IoT-Integrated Mercury Substance Detection System for Cosmetic Product Safety

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ABSTRACT

Mercury is one of the most toxic heavy metals, capable of causing severe health problems such as kidney damage, anxiety, depression, and memory loss. Despite these risks, mercury-containing cosmetics continue to be used as skin-lightening agents, often without consideration of their clinical impacts. To address this issue, this study proposes the development of an IoT-based system for detecting mercury in cosmetic products. The system integrates a pH sensor with a NodeMCU board programmed using Arduino IDE, while Blynk and Google Spreadsheet are employed for real-time monitoring and historical data storage. The detection principle is based on pH analysis, as mercury-containing cosmetics typically fall within the acidic pH range of 5–7. Experimental validation was conducted on five cosmetic samples, of which two (pH 6.0 and 6.2) indicated the presence of mercury. The results demonstrate that the proposed IoT-based system can successfully identify and record mercury contamination, providing accessible monitoring through Blynk and systematic data logging via Google Spreadsheet. This approach highlights the potential of low-cost IoT-based solutions for enhancing cosmetic product safety monitoring.

Keywords: mercury detection, IoT based monitoring, pH Sensor, Blynk, cosmetic safety

INTRODUCTION

Beauty has always been associated with women, who prioritize maintaining attractiveness and style. Throughout history, women have practiced various beauty rituals to enhance their appearance. Modern women are willing to invest in cosmetic products to achieve their beauty goals. A study in the United States revealed that 88% of women aged 18 and above use cosmetics to enhance their beauty and boost their confidence [1][2]. The cosmetics industry has expanded beyond personal use and now encompasses domestic and international businesses. Cosmetic manufacturers utilize technological advancements to introduce innovative products that cater to consumers, especially women, by promoting skin beauty, skincare, and whitening. However, some entrepreneurs and manufacturers prioritize profit over consumer safety, using harmful ingredients like mercury, hydroquinone, and steroids [3]-[5]. These ingredients have been associated with adverse effects on reproductive hormones, including estrogen [6]. In Malaysia, legal provisions such as the Control of Drugs and Cosmetics Regulations 1984 and the Sale of Drugs Act 1952 regulate the production and sale of harmful cosmetic products. These laws ensure consumer safety and prohibit using prohibited substances in cosmetics [7].

Nevertheless, concerns persist regarding the sale and production of products containing harmful chemicals and the sale of unregistered cosmetics. Mercury, a toxic heavy metal, is sometimes used in cosmetic products to lighten skin and reduce the appearance of dark spots and blemishes [8][9]. However, its high absorption rate can cause rapid damage to the skin and internal organs. Although the U.S. FDA banned the use of mercury in most cosmetics in 1974, trace amounts may still be permitted in specific eye-area products when no equally safe alternative is available [10]. Any cosmetic product exceeding the FDA's maximum allowable limit of 1 part per million of mercury is considered a violation and subject to legal action. Products claiming to fade dark spots, blemishes, and fine lines often contain higher levels of mercury. However, topical application of mercury can result in skin irritation, rashes, and discoloration [10]. The sale of cosmetic and personal care products with mercury, other than trace amounts, is prohibited by the New York State Department of Environmental Conservation [11].

Most mercury determination techniques are based on analytical instrumentation methods [12]. These methods are compassionate, selective, and accurate, but they necessitate sophisticated sample preparation procedures, expensive and extensive instruments, and professionally trained individuals to perform the tests. Bohari et al. present a real-time sensor based on PANI/MWCNTs/AuNPs/ITO for mercury determination in cosmetics. The sensor utilizes a rapid and sensitive electrochemical approach with polyaniline, multi-walled carbon nanotubes, and gold nanoparticles directly placed on an indium tin oxide electrode. The modified electrode shows high repeatability and sensitivity for mercury detection. However, implementation of this method is challenging due to sensor modification complexities [13][14]. Sukesan et al. conducted a microchip-based device using extended gate field-effect transistors for instant mercury ion detection. The device features a simple user interface and provides rapid results (less than five minutes) for mercury ion quantification. An N-channel depletion DMOS FET is used, and the device operates in burst mode for repeated measurements. A pulsed gate voltage is applied for sensing, and the device exhibits good thermal characteristics and suitability for amplification applications [14][15].

