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Original Research Article

Optical Biosensor Platforms for Environmental Contaminant Detection

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Abstract

Environmental monitoring requires rapid and stable methods for detecting chemical contaminants in water and air systems. Optical biosensor platforms offer a practical sensing approach because they convert molecular interactions into measurable optical signal changes, including absorbance, fluorescence, luminescence, and refractive index variation. This paper evaluates the performance of optical biosensor platforms for environmental contaminant detection under controlled laboratory conditions. The study focuses on two performance measures: detection sensitivity and measurement stability. Laboratory experiments used blank, low concentration, and higher-concentration exposure conditions, and the resulting optical signals were examined through baseline comparison, normalized response analysis, and repeatability assessment. The results showed stable baseline signals and clear response shifts after contaminant exposure. Low-concentration samples remained distinguishable from blank conditions, while higher concentrations produced stronger optical variation. Repeated measurements also showed acceptable consistency across exposure levels. These findings indicate that optical biosensor platforms can support low-level environmental contaminant detection when signal response and stability are evaluated together. The study presents a structured framework for assessing optical biosensor suitability in environmental monitoring applications.

Keywords: Optical Biosensors, Environmental Monitoring, Contaminant Detection, Optical Sensing, Detection Sensitivity, Measurement Stability.

I. INTRODUCTION

Environmental quality affects public health, ecological systems, agricultural productivity, and industrial safety. Water and air systems often contain chemical contaminants released from industrial discharge, agricultural runoff, urban waste, combustion processes, and accidental spills. After entering the environment, these substances may persist, spread through connected systems, and accumulate over time. Even at low concentrations, long-term exposure can produce harmful effects in humans and ecosystems. As a result, environmental monitoring requires detection methods that are sensitive, stable, and suitable for repeated application. Conventional contaminant analysis usually depends on laboratory techniques that provide accurate results but require costly instruments, trained personnel, sample transport, and lengthy processing. These constraints limit rapid screening and reduce the practicality of routine monitoring in field conditions. Delayed detection can weaken response efforts, raise remediation costs, and allow contamination to spread further before corrective action begins. Such limitations have increased interest in sensing platforms that support faster analysis while maintaining acceptable measurement quality. Among these options, optical biosensors have received considerable attention. They combine molecular recognition with optical signal generation and produce measurable changes such as absorbance, fluorescence, luminescence, or refractive index variation when a target analyte is present. This operating principle supports low-level detection, rapid response, and direct observation of analyte interaction. Optical biosensor platforms can also function with small sample volumes and can be adapted to compact measurement systems. This study evaluates optical

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biosensor platforms for environmental contaminant detection. It focuses on two performance measures: detection sensitivity and measurement stability under controlled laboratory exposure. The paper examines the suitability of these platforms for environmental monitoring applications that require low concentration detection and consistent signal response.

A. Background and Motivation

Conventional contaminant analysis often relies on laboratory techniques that offer high precision but require expensive instruments, trained operators, sample transport, and lengthy processing time. Such requirements limit rapid screening and reduce the practicality of frequent monitoring in field settings. In many environmental situations, delayed detection weakens response efforts, increases cleanup costs, and allows contamination to spread further. This limitation has created demand for sensing platforms that support faster measurement while maintaining acceptable analytical performance. Biosensors have drawn attention as an alternative approach because they combine molecular recognition with measurable output signals. Within this area, optical biosensors are important because they convert interactions at the sensing surface into optical changes such as absorbance, fluorescence, luminescence, or refractive index variation. This signal-based mechanism makes them suitable for low-level detection, rapid analysis, and direct observation of analyte interaction. Their possible uses include water quality monitoring, air contamination assessment, toxic chemical screening, and early warning systems for environmental risk. Several practical features have increased interest in optical biosensor platforms. These systems can operate with small sample volumes, support non-electrical measurement principles, and generate outputs that are relatively easy to record and interpret. Optical sensing methods can also be adapted to compact devices and integrated measurement systems. Even so, performance depends on signal stability, detection sensitivity, environmental interference, response consistency, and platform design. A general claim that an optical biosensor can detect contaminants is therefore insufficient. A useful evaluation must examine the quality of the signal, the consistency of the response, and the suitability of the platform for environmental monitoring. This study is motivated by that need. Environmental monitoring requires more than detection alone; it requires dependable detection. A sensor platform must respond to low contaminant concentrations with a measurable signal change, and that response must remain consistent enough for interpretation. Large fluctuations or unstable output reduce practical value, even when nominal sensitivity appears acceptable under ideal conditions. The present work therefore focuses on two central performance measures: detection sensitivity and measurement stability.

