Low-cost, portable in-situ spectral analysis sensor for monitoring water contamination

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INTRODUCTION

Rivers are essential for supporting agricultural and industrial operations and are crucial components of surrounding ecosystems. Nevertheless, the utilization of these river resources by various economic sectors has led to a deterioration in the quality of river water [1].

Numerous pollutants can cause changes in the visual coloration of water, making it possible to identify these factors through the analysis of water color. In-situ sensors represent a valuable and continuous monitoring tool for these resources [2],[3]. They furnish crucial data that empower governing bodies to respond swiftly and mitigate any potential problems. We suggest the development of a sensor designed to assess water quality by identifying potential contaminants, considering shifts in color and turbidity.

It consists of an optical transmission setup with 11 different excitation wavelengths ranging from 365 nm to 940 nm and a corresponding detection system. The system uses a GSM antenna to transmit real-time information and alarms to a big data server.

OBJECTIVES

Eleven light LED with similar intensities and packages distributed from 360 nm to 940 nm were used, along with three photodetectors (Table 1). To regulate the performance of the LED, a bipolar transistor circuit was implemented to control the current supplied by the microcontroller to each of the 11 LED. The reading circuitry was composed of a transimpedance amplifier followed by the analog-to-digital converter.

TABLE I. LED AND PHOTODETECTORS

PHOTODETECTOR	LED	Wavelength (nm)	Visualization angle (º)
GUVV-T10GD-L	MTE3661N1-UV	360	20
	593-VAOL5EUV8T4	385	15
BPW20RF	749-5BWC	430	20
	593-VAOL-5GSBY4	470	60
	LTL2V3TGX3KS	535	30
	828-OVLFY3C7	589	25
	LTL353QRKNN	639	12
	SSL-LX5093SRC/F	660	30
	SSL-LX5093HD-125	700	30
LTR-323DB	720-SFH4554	850	20
	720-SFH4544	940	20

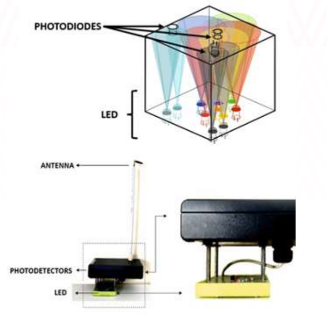

Fig. 1 (Above) 3D model of photodiode lighting scheme. (Below) Final prototype.

The selected communication method was GSM (SIM900A) which contains a socket for a SIM card and an antenna (powered with 5 V and with consumption peaks of 1 A).

The information is then stored on the free-to-use ThingSpeak online platform, which also allows for data export in standard formats.

RESULTS

Food dyes were employed to change the water's color. The sensor's response was investigated in relation to variations in water colour (different levels of dye concentration) and water turbidity.

In Figure 2 , a greater attenuation is evident from UV (360 nm) to the green (535 nm) range. At dye concentration of 333 mg/L, it is already noticeable that four LED (360, 430, 470 and 535 nm) reach maximum measurable attenuation. Despite the high die concentration, transmission above 600 nm wavelength is not affected. Noticeable attenuation patterns are evident among various colors. Specifically, the color yellow displays nearly consistent attenuation across all wavelengths, with a greater emphasis on the lower wavelengths.

To determine the turbidity level at which the sensor can detect the previously obtained colour levels, the turbidity was altered while maintaining a fixed dye concentration. A concentration of 33.3 mg/L of red dye was added, followed by variations in the concentration of organic matter ranging from 0.52 g/L to 7.8 g/L (Fig. 3).

When turbidity levels are low, the color pattern remains distinct. However, as turbidity rises, the pattern becomes less noticeable. Nevertheless, variations in attenuation across multiple wavelengths remain discernible, even though the last three wavelengths (700 nm, 850 nm, and 940 nm) exhibit higher attenuation.

Tests were also carried out in a real environment in a small stream known to be the target of several illegal discharges. (Fig. 4). The obtained results can be analysed in Fig. 5.

All wavelengths experience a shift from the reference line over a span of roughly 40 minutes, with a subsequent return to the reference line. As indicated in Figure 3, the wavelengths most notably impacted by this phenomenon are the lower ones, specifically those at 360, 385, 430, 470, and 535 nm.

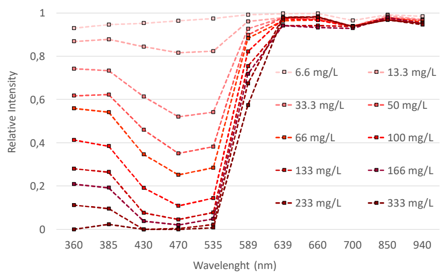

Fig. 2 Light attenuation spectrum with different concentration levels of red dye.

Fig. 4 Photograph of the sampling site (41°27'02.5"N 8°17'30.1"W) when a red discharge was found.

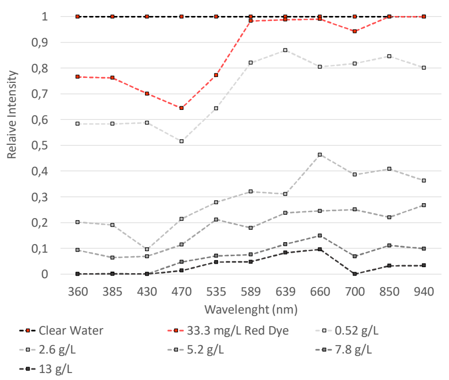

Fig. 3 Spectral attenuation after the addition of 33 mg/L of red dye followed by turbidity variation, using organic matter.

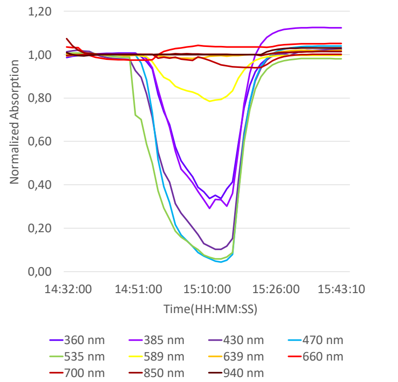

Fig. 5 Variation of absorption throughout a contamination phenomenon in a real environment.

CONCLUSIONS

A transmission methodology covering the range of 365 nm to 940 nm was employed, allowing real-time communication via GSM and providing the user with analytical data. Through tests involving turbidity and dye-based coloration, it was confirmed that the sensor can identify color changes even in situations with significant turbidity, like during rainy weather or soil erosion. **Real-life testing has shown that it effectively detects contamination.**

To enhance its ability to detect lower concentrations, it is advisable to improve the analog-to-digital converter (ADC) resolution and employ more sensitive photodiodes.

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