In addition, W. Xiao et al. present a portable smartphone readout device for detecting mercury contamination using an aptamer-assay nanosensor. The device attaches to a smartphone's ambient light sensor and utilizes a colorimetric aptamer nanosensor to assess mercury levels in aqueous samples. The nanosensor relies on the specific interaction between the aptamer and mercury, leading to a color change in the reaction solution due to gold nanoparticle aggregation (AuNPs). The smartphone-based microwell reader accurately detects mercury within approximately 20 minutes. However, its effectiveness for detecting mercury in cosmetics is uncertain as it has not been tested in that context [16][17]. Talat et al. present a study on mercury's susceptible electrochemical detection using graphene-modified glassy carbon electrodes. It has been confirmed that these electrodes can detect mercury ions in cosmetic cream samples. The electrochemical approach, combined with acid digestion and microscopy techniques, determines mercury concentrations. Graphene sheets on the electrode significantly enhance the electrochemical response to mercury, resulting in accurate and sensitive detection. However, the method's implementation is challenging due to the sensor modification, which complicates the project's development process [18][19].

M. Guo presents a test strip platform for detecting total inorganic mercury pollutants in cosmetics using a whole-cell microbial biosensor. Based on Escherichia coli with a genetic circuit, the biosensor allows simultaneous detection of soluble and insoluble mercury contaminants without pre-digestion. The biosensor's red fluorescent protein (RFP) fluorescence intensity shows a linear relationship with mercury concentrations. The test strip provides a low-cost, instrument-independent method for detecting mercury contamination in cosmetics. However, implementation is challenging due to the use of biosensors, complicating the project's development process [20]. Many of these tests are also not portable, necessitating the collection and return of samples to a laboratory for examination. As a result, they have limited use and are not well suited for on-site mercury detection. This project investigates the relationship between the pH value and the harmful mercury substance in cosmetics. In this project, a circuit of NodeMCU ESP8266 connected with a pH sensor is used to detect harmful mercury substances in cosmetics. The pH sensor will help to measure the pH value of cosmetics accurately. The pH value range detected by the pH sensor is based on projects in the literature review of mercury detection in cosmetics. The pH value range set by the project is from pH 5 to pH 7. The data from the circuit will send an alarm or notification of the presence of mercury to the phone or computer.

METHODOLOGY

In this project, the pH sensor first detects the pH value of mercury-containing substances in cosmetics. Once the pH value is detected, the data is sent to the NodeMCU, which then updates the information in both Blynk and Google Spreadsheets. When the data in Blynk is updated, the user's mobile phone receives a notification indicating the presence of mercury. The user can also access the Google Spreadsheets online to review the pH values of previously tested cosmetics from anywhere with an active data connection. The pH setting for detecting mercury-containing substances is based on research conducted by U. Ekpunobi and M. Arshad [21][22]. Based on the findings of these two studies, it is established that most mercury-containing cosmetics have an acidic pH value, which forms the basis for this project's implementation. Figure 1 presents the project's flow chart, while Figure 2 illustrates the complete hardware circuits of the project utilizing two different sensor modules: PH-4502C sensor and the Logo-Rnaenaor v2.0. The hardware connections are established as follows: (i) the 3.3V pin from the NodeMCU is connected to the VCC pin of the pH sensor module; (ii) the P.O. pin of the sensor module is connected to pin A0 of the NodeMCU; and (iii) the ground pin of the sensor module is connected to the ground pin of the NodeMCU. This configuration ensures proper communication between the NodeMCU and the pH sensor modules, enabling accurate detection and analysis of mercury containing substances in cosmetics.

