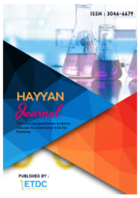

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Visual Detection of Lead Ions (Pb^{2+}) Using a Colorimetric Sensor for Fishery Products

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ABSTRACT

The presence of lead ions (Pb^{2+}) in fishery products poses potential risks to human health. Therefore, simple, rapid, and easily applicable detection methods are highly required. This study aimed to develop a simple colorimetric sensor for the visual detection of Pb^{2+} based on color change as an analytical signal. The sensor was prepared through the interaction of a complexing indicator with the target metal ion, resulting in a distinct and visually observable color response. The novelty of this work lies in the application of a simple colorimetric sensor with a low visual detection limit and high selectivity toward Pb^{2+}, as well as its direct applicability to simulated fishery product samples without the need for complex analytical instruments. The results demonstrate that the developed sensor is capable of selectively detecting Pb^{2+} with a clear visual response, indicating its potential use as a low-cost and practical method for preliminary screening of lead contamination.

Keywords: Visual detection, Colorimetric sensor, Lead ion (Pb^{2+})

I. INTRODUCTION

Lead ion (Pb^{2+}) contamination represents a serious concern in food safety and environmental protection, particularly in fishery products originating from polluted aquatic environments. Pb^{2+} is highly toxic, has no known biological function, and can accumulate in marine organisms. Long-term consumption of food contaminated with Pb^{2+} has been associated with neurological disorders, kidney damage, and impairment of cognitive development (Marchellina et al., 2024; Raissy et al., 2022;Balali-Mood et al., 2021).

Various analytical techniques have been developed for Pb^{2+} determination, including atomic absorption spectroscopy (AAS) and mass spectrometry (MS). Although these methods provide high sensitivity and accuracy, they require expensive instrumentation, complex sample preparation, and skilled operators (Abdelmonem et al., 2025;Mukherjee et al., 2021). Such limitations reduce their practicality for routine monitoring and on-site preliminary screening, especially in small-scale industries and coastal regions.

Colorimetric sensors offer a simple, rapid, and cost-effective alternative for metal ion detection. These sensors operate based on color changes resulting from specific interactions between an indicator molecule and the target ion. The color variation can be directly observed by the naked eye without sophisticated instrumentation, making colorimetric sensors particularly suitable for field applications and preliminary screening (Kaur et al., 2018;Picci et al., 2024). However, the main challenge in developing colorimetric sensors lies in achieving sufficient selectivity and sensitivity toward specific ions, especially when applied to complex matrices such as fishery products (Mukherjee et al., 2021;Hu et al., 2023).

This study aims to develop a simple colorimetric sensor that is selective toward Pb^{2+} and to evaluate its performance through visual observation, semi-quantitative analysis, and application to simulated fishery product samples. The novelty of this research resides in the combination of visual detection with a low detection limit, good selectivity toward Pb^{2+}, and direct applicability to real-like matrices without requiring complex analytical instruments.

II. METHODS

II. 1. Research Design

This study employed a laboratory-based experimental design to develop and evaluate a simple colorimetric sensor for the visual detection of Pb^{2+} in fishery products.

II. 2. Materials and Instruments

The materials used included a colorimetric indicator selective toward Pb^{2+}, an appropriate solvent, and standard Pb^{2+} solutions with concentrations ranging from 0 to 100 µM. Cadmium (Cd^{2+}) and copper (Cu^{2+}) ion solutions were used for selectivity testing. Simulated fishery product samples were prepared by spiking Pb^{2+} into the sample matrix. The instruments used consisted of beakers, volumetric pipettes, test tubes, and a digital camera for documenting color changes.

II. 3. Preparation of the Colorimetric Sensor

The colorimetric sensor was prepared by dissolving the indicator in the selected solvent to obtain a homogeneous and stable solution. The sensor was stored at room temperature and used directly without further treatment.

II. 4. Visual Detection and Determination of Detection Limit

The sensor solution was mixed with Pb^{2+} solutions at various concentrations. Color changes were visually observed under ambient lighting conditions. The visual detection limit (LOD) was defined as the lowest Pb^{2+} concentration that produced a color change clearly distinguishable from the blank.

II. 5. Selectivity Test

Selectivity was evaluated by comparing the color responses of the sensor toward Pb^{2+}, Cd^{2+}, and Cu^{2+} at identical concentrations.

