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# Bacterial Bioluminescent Biosensors: Principle and Applications

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**Abstract**

Numerous hazardous contaminants with detrimental effects a replete in the ecosystem. Bacterial Bioluminescent Biosensors offer an easy and reliable method for monitoring these contaminants towards environmental remediation. These biosensors respond to analyte either constitutively or inducibly on a non-specific or specific basis respectively. Either way, they offer a reliable method for detection and biological interpretation toxicants. Their responses are recorded in terms of bioluminescence; a physiological function that will change variously in response to a toxicant. Bacterial bioluminescent biosensors have been successfully deployed in various areas of science including environmental monitoring and in the food industry.

**Keywords:** Bacterial bioluminescent biosensor; Contaminants; Bioavailability; Toxicant; Remediation

## Introduction

A notable consequence of the global industrial revolution is the contamination of the ecosystem. This has become worse as numerous anthropogenic activities have placed the ecosystem at the receiving end of numerous contaminants. These contaminants are with severe consequences on the environment and inhabiting biota, including man. Presently, the ecosystem threatens to haunt man as a result of severe degradation. This explains numerous global efforts towards ecosystem restoration and preservation. The successful reclamation of the contaminated ecosystem relies heavily on initial assessment of extent of contamination [1,2]. The effective assessment of contaminated sites rely on choice of tools used. Although an understanding of level of contamination is important, estimating the bioavailable fraction is key [3]. Most chemical methods define the bioavailable fraction of a contaminant but fail to interpret in the biological sense [4]. The introduction of biological measurements and peculiar environmental parameters are important in hazard/risk analysis because they reflect the functionality of ecological processes in these environments [1,5]. Biological models such as earthworms and other invertebrates have been used for environmental assessment [3]. However, microorganisms such as bacteria are preferred due to their high sensitivity, low cost, ability to perform in a range of pH and temperature as well as ease of application [6,7]. described microorganisms as unequalled in gene expression and physiology study of complex environments, providing accurate response on various contaminants from a biological standpoint. Biosensors have been extensively applied in health, agriculture, food industries and environmental studies [8-10]. This short review presents a brief into the principle of operation of the bacterial bioluminescent biosensor and further displays their applications in key scientific areas.

### The principle of bacterial bioluminescent biosensor

A biosensor is an integrated analytical device that uses biological recognition element, mostly biomolecules, to bind an analyte or contaminant [8,9]. The binding event is captured by a transduction mechanism measured in terms of bioavailable fraction of the analyte [11,12]. Biosensors are cheap, rapid, selective and usually specific. Based on various criteria, biosensors may be classified as affinity and catalytic based on the activities of

the biorecognition elements [12]. They may be classified (based on biorecognition element used) into enzyme, cofactor, nucleic acid, antibody receptors, organelle, tissues, cells, molecular imprinted polymers, liposomes as well as microbial biosensors [12,13]. reported that the choice of biological response agent depends on analyte, specificity, storage and environmental stability.

Microbial biosensor immobilizes microorganisms on a transducer for the detection of analytes. Although several microorganisms could be used as microbial biosensors, bacteria is preferred as they are major constituents of various environmental biotic community and control most ecosystem functions in terms of biogeochemical cycling [3]. Whole-cell bacterial biosensors usually operate on the principle of bioluminescence and may be constitutively expressed (bioluminescent in the absence of the toxicant) or inducible (bioluminescent in the presence of a specific substrate) (Table1). Several bacterial biosensors with varying detection limits have been developed and successfully applied [7]. The detection limits of the bioluminescent biosensors are range from rather negligible levels to very high contaminant concentrations [8].

**Table 1:** Features of an Ideal Biosensor.

| |
|---|
| 1. Should offer a real time response to analyte studied. |
| 2. Should be highly sensitive in analysis and able to detect target analyte even at negligible concentrations. This will rule out false-negative analysis. |
| 3. High specificity for clear distinction of the target analyte. This will ensure avoidance of false positive results based on similar contaminants. |
| 4. A good biosensor should be Reproducible for ease of calibration. |
| 5. It should be accurate to minimise false negative and positives. |
| 6. Robust and able to cope with environmental conditions such as temperature, pH, etc. |
| 7. An ideal biosensor should be Cost effective. |
| 8. Miniature size and weight so as to allow for use in both process and field monitoring applications. |
| 9. The biosensor should have a regenerate binding surface. This will enable a single biosensing element to be used severally. |
| 10. Should be a Multianalyte detection tool. |
| 11. Easy user interface, requiring little or no skills for routine analysis. |

Just like ability to code for a given protein confers certain functions to various organisms, bacteria is only able to survive a polluted environment if it is able to encode a resistance system [7]. This is a great plus in the constitution of biosensors (Figure 1). Bioluminescent sensing involves detecting change in luminescence emitted by the bacteria in response to a target analyte in a dose dependent manner. The luciferase coded by the lux gene catalyses the oxidation of Flavin Mononucleotide (FMNH2) and a long chain fatty aldehyde to emit of blue-green light. It provides a faster and more sensitive detection than fluorescence since bioluminescence is a measure of enzyme activity instead of protein quantification. Other advantages include no need for external substances as all reactants are produced in vivo and lux gene, may be inducibly or constitutively controlled [11] (Figure 2).