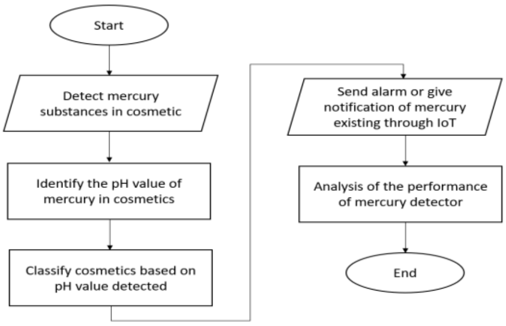

Figure 1. Flow Chart for Mercury Detection in Cosmetics

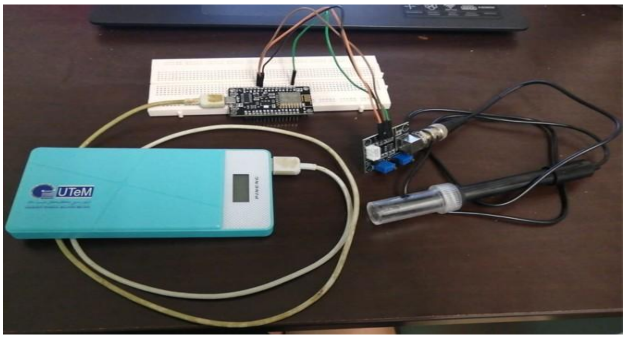

Figure 2. Hardware Configuration for the Mercury Detection System

Five cream samples were used in this project, sourced from the local market in Melaka, Malaysia. These creams were selected based on their affordability, popularity, and widespread availability. It was ensured that all selected creams displayed their production dates and contained no ointment ingredients. Considering these factors, the cream samples obtained for analysis represent a diverse range of products commonly found in the market. This selection approach enables a comprehensive examination of the pH values and potential mercury content in creams that are widely accessible to consumers [23]. The details of the selected cream samples are presented in Table 1.

Table 1cream Samples Sourced From The Local Market In Melaka, Malaysia, Showing Type And Ingredients As Stated On Product Packaging

Type	Ingredients Declared on the Packaging
Cream A	Aqua, Butyrospermum Parkii (Shea Butter), Hydrolyzed Yeast Protein, Glycerin, 3-O-Ethyl Ascorbic Acid, and Sodium Hyaluronate.
Cream B	Vitamin C, Aqua, Butyrospermum Parkii (Shea Butter), Hydrolyzed Yeast Protein, Glycerin, 3-O-Ethyl Ascorbic Acid, Sodium Hyaluronate.

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Cream C	Stearic acid, lanolin, parfum, aqua, propylparaben, and triethanolamine.
Cream D	Sodium hyaluronate nicotinamide.
Cream E	Petrolatum, mineral oil, isopropyl myristate, titanium dioxide carnauba wax, beeswax propylparaben perfume, methylparaben, and iron oxide yellow.

RESULTS AND DISCUSSION: BLYNK SOFTWARE RESULTS

This section presents the outcomes obtained from the Blynk software, the Google Spreadsheet, and the performance assessment between the two sensor modules. Additionally, the implications of these findings are discussed in relation to the study's objectives and the existing literature.

The Blynk results for five types of cosmetic samples are shown in Figures 3 to 7. The detected pH values for each sample are: (i) Cream A: pH 7.9, (ii) Cream B: pH 7.8, (iii)

Cream C: pH 6.0, (iv) Cream D: pH 7.6, and (v) Cream E: pH 6.2. In the Arduino IDE software, the project code is programmed to notify the Blynk application of the presence of mercury when the pH falls within the range of 5 to 7. As a result, notifications were triggered in Figures 5 and 7, corresponding to Cream C and Cream E. This confirms the presence of mercury in these two samples, while no mercury was detected in the other creams. Overall, the results provide a clear overview of the detected pH values, allowing straightforward identification of mercury-containing cosmetics based on the established pH range criteria [24].