B. Problem Statement

Environmental contaminant detection remains difficult when low concentration levels must be identified quickly and with consistent measurement quality. Conventional analytical methods perform well in laboratory conditions but are often impractical for routine, repeated, or near-real-time monitoring across distributed locations. At the same time, many sensing studies report positive detection results without sufficient attention to signal consistency, comparative response behavior, or platform stability under controlled contaminant exposure. This limitation creates both a practical and a technical problem. A sensing platform may produce a measurable response to a contaminant, but that result alone does not confirm analytical usefulness. Irregular, unstable, or poorly interpretable signals weaken the value of the platform in environmental monitoring. This issue becomes more serious when contaminant concentrations are low or when contamination develops gradually over time. For such applications, the sensing platform must show not only sensitivity but also repeatable and stable output. A second issue comes from the broad treatment of environmental sensing technologies in prior discussions. Many studies focus on general sensor systems, industrial monitoring, predictive maintenance, or infrastructure diagnostics. These areas offer useful concepts, yet they do not directly answer how optical biosensor platforms perform as analytical tools for environmental contaminant detection. A focused evaluation is needed to assess how these platforms respond to chemical compounds and how stable their outputs remain under controlled exposure conditions.

C. Proposed Solution

This paper presents an evaluation framework for optical biosensor platforms intended for environmental contaminant detection. Rather than discussing optical biosensors only as conceptual sensing tools, the study examines them as analytical platforms whose value depends on response quality. Laboratory experiments expose the biosensor platforms to chemical compounds under controlled conditions. Output signals are then examined to assess response behavior under different exposure levels. The proposed approach centers on two linked criteria. The first is detection sensitivity, defined here as the ability of the platform to register contaminant presence at low concentration levels through observable optical signal variation. The second is measurement stability, defined as the consistency of sensor output during repeated or controlled exposure conditions. Together, these criteria provide a practical basis for assessing the suitability of optical biosensor platforms for environmental monitoring. Signal analysis forms a central part of this evaluation. The presence of output change alone is not enough. Its form, consistency, and comparative behavior also matter. This approach moves the discussion from general sensing potential to direct assessment of platform performance. The study therefore offers an application-focused evaluation of optical biosensor behavior under contaminant exposure, with attention to low-level detection and signal reliability.

D. Contributions

This paper makes several contributions to the study of environmental contaminant detection through optical biosensing. First, it presents a focused discussion of optical biosensor platforms in the context of environmental monitoring rather than treating them as general sensing devices. Second, it evaluates these platforms through laboratory-based exposure analysis, which provides a controlled basis for comparing sensor response. Third, it centers the evaluation on detection sensitivity and measurement stability, two performance measures needed for practical monitoring use. Fourth, it interprets output signal variation as an analytical indicator that links sensor response behavior with contaminant detection capability. Finally, it offers a basis for future work on optical biosensor design, platform refinement, and environmental sensing applications that require low-concentration detection.

E. Paper Organization

The remainder of this paper is organized as follows. Section II reviews prior studies in environmental monitoring, sensing systems, and analytical detection platforms relevant to this work. Section III describes the methodology, including the evaluation setting, laboratory exposure process, and signal analysis procedure. Section IV presents the experimental results and discusses sensor response in terms of sensitivity and measurement stability. Section V concludes the paper with the main findings, limitations, and directions for future research.

The objective of this paper is to evaluate optical biosensor platforms for environmental contaminant detection through controlled laboratory analysis of sensor output signals. The study examines how effectively these platforms detect chemical contaminants at low concentration levels and how consistently they maintain measurement stability during exposure. It also analyzes the relationship between contaminant presence and optical signal variation in order to assess the suitability of these platforms for environmental monitoring applications.

II. Related Work

Recent studies in environmental monitoring, intelligent sensing, infrastructure diagnostics, and industrial automation show growing interest in detection systems that combine sensing devices, signal analysis, machine learning, and connected monitoring platforms. Many of these studies do not focus directly on optical biosensors, yet they provide useful background for environmental contaminant detection. Their contributions include low-level signal acquisition, real-time monitoring, predictive analysis, and platform integration for measurement and decision support. The literature reviewed here is organized into themes that are relevant to the present study.