II. 6. Application to Simulated Fishery Product Samples

The sensor was applied to simulated fishery product samples spiked with Pb^{2+} at selected concentrations. Prior to analysis, the samples were subjected to simple filtration to minimize matrix interference.

III. RESULTS AND DISCUSSION

The colorimetric sensor exhibited a distinct color change upon interaction with Pb^{2+} ions. The initial color of the sensor gradually transformed into a more intense color with increasing Pb^{2+} concentration. The color change became visually observable at a Pb^{2+} concentration of approximately 5 µM, which was defined as the visual detection limit.

Table 1. Visual Response and Relative Intensity of the Colorimetric Sensor toward Pb^{2+} and Interfering Ions

Ion	Concentration (µM)	Visual Color Change	Relative Color Intensity	Remark
Pb^{2+}	0	No change	0.05	Blank
Pb^{2+}	5	Slightly visible	0.18	Weak response
Pb^{2+}	25	Clear	0.46	Strong response
Pb^{2+}	50	Very Clear	0.71	Optimal response
Cd^{2+}	50	Very Weak	0.09	Non-selective
Cu^{2+}	50	No response	0.06	Non-responsive

Within the concentration range of 5–50 µM, the relative color intensity increased consistently, indicating an adequate working range for visual Pb^{2+} detection. To support visual observations, semi-quantitative analysis was conducted by converting color intensity into relative intensity values using digital image analysis. The selectivity test revealed that Cd^{2+} and Cu^{2+} induced negligible color changes compared to Pb^{2+}, confirming the sensor's selectivity toward lead ions.

The relationship between Pb^{2+} concentration and relative color intensity exhibited a clear linear trend. Although the coefficient of determination (R^2) was not numerically calculated, the data trend suggests a strong correlation, reflecting the consistency of the sensor response to increasing Pb^{2+} concentrations. The analysis results indicate a clear tendency toward a linear relationship between Pb^{2+} concentration and relative color intensity.

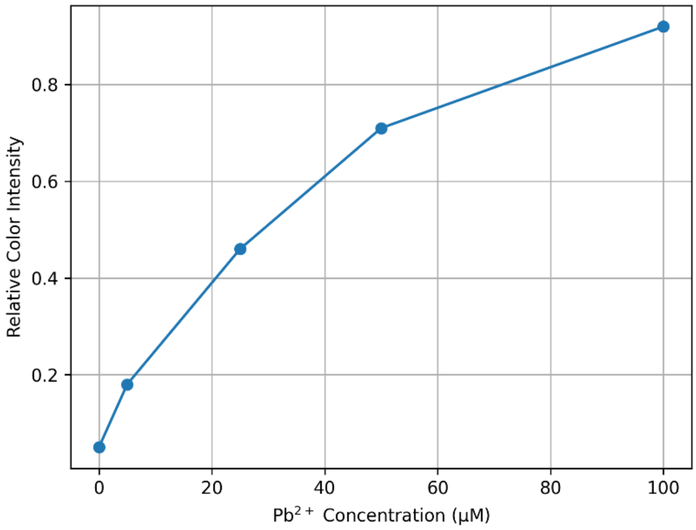

Figure 1 Semi-Quantitative Relationship between Pb^{2+} Concentration and Relative Color Intensity

The graph demonstrates a gradual increase in the relative color intensity of the sensor with increasing Pb^{2+} concentration in the range of 0–100 µM. The observed trend exhibits good linearity, indicating a consistent sensor response toward increasing concentrations of lead ions. Color intensity values were obtained through digital image analysis using a smartphone camera. Although the coefficient of determination (R^2) was not numerically calculated, the overall trend suggests a strong correlation, reflecting the stability and reproducibility of the sensor response across different Pb^{2+} concentrations.

Table 2. Application of the colorimetric sensor to simulated fishery product samples

Sample	**Added Pb^{2+} (μM)**	**Visual Color Change**	**Relative Color Intensity**	**Remark**
Blank (wihout Pb^{2+})	0	No change	0.06	Not detected
Pb^{2+} Standart	25	Clear	0.46	Standart solution
Pb^{2+} Standart	50	Very Clear	0.71	Standart solution
Skipjack tuna meat	25	Clear	0.39	Slight matrix effect
Skipjack tuna meat	50	Very Clear	0.63	Visually detectable
Skipjack tuna meat	100	Very Clear	0.85	Stable response

Application of the sensor to simulated fishery product samples revealed that the color change remained clearly observable despite the presence of a more complex sample matrix. The relative color intensity obtained from fish tissue samples was slightly lower than that observed in standard solutions, indicating a minor matrix effect. Nevertheless, the signal remained within a visually distinguishable range, demonstrating the feasibility of the sensor for preliminary screening of Pb^{2+} contamination in fishery products.