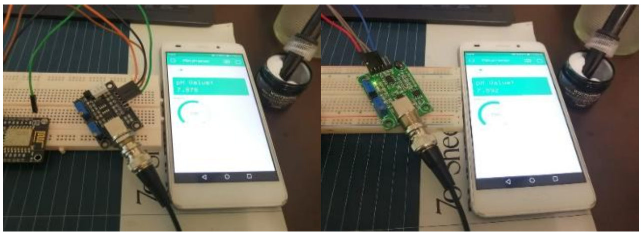

Figure 3. Cream A

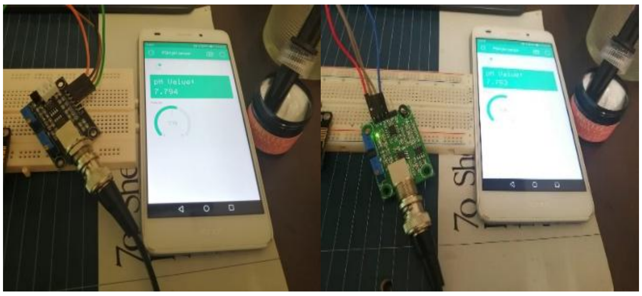

Figure 4. Cream B

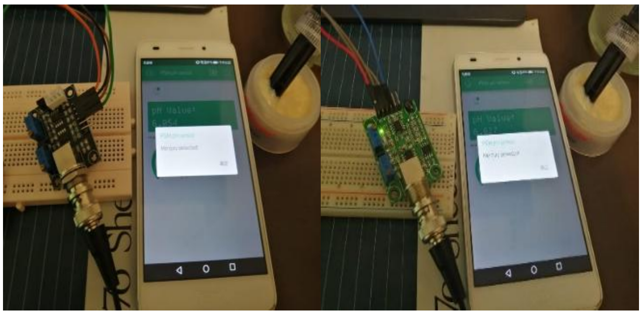

Figure 5. Cream C

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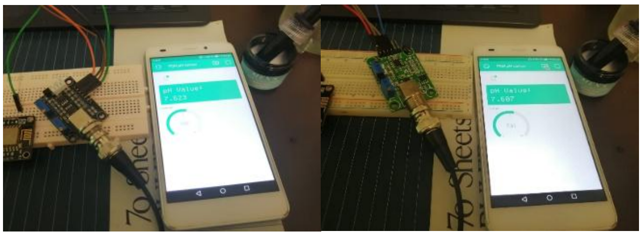

Figure 6. Cream D

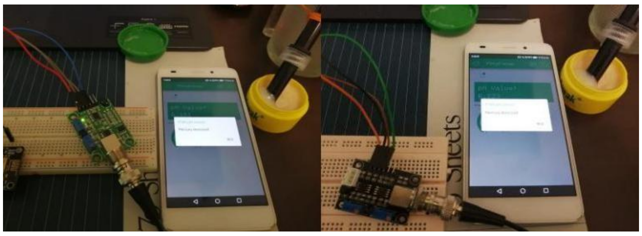

Figure 7. Cream E

The measurement results obtained from the PH-4502C and the Logo-Rnaenaor v2.0 sensor modules are displayed in the Google spreadsheet, as shown in Figures 8 to 12. These results are transmitted to the spreadsheet by NodeMCU, which can be accessed through a mobile phone or computer via a provided link. The graphs provide a detailed view of the project data and allow for comprehensive analysis of the detected pH values. By examining these graphs, the differences in measurement results between the two sensor modules for each cosmetic sample can be observed. In Figure 8, the measurement results of Cream E obtained from both sensor modules converge around a pH value of approximately 6.2. Similarly, Figure 9 shows that the results for Cream C consistently hover around pH 6 for both modules. In contrast, Figures 10 and 12 indicate higher pH values for Cream A and Cream B, both exceeding 7.8. Figure 11 demonstrates that the measurement results of

Cream D align closely with pH 7.6. These variations in pH values among the different creams are clearly represented in the Google spreadsheet graphs. Overall, the data presented in Figures 8 to 12 provide valuable insights into the pH characteristics of the tested cosmetic samples and highlight the differences in measurement outcomes between the two sensor modules [25].

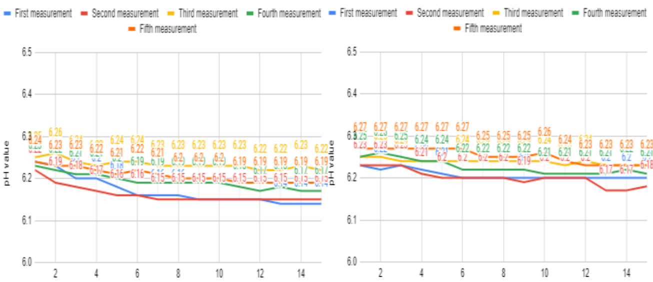

Fig. 8. pH measurements of Cream E using (a) the PH-4502C sensor module and (b) the Logo-Rnaenaor v2.0 sensor module.