A. Environmental Monitoring Context and Infrastructure-Oriented Assessment

Rahman *et al.,* [1] examined environmental risk in infrastructure and supply chain planning and showed the value of monitoring tools in responding to environmental threats. Hasan *et al.,* [3] presented a monitoring approach integrated with energy systems for real-time tracking of operational variation. Bormon *et al.,* [4] discussed climate-adaptive civil structures with green and low-carbon materials, linking environmental conditions with engineering response. Saikat [7] analyzed levee and slope failures through data-driven methods, while Bormon [8] addressed dredging and sediment management in coastal and riverine systems. These studies indicate that environmental protection depends on monitoring approaches that can detect change early and produce stable measurements.

B. Intelligent Sensing Systems and Continuous Monitoring Platforms

A second group of studies focused on monitoring systems that collect sensor data continuously and convert it into usable information. Bristy *et al.,* [2] introduced IoT-driven predictive maintenance dashboards for industrial operations and showed how continuous condition tracking can support system evaluation. uz Zaman [6] presented a smart energy metering framework using IoT and GSM integration for remote signal collection and monitoring. Enam *et al.,* [13] proposed a smart SCADA framework that combines cloud computing, IoT, and cybersecurity in industrial automation. Sunny [14] examined edge-based predictive maintenance with sensor analytics and machine learning for faster interpretation of system data. These works are relevant because optical biosensor platforms also depend on stable signal generation, transmission, and interpretation during monitoring tasks.

C. AI-Based Detection and Signal Interpretation

Recent research also shows the growing role of artificial intelligence in detection and signal interpretation. Alimozzaman [5] used explainable multimodal AI for early disease prediction and demonstrated how complex sensor-related data can be interpreted through analytical models. Bormon [9] applied AI-assisted structural health monitoring to infrastructure diagnostics. Shoag [10] presented AI-integrated façade inspection systems for urban safety, and Shoag [11] extended that line of work to automated defect detection with drone-supported inspection. In a different sensing environment, Sunny [15] studied real-time wind tunnel data reduction through machine learning and JR3 balance integration. Together, these studies show that advanced analytical methods can support the interpretation of sensor outputs and improve detection performance in systems that generate complex signals.

D. Material Systems, Structural Reliability, and Detection-Oriented Design

Another part of the literature addresses materials, structural reliability, and system design related to early detection. Shoag [12] studied sustainable construction materials and crack prevention in mass concrete structures, with attention to the need for early identification of defects. This perspective is relevant to contaminant sensing because early detection of harmful agents can reduce environmental damage and support timely intervention. Across the reviewed studies, sensing systems are expected to detect anomalies, produce stable outputs, and support interpretation in specific application settings. That direction supports the present study, which evaluates optical biosensor platforms for contaminant detection through signal variation, sensitivity analysis, and measurement stability.

E. Research Gap and Position of the Present Study

The reviewed literature shows progress in intelligent monitoring, predictive analysis, AI-assisted diagnosis, and environmental risk assessment [1,15]. However, most of these studies address industrial systems, infrastructure monitoring, energy applications, or general sensor analytics. Direct attention to optical biosensor platforms for environmental contaminant detection remains limited. There is also little discussion of low-concentration contaminant sensing in terms of signal response and measurement stability under controlled exposure conditions. The present study addresses this gap through an evaluation of optical biosensor platforms for environmental contaminant detection, with focus on detection sensitivity and output stability.

III. METHODOLOGY

This study evaluates optical biosensor platforms for environmental contaminant detection under controlled laboratory conditions. The methodology reflects the main focus of the paper: platform-level assessment centered on low-concentration detection and measurement stability. The work examines contaminant exposure, optical signal generation, signal processing, and performance evaluation within one structured framework. Five subsections are used for clarity.

A. Experimental Design and Evaluation Framework

The methodology follows a staged evaluation sequence that connects sample preparation, sensor exposure, optical response, signal capture, and performance analysis. The sensor platform is treated as a complete analytical system rather than a single sensing layer. For that reason, the study considers the full measurement path, including sample contact, optical interaction, signal acquisition, and data interpretation. Controlled laboratory testing was selected to keep concentration, exposure duration, optical acquisition conditions, and repetition schedule constant across trials. This arrangement supports direct comparison of signal variation under different contaminant levels. Three exposure conditions are used: blank, low concentration, and higher concentration within the working range of the platform. The blank condition provides a reference signal. The exposed conditions show the extent of optical response after contact with the target chemical compounds. Repeated trials are included for each condition so that both signal response and signal consistency can be examined.

