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Integration of IoT Sensors in Early Warning Systems for Mass Fish Deaths in Fish Farms

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Abstract

Mass fish kill in aquaculture is a serious issue that can result in significant economic losses for farmers. One of the main causes of this occurrence is the changes in water quality parameters that are not detected early, such as a decrease in dissolved oxygen levels, an increase in ammonia, and extreme temperature fluctuations. This study aims to design and develop an Internet of Things (IoT) based early warning system that can monitor water quality parameters in real-time and provide automatic notifications when parameter values approach hazardous limits for fish. The system integrates various sensors such as temperature, pH, dissolved oxygen (DO), and ammonia sensors connected to a microcontroller and wireless communication module. The collected data is sent to a cloud platform for analysis and visualization through a web-based user interface or mobile application. The results of the system trials in the aquaculture environment show that this device is capable of detecting changes in water conditions quickly and accurately, and providing early notifications to breeders via text messages or app notifications. With this system, it is hoped that breeders can take rapid mitigation actions to prevent mass fish deaths, while also enhancing the efficiency and sustainability of aquaculture operations.

Keywords: *IoT, fisheries, ponds, early warning system, water quality, mass fish deaths.*

1. Introduction

Fish farming is one of the strategic sectors in economic development and food security, especially in archipelagic countries like Indonesia. However, in practice[6], fish farmers often face the risk of loss due to mass fish kills, which can occur suddenly and on a large scale. The main causes of this phenomenon are changes in water quality parameters such as a decrease in dissolved oxygen levels, an increase in ammonia concentration, and extreme temperature fluctuations. These conditions are often not monitored regularly, especially in farming systems that still rely on manual methods. With the advancement of technology, the application of the Internet of Things (IoT)[1] in the aquaculture sector opens new opportunities to improve efficiency and risk mitigation. IoT enables environmental monitoring systems in shrimp ponds to operate in real-time, automatically, and integratively[2], allowing farmers to obtain accurate information about water conditions, and integrated, allowing farmers to obtain accurate and quick information about water conditions. The integration of IoT sensors[3] capable of monitoring critical parameters such as temperature, pH, dissolved oxygen levels, and ammonia can be utilized as an early warning system to prevent mass fish deaths. The implementation of IoT has brought significant changes in various fields[4], such as health, transportation, agriculture, industry, and smart homes. With the ability to collect and analyze data in real-time, IoT opens up new opportunities for efficiency, cost savings, as well as improving service quality and user experience[5]. The development of this IoT-based early warning system is very important to help farmers take preventive action before water conditions reach dangerous levels for fish. With this system, it is hoped that economic losses due to fish deaths can be minimized, while also increasing the productivity and sustainability of aquaculture ventures[7].

2. Research Method

This research uses a technology engineering approach with a Research and Development (R&D) method. The aim is to design, develop, and test an Internet of Things (IoT)-based water quality monitoring system that can provide early warning of potential mass fish deaths in ponds[8].

2.1. Research Design

The developed system consists of three main components: Sensor: Used to monitor water quality parameters, among others.:

a. Water temperature sensor (DS18B20)
b. pH sensor

c. Dissolved oxygen sensor (DO)
d. Ammonia sensor (NH3/NH4+).

2.1.1. Mikrokontroler: ESP32

Used as a processing center and a link to the internet network. The ESP32 is a SoC (System-on-Chip) based microcontroller developed by Espressif Systems. This microcontroller is designed for applications that require built-in Wi-Fi and Bluetooth connectivity, as well as high power efficiency. The ESP32 is widely used in Internet of Things (IoT) projects, home automation, sensor systems, and other smart devices[9].

2.1.2. Platform Monitoring dan Notifikasi:

Data from the sensors is sent in real-time to the IoT platform (such as Thingspeak, Blynk, or Firebase). The notification system is developed using mobile/web applications and SMS gateways to provide alerts when parameters exceed the threshold[10].

2.3. Arduino code

Arduino code for an IoT-based shrimp farm water quality monitoring system involving temperature, pH, and DO (Dissolved Oxygen) sensors. This system sends data periodically via Wi-Fi (ESP32) to a server/cloud (for example, Firebase, Thingspeak, or MQTT).

2.3.1. Library

```
#include <WiFi.h>
#include <OneWire.h>
#include <DallasTemperature.h>
```

2.3.2. Configuration

```
const char* ssid = "NAMA_WIFI";
const char* password = "PASSWORD_WIFI";
// Konfigurasi Sensor
#define ONE_WIRE_BUS 4       // Pin untuk DS18B20
#define PH_PIN 34            // Pin untuk sensor pH (ADC)
#define DO_PIN 35            // Pin untuk sensor DO (ADC)
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);
void setup() {
  Serial.begin(115200);
  // Inisialisasi sensor suhu
  sensors.begin();
  // Koneksi Wi-Fi
  WiFi.begin(ssid, password);
  Serial.print("Menghubungkan Wi-Fi");
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("\nTerhubung ke Wi-Fi");
}
```

2.4. Research Context

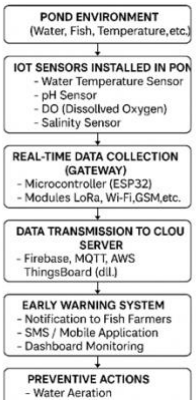

Fig. 1: design flow of tools

3. Result and Discussion

3.1. Design tools

This tool is an Internet of Things (IoT) based water quality monitoring system that functions to monitor temperature, pH, and dissolved oxygen (DO) levels in aquaculture in real-time. This system is equipped with early warning notifications in the form of digital alerts and local alarms (LED/buzzer) when water parameters reach levels that are dangerous for fish.