The colorimetric response is attributed to the formation of a complex between the indicator molecule and Pb^{2+} ions, which induces changes in the electronic structure of the indicator. These electronic alterations affect the optical properties of the sensor, resulting in a visible color change that serves as the analytical signal (Pince Salempa et al., 2023).

Despite the promising results, this study has certain limitations, including reliance on visual and semi-quantitative analysis without instrument-based quantification and limited evaluation of potential interfering ions. Future work should focus on quantitative validation using UV–Vis spectrophotometry, assessment of sensor stability, and application to real fishery samples collected from markets or aquaculture sites.

IV. CONCLUSION

A simple colorimetric sensor for the detection of Pb^{2+} ions has been successfully developed and evaluated. The sensor exhibited a clear visual response within a concentration range of 5–100 µM, with a visual detection limit of approximately 5 µM. Selectivity tests confirmed a stronger response toward Pb^{2+} compared to Cd^{2+} and Cu^{2+} ions. Application to simulated fishery product samples demonstrated that Pb^{2+} could still be visually detected in complex matrices. These results highlight the potential of the developed colorimetric sensor as a simple, rapid, and cost-effective preliminary screening method for Pb^{2+} contamination in fishery products.

V. REFERENCES

Abdelmonem, B. H., Kamal, L. T., Elbaz, R. M., Khalifa, M. R., & Abdelnaser, A. (2025). From contamination to detection: The growing threat of heavy metals. *Heliyon*, *11*(1), e41713. https://doi.org/https://doi.org/10.1016/j.heliyon.2025.e41713

Balali-Mood, M., Naseri, K., Tahergorabi, Z., Khazdair, M. R., & Sadeghi, M. (2021). Toxic Mechanisms of Five Heavy Metals: Mercury, Lead, Chromium, Cadmium, and Arsenic. *Frontiers in Pharmacology*, *12*. https://doi.org/10.3389/fphar.2021.643972

Hu, T., Lai, Q., Fan, W., Zhang, Y., & Liu, Z. (2023). Advances in Portable Heavy Metal Ion Sensors. *Sensors*, *23*(8), 4125. https://doi.org/10.3390/s23084125

Kaur, B., Kaur, N., & Kumar, S. (2018). Colorimetric metal ion sensors – A comprehensive review of the years 2011–2016. *Coordination Chemistry Reviews*, *358*, 13–69. https://doi.org/https://doi.org/10.1016/j.ccr.2017.12.002

Marchellina, A., Soegianto, A., Putranto, T. W. C., Mukholladun, W., Payus, C. M., & Irnidayanti, Y. (2024). An assessment of the potential health hazards associated with metal contamination in a variety of consumable species living along the industrialized coastline of East Java, Indonesia. *Marine Pollution Bulletin*, *202*, 116375. https://doi.org/https://doi.org/10.1016/j.marpolbul.2024.116375

Mukherjee, S., Bhattacharyya, S., Ghosh, K., Pal, S., Halder, A., Naseri, M., Mohammadniaei, M., Sarkar, S., Ghosh, A., Sun, Y., & Bhattacharyya, N. (2021). Sensory development for heavy metal detection: A review on translation from conventional analysis to field-portable sensor. *Trends in Food Science & Technology*, *109*, 674–689. https://doi.org/https://doi.org/10.1016/j.tifs.2021.01.062

Picci, G., Montis, R., Gilchrist, A. M., Gale, P. A., & Caltagirone, C. (2024). Fluorescent and colorimetric sensors for anions: Highlights from 2020 to 2022. *Coordination Chemistry Reviews*, *501*, 215561. https://doi.org/https://doi.org/10.1016/j.ccr.2023.215561

Pince Salempa, Muharram, Ahmad Fudhail Majid, & Sitti Faika. (2023). *Senyawa Steroid dan Terpenoid*. CV. Sahabat Hard.

Raissy, M., Ansari, M., Chaleshtori, R. S., Mahdavi, V., Hadian, Z., Lorenzo, J. M., Oliveri Conti, G., Huseyn, E., & Mousavi Khaneghah, A. (2022). A systematic review of the concentration of potentially toxic elements in fish from the Persian Gulf: A health risk assessment study. *Food and Chemical Toxicology*, *163*, 112968. https://doi.org/https://doi.org/10.1016/j.fct.2022.112968