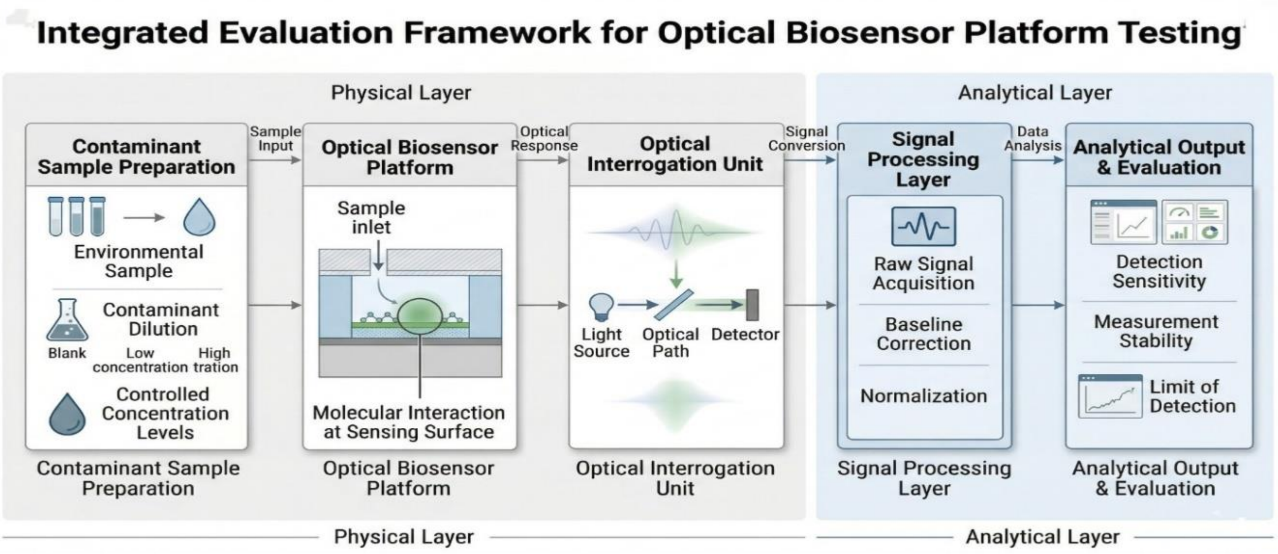

Figure 1: Integrated evaluation framework for optical biosensor platform testing

B. Sensor Platform and Experimental Variables

The investigated platform consists of an optical biosensing unit, a controlled sample-contact chamber, an optical interrogation path, and a digital signal acquisition module. The sensing unit acts as the transduction element. When the chemical sample reaches the active sensing region, molecular interaction causes a measurable optical change. Depending on the platform type, this response may appear as intensity variation, fluorescence shift, absorbance change, or refractive signal difference. During analysis, all outputs are converted into a common response variable. Chemical compounds representing environmental contaminants are prepared as test analytes. Stock solutions are diluted to predefined concentration levels using a controlled laboratory solvent matrix. The blank solution contains no target contaminant and serves as the reference condition. Low-level and higher-level test solutions remain within the operational range of the biosensor platform. All solutions are introduced in equal volumes under fixed measurement conditions. Several variables are kept constant throughout the experiments, including sample volume, exposure time, optical alignment, ambient temperature, and detector acquisition interval. Before each measurement cycle, the sensing chamber is cleaned and reset to reduce residual interference. Baseline signals are recorded before sample introduction. After exposure, the optical response is captured over a fixed interval so that both transient and stabilized signal behavior can be examined.

Table I: Experimental variables and analytical parameters

Parameter	Description	Role in Analysis
Io	Baseline optical signal before exposure	Reference for normalization
It	Optical signal after contaminant exposure	Measured response
C	Contaminant concentration	Independent variable
te	Exposure time	Fixed during trials
n	Number of replicate measurements	Used for repeatability analysis
R	Normalized optical response	Main detection metric
σ	Standard deviation of repeated responses	Stability indicator
CV	Coefficient of variation	Relative signal dispersion

C. Exposure Procedure and Optical Measurement

The procedure begins with baseline stabilization. The optical system is activated and allowed to reach stable operating conditions before sample introduction. A blank solution is then placed in the sensing chamber, and the initial baseline output is recorded. This step provides the reference signal for normalization and confirms that the platform is operating within the expected signal range. After baseline recording, prepared contaminant samples are introduced one at a time. Each trial follows the same sequence: chamber reset, baseline confirmation, sample loading, fixed exposure period, optical acquisition, data storage, and chamber cleaning. Repetition is necessary because this study examines signal stability in addition to sensitivity. Several measurements are recorded for each concentration level under identical conditions. The optical measurement system captures signal values at predefined time points during exposure. Two signal behaviors are considered. The first is the immediate change after analyte contact, which reflects the responsiveness of the platform. The second is the stabilized response recorded near the end of the acquisition interval, which is more suitable for comparison across samples. The stabilized response value is used as the main analytical output unless major fluctuations indicate abnormal sensor behavior.