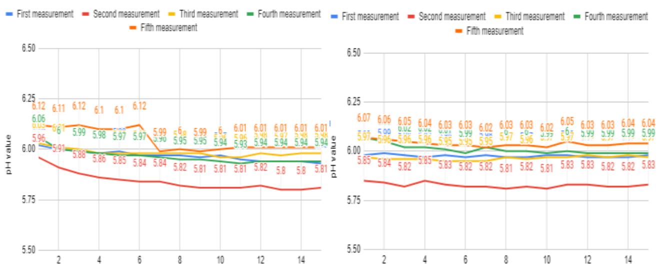

Fig. 9. pH measurements of Cream C using (a) the PH-4502C sensor module and (b) the Logo-Rnaenaor v2.0 sensor module.

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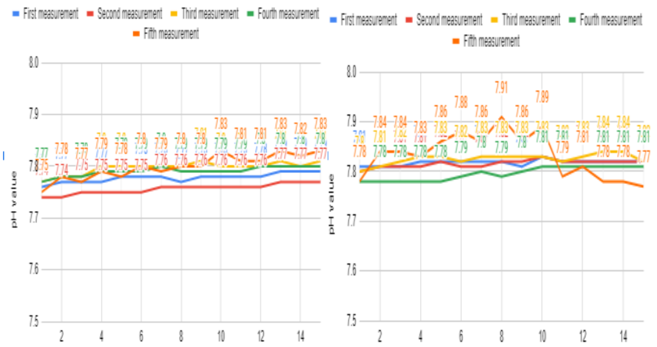

Fig. 10. pH measurements of Cream B using (a) the PH-4502C sensor module and (b) the Logo-Rnaenaor v2.0 sensor module.

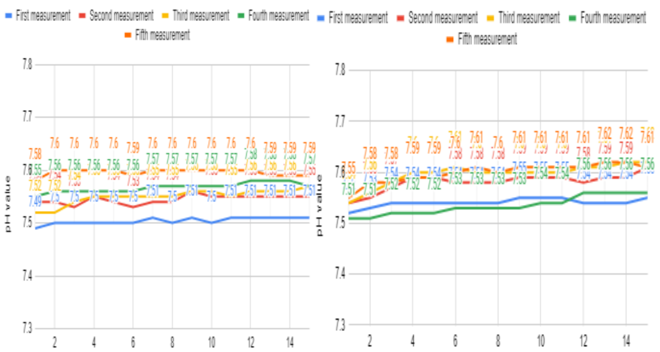

Fig. 11. pH measurements of Cream D using (a) the PH-4502C sensor module and (b) the Logo-Rnaenaor v2.0 sensor module.

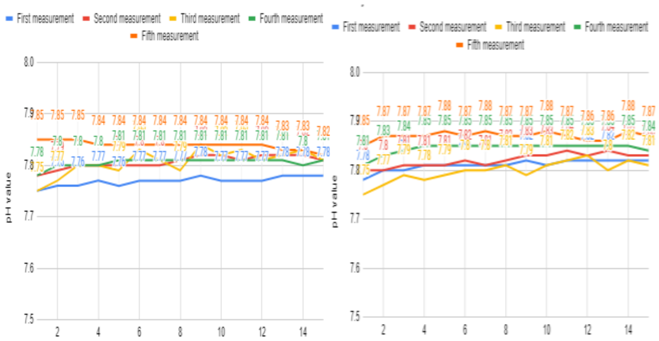

Fig. 12. pH measurements of Cream A using (a) the PH-4502C sensor module and (b) the Logo-Rnaenaor v2.0 sensor module.