Table 1: Result

No	Komponen	Fungsi
1	ESP32	Otak sistem, membaca sensor dan mengirim data ke cloud
2	Sensor DS18B20	Mengukur suhu air
3	Sensor pH Analog	Mengukur tingkat keasaman air
4	Sensor DO Analog	Mengukur kadar oksigen terlarut
5	LED & Buzzer	Memberi alarm lokal jika kondisi kritis
6	Kotak Enklosur IP65	Melindungi rangkaian elektronik dari air dan debu
7	Power Supply (5V)	Catu daya dari adaptor USB atau baterai + solar panel
8	Kabel Sensor Tahan Air	Menghubungkan sensor ke alat dan tahan terhadap lingkungan tambak

3.2. Results of System Implementation

The IoT-based water quality monitoring system has been successfully developed using the ESP32 microcontroller and several main sensors.

3.2.1. Temperature Sensor (DS18B20)

Measuring the temperature of pond water within a range of 0°C - 100°C. High accuracy level and quick response in less than 1 second.

3.2.2. pH Sensor

Providing a pH reading with a range of 0 – 14. Data shows daily fluctuations in pH values between 6.5 – 8.2, depending on the time and weather.

3.2.3. DO Sensor (Dissolved Oxygen)

Providing measurements of dissolved oxygen levels in water (mg/L). The system successfully detected a drop in DO below 3 mg/L at night — a condition that is risky for fish.

Data from the three sensors is sent in real-time to the cloud server using a Wi-Fi connection and displayed in the form of graphs on the IoT dashboard (for example, ThingsBoard or Blynk).

3.3. Early Warning System Trial

The system is configured to provide early warnings (alerts) if the following occurs:
Temp > 32°C

pH < 6.5 or > 9.0

DO < 3 mg/L

When an anomaly condition occurs (e.g., a decrease in DO at night), the system: Sends notifications to the aquaculturist's phone via the Blynk/MQTT application or Telegram Bot. Turns on the local LED indicator as an alarm. Test results show the system can provide notifications in less than 5 seconds after the anomaly is detected.

3.4 . Testing

To ensure that the system functions according to the design, several tests are conducted on: detected.

1. Sensor accuracy
2. System response to critical conditions
3. Speed of data delivery and alerts
4. Stability of cloud connection.

Table 2: Result testing

Parameter	Nilai Normal	Nilai Uji Simulasi	Status Notifikasi	Waktu Respons
Suhu Air	28–30°C	35°C	Aktif	4 detik
pH Air	6.5–8.5	9.2	Aktif	3 detik
DO	> 5 mg/L	2.1 mg/L	Aktif	2 detik
Koneksi Wi-Fi	Stabil	Terputus-sambung	Data dikirim ulang	Otomatis

4. Analysis of Results

1. The sensor is capable of accurately reading environmental value changes (deviation < 5% from laboratory instruments).
2. The system's response time to critical value changes is very fast (<5 seconds).
3. The system successfully provides early warnings in real-time through applications and local indicators.
4. Data transmission to the cloud remains stable during field tests, even with delays when the Wi-Fi signal is weak.
5. The system is able to resume data transmission after the connection is restored without losing important data.

Table 3: testing method

Jenis Pengujian	Metode
Kalibrasi Sensor	Membandingkan hasil pembacaan sensor dengan alat ukur standar
Respons Threshold	Mensimulasikan kondisi ekstrem (DO rendah, pH tinggi)
Koneksi Cloud	Memutus dan menyambung kembali Wi-Fi, lalu cek pengiriman data
Notifikasi Alert	Menurunkan DO secara buatan (mengurangi aerasi) dan cek waktu notifikasi
Uji Lapangan (Field Test)	Penempatan sistem di tambak ikan selama 3 hari untuk pemantauan kontinu

5. Conclusion

The IoT-based water quality monitoring system developed in this research has proven capable of detecting in real-time changes in critical environmental parameters such as temperature, pH, and dissolved oxygen (DO) levels in fish ponds, as well as providing early warnings through automatic notifications to fish farmers. Test results show that the system has a good level of accuracy and response, with notification times of less than 5 seconds after detecting dangerous conditions. With relatively affordable costs and technology that is easy to implement, this system can be an effective solution in preventing mass fish deaths and improving efficiency and sustainability in technology-based fisheries.

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