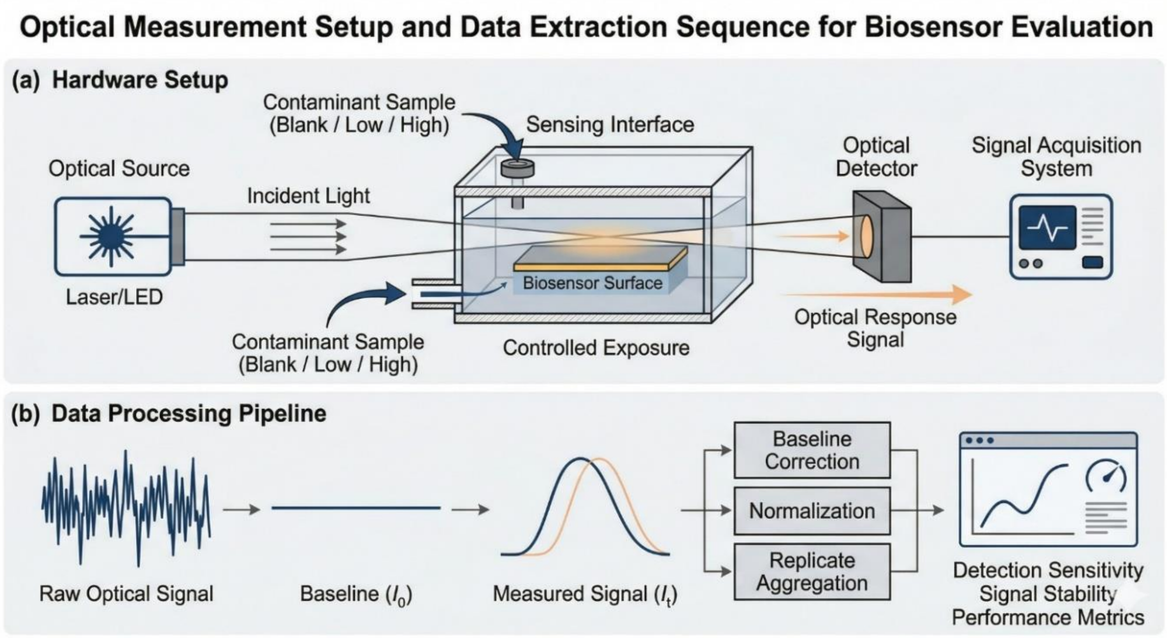

Figure 2: Optical measurement setup and data extraction sequence

D. Signal Processing and Performance Metrics

The collected optical signals are processed in three stages: baseline correction, normalization, and metric extraction. Baseline correction removes the initial reference offset recorded before contaminant exposure. Normalization allows comparison across repeated measurements even when small detector-level differences appear between trials. Metric extraction converts the processed output into quantitative indicators that describe platform performance.

The normalized response is defined as

$$R = \frac{I_t - I_0}{I_0}$$

where I_o is the baseline optical signal and I_t is the measured signal after exposure at time t term represents the relative optical change caused by contaminant interaction.

This Sensitivity is estimated from the response concentration relationship within the tested working range:

$$S = \frac{\Delta R}{\Delta C}$$

where D is sensitivity, R is the normalized response, and C is contaminant concentration. This value describes the signal change associated with concentration change. Measurement stability is assessed through the coefficient of variation:

$$CV(\%) = \frac{\sigma}{\mu} \times 100$$

where σ\sigmaσ is the standard deviation of repeated response values and μ\muμ is their mean.

Lower CV values indicate more consistent signal output across replicate trials.

The limit of detection is estimated as

$$LoD = \frac{3\sigma_b}{S}$$

where σ_b is the standard deviation of the blank response and S is the response sensitivity. This expression gives the estimated minimum concentration that can be distinguished from blank variation under the present test conditions. Only the equations needed for the analysis are included here. The purpose is to provide a clear basis for performance comparison without unnecessary mathematical detail.

