Biochemical fiber sensor based on evanescent field for detection persistent organic pollutants (POPs)

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Abstract. Fiber optic is a light waveguides media that are cylindrical. Optical fiber has certain properties when it transmits light so it can be developed to be a sensing device or sensor. Evanescent wave phenomena appear when there are total internal reflections from many modes in an optical fiber. In this research, the Biochemical Fiber Sensor (BFS) using polishing cladding and some of the core fiber will be fabricated. BFS is used to interact with a biochemical compound.The principle of BFS is based on evanescent absorption which absorbs the typical spectrum of a biochemical compound. By measuring the spectrum from the light output in the BFS, evanescent absorption spectra can be analyzed an optical fiber. In this study, the biochemical compounds that used are lindane that is one of the Persistent Organic Pollutants (POPs). The result showed that there is a change from BFS spectra when it was exposed by POPs compound with various concentration. That change showed that there is evanescent absorption in BFS. Concentration of POPs compound is proportional with evanescent absorption of the POPs compound.

1. Introduction

The environment is a place to grow and reproduce for all organism. Environment conditions will determine the quality of life for living things, especially humans. Recently the environmental pollution is a problem occurred in almost all places in the world. The development of science and technology have had an impact on the appearance of harmful substances to the environment. Human behavior is irresponsible make harmful substances released into the environment that causes environmental pollution. One of the harmful substances are often found is Persistent Organic Pollutants (POPs) from the disposal of industry [1]. POPs are organic compounds that are produced by human activity where the compound cannot be decomposed by the environment [2]. POPs compounds indicated the risk that can affect human health and the environment. The affect in humans include leukemia, aplastic anemia, allergies and asthma. Also, contamination of POPs in the environment cause the extinction of certain species, the decline of fish populations, the emergence of resistance or pest resurgence, and the killing of birds or insects that are useful [3].

Relating to the problem of optical fiber-based sensor technology may seem to be a solution. Fiber optic is a light waveguides media that are cylindrical. Optical fiber has certain properties when it transmits light so it can be developed to be a sensing device or sensor. Various methods based on optical sensing techniques have been developed to detection biochemical compounds, such as fiber bragg gratings [4], grating coupled waveguide[5], surface plasmon resonance (SPR) [6].

In this research, we created biochemical fiber sensor (BFS) with optical spectroscopy method based on evanescent field that occurs in optical fiber. Evanescent phenomena appears when there are total internal reflection from many modes light in optical fiber. Evanescent phenomena occur in boundaries between core and cladding [7]. POPs compounds were placed in the sensing area interact with evanescent field which resulted from the absorption at spectrum light that propagates in the fiber optic. Every molecule on earth has the emission spectrum and absorption spectrum that has a unique spectrum. The Emission spectrum is spectrum radiated by an element when the excitation of atoms. Emission spectrum radiated having the spectrum that contains only certain wavelengths. The Absorption spectrum is the spectrum of the radiation absorption results of the molecule. When polychromatic light is passed through a molecule, it turns out the molecule absorb light of a certain wavelength of wavelengths contained in the emission spectrum [8]. Therefore with knowing typical absorption we can detect POPs compounds. This research used a lindane as sample POPs compounds.

2. Method

2.1. Fabrication Biochemical Fiber Sensor

Fiber sensor is optical fiber used for sensing purposes. BFS based on the evanescent field created by removing the cladding and reducing some of the core diameters in some long fiber optic. Cladding and some of the core diameter core removed by using a polishing machine. After that, the fiber sensor is cleaned by water. The length of fiber sensor sensing area is 3 cm and depth of polish is 1,5 mm shown in Figure 1.

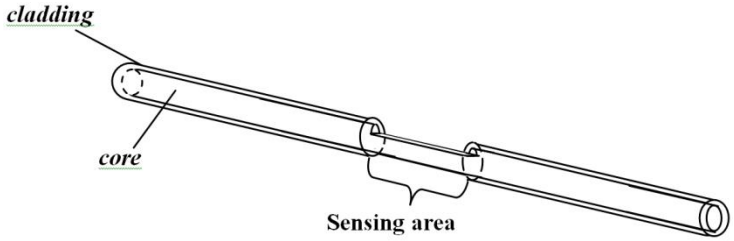

Figure 1. fiber sensor scheme

2.2. Experiment

Experimental set up is shown in Figure 2. The devices used in the experimental setup consists of a light source form halogen lamp, fiber sensors, spectrophotometer and software acquisition. Evanescent phenomena occur in boundaries core and cladding when incoming light and propagates through fiber sensor. In the sensing area, the light interact with lindane because evanescent field phenomena and absorbsition evanescent was occurred. Spectrophotometer is used for measurement spectrum wavelength light that propagates through fiber sensor. The Measurement result is displayed a personal computer with software acquisition.