Results and Discussion : Performance Assessment of Low-Cost pH Sensor Modules

The term accuracy refers to the degree to which a measured or calculated value aligns with the actual value, typically expressed as a percentage. In this section, percent error is used to evaluate and compare the accuracy of the pH sensor modules [26]. The percent error is calculated by dividing the absolute difference between the measured (or calculated) value and the actual value by the actual value, and then multiplying the result by 100 to obtain a percentage, as shown in Equation (1). A higher percent error indicates lower accuracy, while a lower percent error indicates higher accuracy. The percent error values for the PH-4502C sensor module and the Logo-Rnaenaor v2.0 sensor module are presented in Table 2.

$$\%Error = \frac{Error}{Actual\ Value} x\ 100\% \qquad (1)$$

Table 2 Percent Error Comparison Between Ph-4502c And Logo-Rnaenaor V2.0 Sensor Modules.

Actual pH value of cosmetics	PH-4502C sensor module		Logo-Rnaenaor v2.0 sensor module	
	pH	**%Error**	**pH**	%Error
pH6.2	pH6.26	0.97%	pH6.27	1.13%
pH6.0	pH6.12	2%	pH6.07	1.17%
pH7.8	pH7.83	0.38%	pH7.91	1.41%
pH7.6	pH7.6	0%	pH7.62	0.26%
pH7.8	pH7.85	0.64%	pH7.88	1.03%

Table 2 presents the comparison between the actual pH values of the cosmetic samples and those measured using the PH-4502C and Logo-Rnaenaor v2.0 sensor modules, together with the corresponding percent errors. Overall, both sensors are capable of measuring cosmetics pH values with reasonable accuracy, maintaining percentage errors below 2%. This error margin is acceptable for preliminary screening applications, particularly in determining the potential presence of mercury contamination, where deviations in pH can serve as an indirect indicator. The PH-4502C module sensor generally provides more consistent readings with lower error percentages across different pH values, indicating higher accuracy. Its zero-error reading at pH 7.6 demonstrates stability in detecting neutral to slightly alkaline cosmetics. This reliability confirms its suitability for integration into IoT-based detection systems, where minimal calibration and consistent output are critical. In contrast, the Logo-Rnaenaor v2.0 module shows slightly higher deviations, particularly at higher pH levels (up to 1.41% error). Despite this, it still delivers acceptable performance for cosmetic testing, although additional calibration is required to ensure accuracy in real-time monitoring systems. From a practical perspective, the findings confirm that both sensors can be integrated into low-cost, portable systems for cosmetic testing. However, selecting the PH-4502C ensures higher reliability and reduces the risk of false positives or negatives in detecting abnormal pH shifts. Accuracy is crucial in the context of regulatory compliance and consumer safety, where even small measurement discrepancies influence the classification of a product's safety.

In addition to the percent error analysis presented earlier, a comprehensive evaluation of sensor performance encompasses calibration accuracy, repeatability, and environmental stability. The PH-4502C and Logo-Rnaenaor v2.0 modules were calibrated using standard buffer solutions (pH 4.0, 7.0, and 10.0) prior to each test session to ensure linear response consistency across the measurement range. Calibration drift was observed to increase slightly (by 0.05–0.1 pH units) after two hours of continuous use, mainly due to electrode surface fouling caused by cosmetic residues. To mitigate this, the electrodes were rinsed with distilled water and recalibrated after every five measurements, which successfully minimized drift and maintained sensitivity [27]. Error sources were primarily categorized as (i) calibration offset errors, arising from potential differences in reference voltage; (ii) temperature variations, affecting the electrode potential at approximately 0.03 pH per °C; and (iii) sample matrix interference, particularly in viscous or oil-based cosmetics that hinder hydrogen ion exchange. These factors collectively contribute to a total measurement uncertainty of approximately ±0.12 pH units. Among the two modules, the PH-4502C exhibited lower thermal sensitivity and better stability against sample matrix effects, confirming its suitability for real-time monitoring in the IoT-based detection system [28].

Environmental influences were also investigated to assess sensor robustness. The IoT system was tested under various ambient conditions typical of tropical environments (25–35°C and 50–80% relative humidity). The sensors maintained stable readings, showing less than 0.1 pH deviation across these conditions. This indicates sufficient environmental tolerance for semi-field applications. Nevertheless, implementing temperature compensation algorithms or a thermistor-based correction method is recommended for more consistent accuracy in long-term use [29]. (Minami et al., 2021).