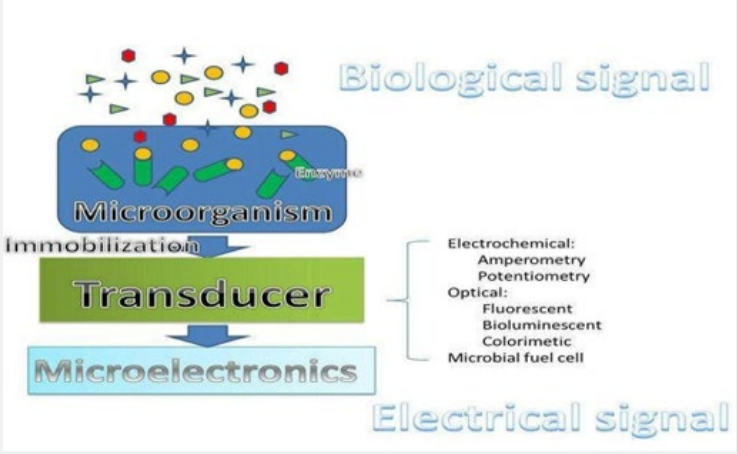


**Figure 1:** Principle of Bacteria Bioluminescent Biosensor.


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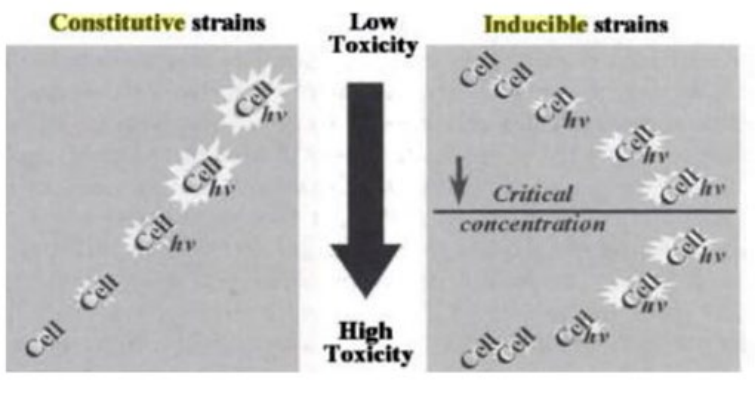


The Key Difference as Shown by the Arrow is that Bioluminescence goes on and is Disrupted by Toxic Analyte in the Constitutive, but None is Observed in the Inducible Until the Target Analyte is Encountered so that Luminescence Increases till the Toxic dose is Attained. the 1st Gets Total while the Latter Pursues Basal Expression which Increases in the Presence of Target Analyte.
**Figure 2:** Microbial Biosensor Constitutive and Inducible Biosensors at a glance.

## Applications of Bacterial Bioluminescent Biosensors

### Detection of environmental contaminants

Numerous contaminants such as Polycyclic Aromatic Hydrocarbons, heavy metals and crude oil, result from various anthropogenic activities. Primarily, industrial processes has led to the introduction of these contaminants to the environment. These substances are present at different levels and usually with adverse effects to the biota. The use of bacterial bioluminescent biosensors have been useful in the detection of these toxicants even at very low concentrations. More so, the detection is assessed by these sensors with a biological interpretation of the effects at once. These sensors provide a cost effective, reliable and specific assessment method for evaluation of numerous contaminants. Some bioluminescent biosensor that have been used in monitoring environmental pollution include E. coli [14], Pseudomonas sp. [15], Bacillus subtilis [16]. Studies have successfully applied these biosensors for detection and monitoring contaminants in water, soil and air environments [14,17-19].

### Applications in the food industry

The food industry is a very sensitive one with high quality expectations. However, food products integrnty have been compromised severally. This has led to many adverse effects. Numerous traditional testing methods may fail to identify hazardous contaminants in food at certain low levels. Bacterial luminescent sensors have been applied to detect toxicants in food at very negligible levels. This has been applied successfully to monitor bacteria contamination and count in food [19-21]. The food industry presents with a high need for quality assurance now than ever. Biosensors offer specific and affordable methods to meet this quality assurance needs [14].

## Conclusion

Bacterial bioluminescent biosensors present with numerous beneficial, desirable attributes for the monitoring and assessments. They are able to detect at negligible levels so long as the analyte is bioavailable. These biosensors have been successfully applied in various areas of science. Biotechnology could aid in the development of various biosensors for specific monitoring of analytes.

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