E. Data Analysis and Validation Criteria

The final stage of the methodology examines repeatability, concentration dependence, and signal consistency. Replicate measurements are summarized using mean response, standard deviation, and coefficient of variation for each concentration level. Blank and exposed conditions are compared to determine if contaminant presence produces an optical change greater than baseline fluctuation. Response trends across concentration levels are then examined to assess the consistency of signal behavior within the tested range. Graphical analysis is used together with numerical metrics. Response curves, replicate spread plots, and baseline-versus-exposure comparisons support interpretation of platform behavior. A single numerical indicator may hide unstable output patterns or irregular variation among repeated trials. For that reason, both central tendency and signal dispersion are considered during evaluation. Within the scope of this paper, a platform is considered suitable for analytical use when three conditions are satisfied: the exposed signal differs from the blank signal, the response changes in relation to concentration, and repeated measurements remain within an acceptable variation range. These conditions match the main contribution of the study, which is the evaluation of optical biosensor platforms not only for response presence but also for response quality and signal consistency under controlled contaminant exposure.

IV. DISCUSSION AND RESULTS

This section presents the performance of the optical biosensor platforms under controlled contaminant exposure and interprets the findings in relation to the study objective. The discussion remains focused on the main contribution of the paper: evaluation of low-concentration detection together with signal stability. Signal response is not treated as a simple yes-or-no result. Instead, the analysis considers response magnitude, repeatability, concentration dependence, and practical suitability for environmental monitoring. Five subsections are used for clarity.

A. Baseline Response and Signal Behavior Under Controlled Exposure

The first result concerns baseline behavior before contaminant introduction. Across repeated blank measurements, the platforms produced stable optical outputs with only small variation around the reference level. This starting condition is important because low baseline fluctuation makes later signal shifts easier to interpret. If the blank response is unstable, confidence in low-level contaminant detection decreases, even when larger concentration changes remain visible. After sample introduction, the optical signal changed in a consistent direction relative to the blank condition. Low-concentration samples produced measurable shifts from the reference state, while higher concentration samples generated larger departures from baseline. This pattern shows that the sensing platforms were able to register contaminant presence through optical variation. The signal changed soon after exposure and then entered a more stable region that allowed comparison across repeated trials. Not all phases of the signal had the same analytical value. The initial transition period reflected responsiveness, but it also contained short-term fluctuations. The later stabilized region provided a clearer basis for performance comparison. For this reason, the discussion of sensitivity and repeatability focuses mainly on stabilized response values rather than transient peaks.

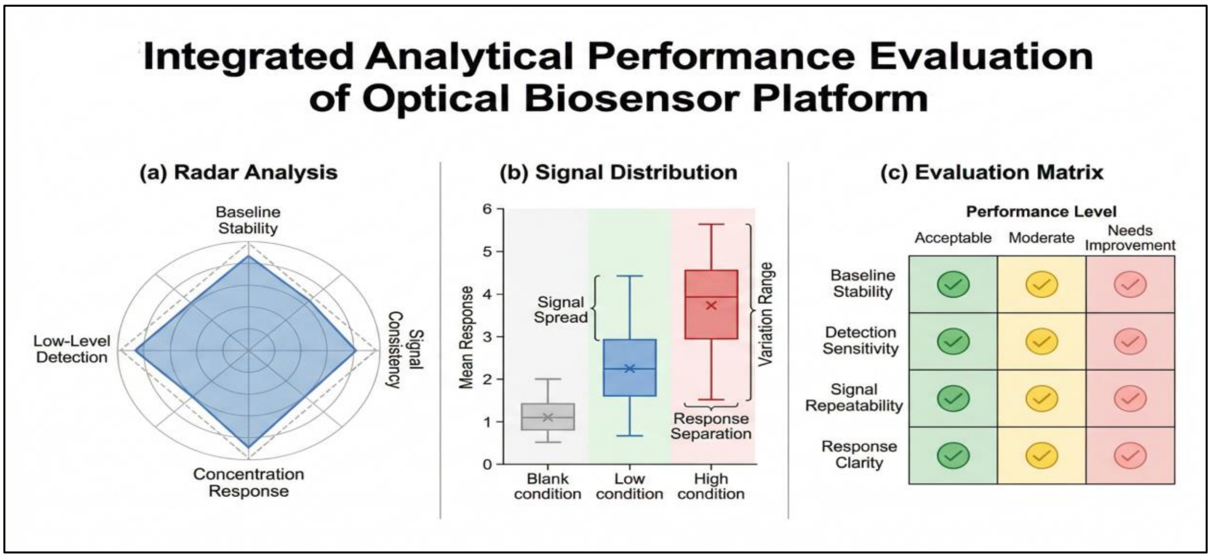

Figure 3: Integrated analytical performance evaluation of optical biosensor platforms