In conclusion, the PH-4502C sensor module is the most suitable choice for deployment in the proposed IoT-based mercury detection system due to its superior accuracy and stability. By integrating this sensor with real-time data logging and cloud connectivity, the system provides reliable screening of cosmetic products, thereby supporting consumer protection efforts and strengthening regulatory monitoring.

CONCLUSIONS

In summary, this paper focuses on the development and implementation of an IoT-based system for detecting harmful mercury substances in cosmetics. The system employs a NodeMCU with an ESP8266 WiFi module to transmit data to Blynk software and Google Spreadsheets, enabling remote monitoring and analysis. Mercury detection is based on pH analysis, as mercury-containing cosmetics typically exhibit acidic pH levels within the range of 5 to 7. When values within this range are detected, the NodeMCU sends notifications to the Blynk software, while the pH data is simultaneously stored in Google Spreadsheets for historical analysis. Both the PH-4502C and Logo-Rnaenaor v2.0 sensor modules were able to detect the target pH range; however, the PH-4502C demonstrated lower percent error values, indicating higher accuracy. Therefore, the PH-4502C sensor module is recommended for detecting harmful mercury substances in cosmetics. The integration of calibration control, error characterization, and environmental influence analysis confirms that the IoT-based mercury detection system achieves reliable performance under real-world operating conditions. The inclusion of comparative cost–benefit evaluation strengthens the argument for its real-world applicability as a low-cost pre-screening tool prior to confirmatory laboratory analysis. Consequently, the proposed system provides a practical bridge between consumer safety monitoring and advanced analytical techniques, enhancing early detection and regulatory enforcement in the cosmetic industry

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REFERENCES

1. Ho, Y. B., Abdullah, N. H., Hamsan, H., & Tan, E. S. S. (2017). Mercury contamination in facial skin lightening creams and its health risks to users. Regulatory Toxicology and Pharmacology, 88, 72–76.
2. Abbas, H. H., Sakakibara, M., Sera, K., Nurgahayu, & Andayanie, E. (2020). Mercury exposure and health problems of the students using skin-lightening cosmetic products in Makasar, South Sulawesi, Indonesia. Journal of Cosmetic, 7, 58.
3. Seewan, S., & Benjarongkij, Y. (2014). The influencing factors pressuring Thai women on decision making on beauty and appearance transformation. Journal of Public Relations, 7.
4. Zhao, M., Li, Y., & Wang, Z. (2022). Mercury and mercury-containing preparations: History of use, clinical applications, pharmacology, toxicology, and pharmacokinetics in traditional Chinese medicine. Frontiers in Pharmacology, 13, 807807.
5. Majeed, T., Shah, S. H., & Anjum, I. (2021). Estimation of mercury and hydroquinone content in skin whitening creams and the potential risks to the health of women in Lahore, Pakistan. Journal of Pakistan Association of Dermatologists, 31(1), 33–41.
6. Yoshimoto, N., Takaoka, M., Fujimori, T., Oshita, K., Sakai, N., & Abd Kdir, S. A. S. (2016). Substance flow analysis of mercury in Malaysia. Atmospheric Pollution Research, 7(5), 799–807.
7. Wang, Z., & Fang, X. (2021). Chronic mercury poisoning from daily cosmetics: Case report and brief literature review. Cureus, 13(11).
8. Sin, K. W., & Tsang, H. F. (2003). Large-scale mercury exposure due to a cream cosmetic: Community-wide case series. Hong Kong Medical Journal, 9(5), 329–334.
9. Zhang, L., et al. (2017). A synthesis of research needs for improving the understanding of atmospheric mercury cycling. Atmospheric Chemistry and Physics, 17(14), 9133–9144.
10. Pratiwi, R., Auliya, N. N., Yusar, R. F., & Shofwan, A. A. A. (2022). Analysis of prohibited and restricted ingredients in cosmetics. Cosmetics, 9(4), 87.
11. Girolametti, F., et al. (2023). Essential and potentially toxic elements (PTEs) content in European tea (Camellia sinensis) leaves: Risk assessment for consumers. Molecules, 28(9), 3802.

