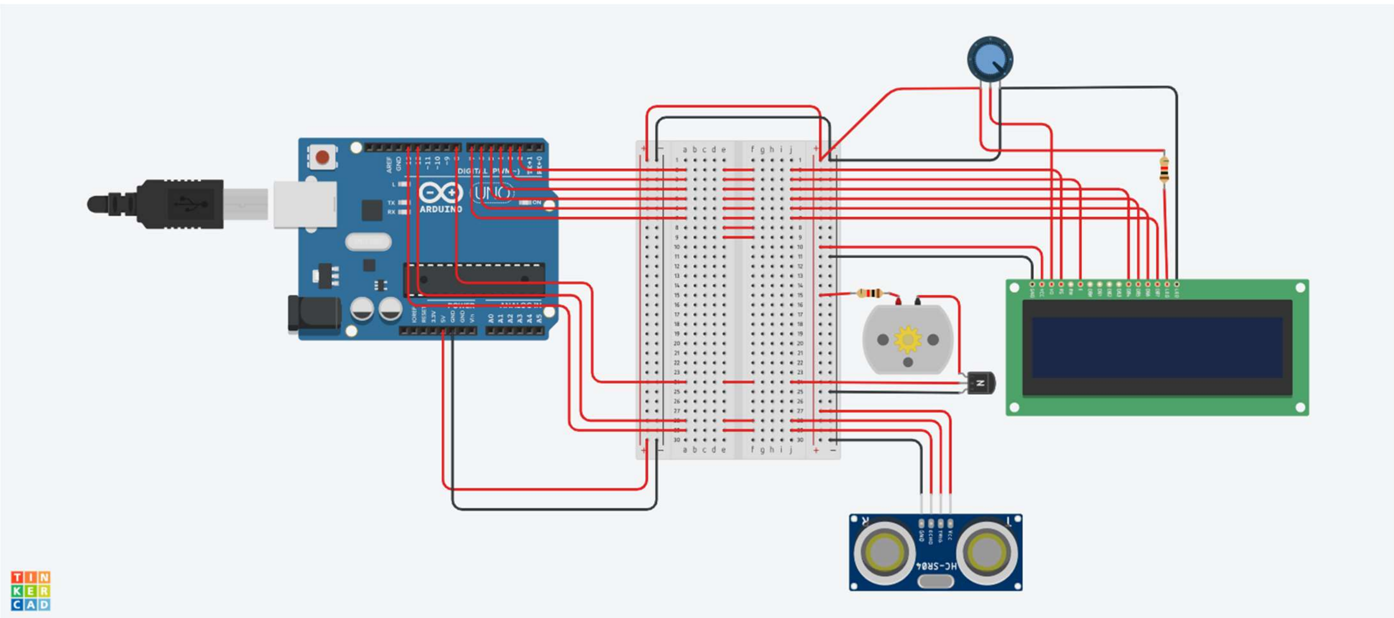
Hardware Used:

- Water Level Sensor: Detects the water level in the jars.
- Arduino UNO: Microcontroller to read sensor data and control the filling process.
- Relay Module (LU-5-R): Controls the water nozzle and conveyor motor.
- Conveyor Belt Motor: Moves the jars after they are filled.
- Power Supply: Provides necessary power for the sensor, Arduino, and motors.

How It Works:

- The jar is moved under the filling nozzle by the conveyor belt.
- The water level sensor monitors the water level in the jar.
- When the jar is full, the sensor sends a signal to the Arduino.
- The Arduino stops the water nozzle and activates the conveyor belt to move the filled jar and position the next one under the nozzle.