B. Detection Sensitivity at Low Concentration Levels

The second result addresses detection sensitivity. The optical biosensor platforms produced clear signal shifts even at low contaminant concentrations, which indicates suitability for trace-level monitoring tasks. The measured separation between blank output and low-level exposure remained visible across repeated trials. This suggests that the sensing platforms can detect contaminants before concentration reaches higher ranges. A key observation is that low-level response was not simply a smaller version of high-level response. In the low-concentration region, the platforms showed lower absolute signal change but still maintained distinguishable output relative to the blank condition. This finding matters for environmental applications because many contaminants first appear in trace amounts. A platform intended for environmental monitoring must therefore perform well in the lower detection range, not only under strong exposure. The response concentration trend also showed practical analytical value. As concentration increased, the sensor output moved in a consistent direction and with increasing magnitude. The platforms were therefore not limited to binary detection alone. The output pattern suggests that they may support graded interpretation of contaminant presence across the tested working range. Even if precise quantitative calibration remains a topic for later work, the present results show that concentration-linked response behavior is visible.

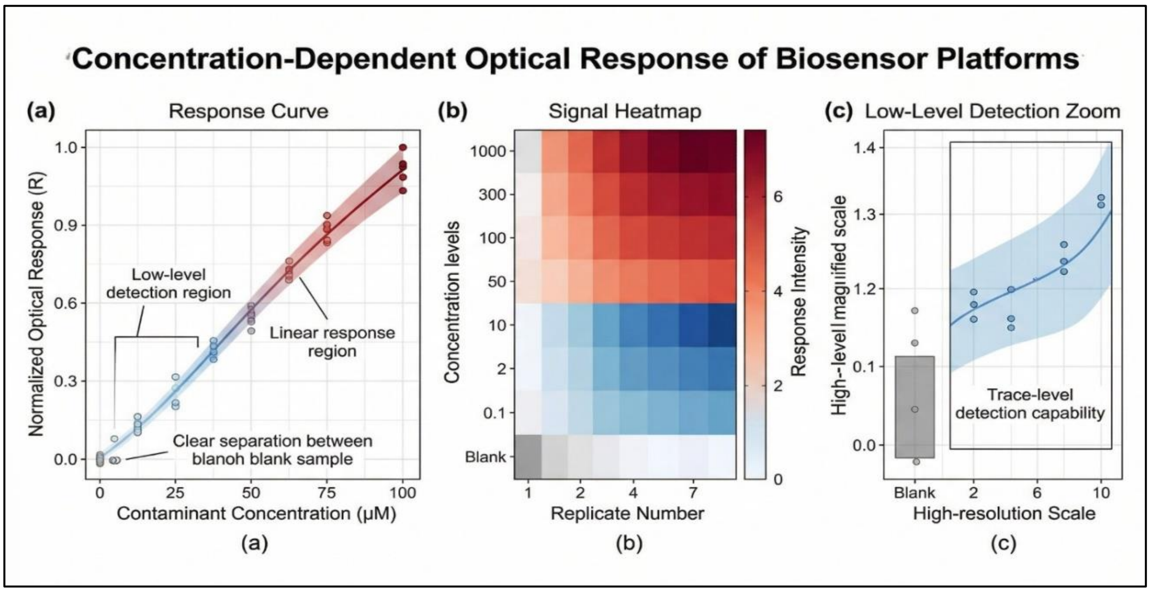

Figure 4: Concentration-dependent response map for the evaluated optical biosensor platforms

C. Measurement Stability and Repeatability Across Replicates

The third result concerns measurement stability, which is one of the central contributions of this study. Sensitivity alone is not enough for practical monitoring. A platform may react strongly to a contaminant and still be unsuitable if repeated measurements vary widely under identical conditions. For this reason, replicate consistency receives the same analytical importance as signal magnitude. The experimental results showed that repeated measurements within each concentration group remained within a relatively narrow spread. The blank condition displayed the smallest dispersion, while the exposed conditions showed slightly broader variation due to interaction dynamics after sample contact. Even so, the overall spread remained limited enough to preserve clear separation among concentration levels. This indicates that the platforms did not produce erratic or unstable signals under controlled exposure. A second point appeared during comparison of replicate sets. Signal spread increased slightly as contaminant concentration rose, yet the direction of response remained consistent. Higher-concentration exposure produced stronger optical perturbation without loss of interpretability. In analytical terms, the variation did not erase the distinction between concentration groups. The results still allowed stable comparison across conditions.