12. Selid, P. D., Xu, H., Collins, E. M., Face-Collins, M. S., & Zhao, J. X. (2009). Sensing mercury for biomedical and environmental monitoring. Sensors, 9(7), 5446–5459.
13. Bohari, N. A., Siddiquee, S., Saallah, S., Misson, M., & Arshad, S. E. (2021). Electrochemical behaviour of real-time sensor for determination of mercury in cosmetic products based on PANI/MWCNTs/AuNPs/ITO. Cosmetics, 8(1), 17.
14. Sukesan, R., et al. (2019). Instant mercury ion detection in industrial wastewater with a microchip using extended gate field-effect transistors and a portable device. Sensors, 19(9), 2209.
15. Minami, T., Minamiki, T., & Tokito, S. (2016). Detection of mercury (II) ion in water using an organic field-effect transistor with a cysteine-immobilized gold electrode. Japanese Journal of Applied Physics, 55(4S), 04EL02.
16. Minami, T., Tang, W., & Asano, K. (2021). Chemical sensing based on water-gated polythiophene thin-film transistors. Polymer Journal, 53(12), 1315–1323.
17. Xiao, W., et al. (2016). A portable smart-phone readout device for the detection of mercury contamination based on an aptamer-assay nanosensor. Sensors, 16(11), 1871.
18. Ghanei-Motlagh, M., Taher, M. A., Heydari, A., Ghanei-Motlagh, R., & Gupta, V. K. (2016). A novel voltammetric sensor for sensitive detection of mercury (II) ions using glassy carbon electrode modified with graphene-based ion imprinted polymer. Materials Science and Engineering C, 63, 367–375.
19. Talat, M., Tripathi, P., & Srivastava, O. N. (2018). Highly sensitive electrochemical detection of mercury present in the beauty creams using graphene modified glassy carbon electrode. Innovative Corrosion and Materials Science, 8(1), 24–31.
20. Guo, M., et al. (2020). A test strip platform based on a whole-cell microbial biosensor for simultaneous on-site detection of total inorganic mercury pollutants in cosmetics without the need for predigestion. Biosensors and Bioelectronics, 150, 111899.
21. Ekpunobi, U. E., Okonkwo, E. O., Udeh, C. V., Ogbuagu, A. S., & Duru, C. B. (2014). Determination of hydroquinone and mercury concentrations in some skin lightening lotions and creams sold in Southeastern Nigeria. International Journal of Biotechnology Research, 2(1), 11–16.
22. Arshad, M., et al. (2021). Quantitative estimation of the hydroquinone, mercury and total plate count in skin-lightening creams. Sustainability, 13(16), 8786.
23. Matangi, S. P., Mamidi, S. A., Raghavamma, S. T. V., & Nadendla, R. R. (2014). Formulation and evaluation of anti-aging poly herbal cream. Skin, 5(6).
24. Khodijah, S., Junus, N., & Achir, N. (2022). The role of supervisory agency in the circulation of cosmetics with fake distribution permission. Estudiante Law Journal, 4(2), 1–16.
25. Fu, Q., et al. (2016). A portable smart phone-based plasmonic nanosensor readout platform that measures transmitted light intensities of nanosubstrates using an ambient light sensor. Lab on a Chip, 16(10), 1927–1933.
26. Toan, T. T. T. (2022). Detection of methylparaben in cosmetics by poly L–lysine/reduced graphene oxide-based sensor. ECS Sensors Plus, 1(3), 031603.
27. Selid, P. D., Xu, H., Collins, E. M., Face-Collins, M. S., & Zhao, J. X. (2009). Sensing mercury for biomedical and environmental monitoring. Sensors, 9(7), 5446–5459.
28. Bohari, N. A., Siddiquee, S., Saallah, S., Misson, M., & Arshad, S. E. (2021). Electrochemical behaviour of real-time sensor for determination of mercury in cosmetic products based on PANI/MWCNTs/AuNPs/ITO. Cosmetics, 8(1), 17.
29. Minami, T., Tang, W., & Asano, K. (2021). Chemical sensing based on water-gated polythiophene thin-film transistors. Polymer Journal, 53(12), 1315–1323.