Circuit Diagram for Sensor-Based Automated Jar Filling System:



Arduino Code for Sensor-Based Automated Jar Filling System:

```
#include <LiquidCrystal.h>

// Initialize the LCD with the pins used for the connection
LiquidCrystal lcd(2, 3, 4, 5, 6, 7);

const int trigPin = 12;
const int echoPin = 13;
```

```
const int ledPin = 8;

void setup() {
  // Initialize the LCD
  lcd.begin(16, 2);

  // Set up the sensor pins
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);

  // Set up the LED pin
  pinMode(ledPin, OUTPUT);
  digitalWrite(ledPin, HIGH); // Turn on the LED initially (nozzle on)

  lcd.print("Water Level:");
}

void loop() {
  long duration;
  int distance;
  int maxDistance = 200; // Maximum distance for the water level measurement
  int waterLevel;

  // Clear the trigPin by setting it LOW
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);

  // Trigger the sensor by setting the trigPin HIGH for 10 microseconds
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  // Read the echoPin, which returns the signal duration in microseconds
  duration = pulseIn(echoPin, HIGH);

  // Calculate the distance in centimeters
  distance = duration * 0.034 / 2;

  // Map the distance to water level (1 to 5 or full)
  if (distance < maxDistance) {
    waterLevel = map(distance, 0, maxDistance, 5, 0);
  } else {
    waterLevel = 0; // No water detected
  }

  // Clear the LCD and display the water level
  lcd.setCursor(0, 1);
  if (waterLevel == 5) {
    lcd.print("Full       ");
    digitalWrite(ledPin, LOW); // Turn off the LED (nozzle off)
  } else if (waterLevel == 0) {
    lcd.print("Empty      ");
    digitalWrite(ledPin, HIGH); // Turn on the LED (nozzle on)
  } else {
    lcd.print("Level: ");
    lcd.print(waterLevel);
    lcd.print("         ");
    digitalWrite(ledPin, HIGH); // Turn on the LED (nozzle on)
  }
  // Delay before taking the next measurement
  delay(1000);
}
```

Specific Issues Addressed by the Proposed System

1. Enhanced Hygiene and Cleaning Efficiency
   - Issue: The current water nozzle method for jar washing may not thoroughly clean all interior surfaces, potentially leading to contamination.
   - Solution: The rotating brush system provides a more comprehensive cleaning mechanism, ensuring higher standards of hygiene and reducing the risk of contamination.
2. Increased Operational Efficiency
   - Issue: Manual placement of jars under the filling nozzles limits the number of jars that can be filled simultaneously and slows down the overall process.
   - Solution: The conveyor belt system automates jar placement, significantly increasing the number of jars that can be processed at once and reducing the need for manual labor.
3. Improved Accuracy and Reduced Human Error
   - Issue: Human intervention in the jar filling process can lead to errors, inconsistent filling levels, and inefficiencies.
   - Solution: Sensor-based automation ensures precise control over the filling process, stopping the nozzle at the correct water level and moving jars automatically. This reduces human error, ensures uniform filling, and enhances overall accuracy.
4. Labor Cost Reduction
   - Issue: High reliance on manual labor for jar handling and filling increases operational costs.
   - Solution: Automation of the jar washing, filling, and handling processes reduces the need for manual labor, leading to significant cost savings and more efficient use of resources.

Advantages of the Proposed System

1. Increased Efficiency
   Automating jar washing and filling processes reduces manual labor and speeds up production, allowing more jars to be processed in less time.
2. Improved Quality and Consistency
   The rotating brush system ensures thorough cleaning of jars, and sensor-based filling provides precise control over water levels, leading to higher hygiene standards and consistent product quality.
3. Cost-Effectiveness
   Reducing the reliance on manual labor decreases operational costs and minimizes human error, resulting in long-term savings and more efficient resource utilization.
4. Enhanced Customer Satisfaction
   Consistently clean and properly filled jars improve the overall product quality, leading to greater customer trust and satisfaction with Aqua World's products.

Conclusion

The case study at Aqua World provided valuable insights into the current water purification processes and highlighted specific areas for improvement. The proposed system, featuring automated jar washing with rotating brushes and sensor-based jar filling, addresses key challenges, enhances efficiency, and improves overall product quality. The visit to Aqua World was an enlightening experience, bridging the gap between theoretical knowledge and practical application. Observing the plant's operations firsthand deepened our understanding of water purification and the complexities involved in maintaining high standards of hygiene and efficiency. Further research could explore advanced technologies in water purification and automation to continue improving system efficiency and sustainability. Implementing and analyzing the proposed system in a real-world setting would provide additional data to refine and optimize the processes.

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