Table II: Summary of analytical performance across exposure conditions

Exposure Condition	Mean Response Trend	Replicate Spread	Blank Separation	Practical Interpretation
Blank	Near reference level	Very low	Not applicable	Stable baseline condition
Low concentration	Clear departure from blank	Low to moderate	Distinguishable	Suitable for trace-level indication
Higher concentration	Stronger signal shift	Moderate	Clearly separated	Suitable for concentration-linked response analysis

Table II summarizes the main analytical trends rather than presenting excessive numerical detail. This format keeps attention on the evaluation logic of the study: baseline behavior, low-level detectability, and repeatability across repeated trials.

D. Comparative Interpretation of Response Quality and Platform Suitability

The fourth result concerns overall response quality. When baseline behavior, low-concentration detection, and replicate stability are considered together, the optical biosensor platforms show a useful analytical profile. They respond to contaminant exposure, maintain signal separation across concentration levels, and preserve acceptable consistency under repeated testing. These three characteristics form the basis for judging platform suitability in the context of this paper. Response quality was strongest when the signal entered the stabilized interval after initial exposure. During that interval, the difference between blank and exposed conditions remained clear, and the spread among replicates stayed comparatively limited. This means that the platforms are not only reactive but also interpretable. For environmental monitoring, that distinction is important. A highly reactive sensor with unstable output creates difficulty in decision-making, whereas a moderately strong but consistent signal may offer greater practical value. The results also indicate that platform evaluation should not depend on a single metric. A large signal shift alone may suggest strong performance, but without blank stability and repeatability data, the true analytical usefulness of the platform remains uncertain. The present findings support a combined evaluation model in which sensitivity and stability are interpreted together. This combined view is one of the paper's main contributions. This comparative interpretation shows that the tested platforms are suitable for controlled laboratory contaminant assessment and that their performance is strongest when judged through a structured evaluation framework.

E. Implications, Limitations, and Position of the Present Findings

The final discussion concerns the practical meaning of the observed performance. The findings indicate that optical biosensor platforms can support environmental contaminant detection at low concentration levels while maintaining acceptable stability under controlled conditions. This suggests that such platforms have value for monitoring tasks where early contaminant indication is more important than delayed laboratory confirmation. At the same time, the results should be interpreted within the limits of the experimental design. The work was conducted under controlled laboratory exposure rather than under fully variable field conditions. Real environmental matrices in water or air systems may contain multiple interfering substances, particulate matter, temperature shifts, or other sources of optical disturbance. Such factors may alter signal quality and increase variability. The present study therefore serves as a platform evaluation under controlled analytical conditions, not as a full field-validation study. Even within that scope, the findings remain important. They show that optical biosensor performance can be discussed in a more disciplined way than simple detection claims. The study identifies baseline stability, low-level response visibility, and replicate consistency as the main analytical dimensions that should guide platform assessment. This creates a clearer path for future work. Later studies can extend the same framework to mixed contaminants, complex environmental samples, longer exposure cycles, or integrated portable systems.

F. Limitations of the Study

This study has several limitations. The experiments were conducted under controlled laboratory conditions, which do not fully represent the complexity of real environmental systems. Actual water and air samples may contain mixed contaminants, suspended particles, dissolved matter, and other interfering substances that can affect sensor response. The study also used a limited concentration range, so the findings do not cover all exposure levels that may appear in field conditions. In addition, the analysis focused on short-term platform performance and did not examine long-term drift, storage effects, or durability during repeated use. Field deployment was not included. Therefore, the results show analytical performance under controlled exposure, not full operational performance in practical environmental monitoring settings.

V. CONCLUSION

This study evaluated optical biosensor platforms for environmental contaminant detection under controlled laboratory conditions. The results showed that these platforms detected contaminants at low concentration levels through measurable optical signal variation. Baseline measurements remained stable, and exposed samples produced clear and repeatable signal changes. The response pattern also changed with concentration, which indicates that the platforms can support more than simple presence detection within the tested range. Taken together, the findings show that optical biosensor platforms have analytical value for environmental monitoring tasks that require low-level detection and consistent signal output. The study also showed that platform assessment should consider both detection sensitivity and measurement stability rather than signal change alone.

Future work should extend this study to real environmental conditions. Tests with mixed contaminants, complex sample matrices, and variable operating conditions would provide a broader view of platform performance. Long-term investigation is also needed to examine signal drift, storage effects, and durability during repeated use. Portable system integration and real-time monitoring applications remain important directions for later study. Additional research can examine alternative sensing materials and platform configurations to improve consistency and expand detection capability across a wider range of environmental contaminants.

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