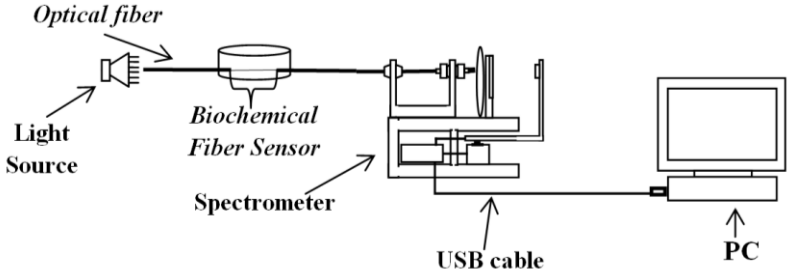

Figure 2. Experiment set up schema.

This research used a lindane as sample POPs compounds. In this experiment, a pure lindane compounds was dissolved with methanol 70% with variations concentration 2,06x10^{-3} ;1,06x10^{-3} ; 5,15x10^{-4}; 3,43x10^{-4} ; 2,58x10^{-4}. For calculating absorption evanescent value, use formula 5.

$$A = -\log T = -log\frac{I_t}{I_{ref}} \quad (1)$$

Where I_{ref} is methanol 70% intensity and I_t is lindane compounds [9,10].

3. Result

The light that propagate through optical fiber cause total internal reflection. Total internal reflection occurs when light propagates in the optical fiber toward the boundary between the core and the cladding have the angle of incidence exceeds the critical angle, the light will be reflected back into the core.When light propagates in the optical fiber and reaches the boundary between the core and the cladding, light penetrate the cladding before returning to the core. The light that penetrate the cladding is called evanescent field. The graph in figure 3. shows the spectrum of light in fiber sensor when given a lindane. Lindane solution fills cladding and some of core diameter fiber optic that removed so that lindane function as cladding. Phenomena evanescent cause light propagates in fiber optic interact with lindane and occurs absorption of light propagates in fiber sensor by lindane compounds or can be called by the absorption evanescent.

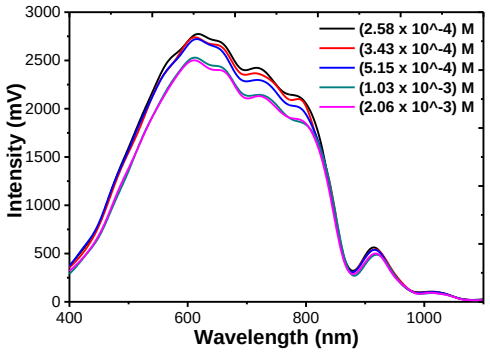

Figure 3. Graph spectrum light fiber sensor.

Absorption evanescent is calculated with use formula 1 and be obtained graph absorption as wavalenght function. Graph absorption evanescent is shown in Figure 4. Absorbance evanescent according to the characteristics of lindane solution absorbs certain wavelengths that are characteristic compound lindane. The results obtained showed absorbance evanescent lindane absorption peak at 913 nm and 1003 nm.

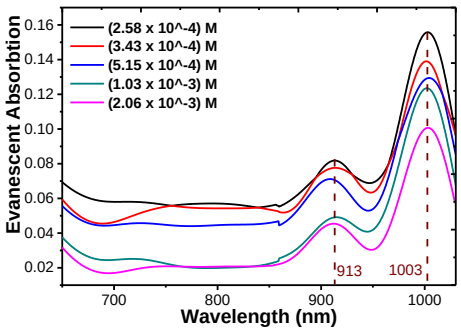

Figure 4. Graph absorption evanescent from lindane.

Coefficient absorption evanescent given by

$$A = \gamma LC \quad (2)$$

Where A is the absorbance, C is the concentration of the solution, L is the length of the sensing area and is the coefficient absorption evanescent[11]. Based on the equation 2 can be obtained the relationship between the absorption evanescent with the concentration of lindane as shown in Figure 5.

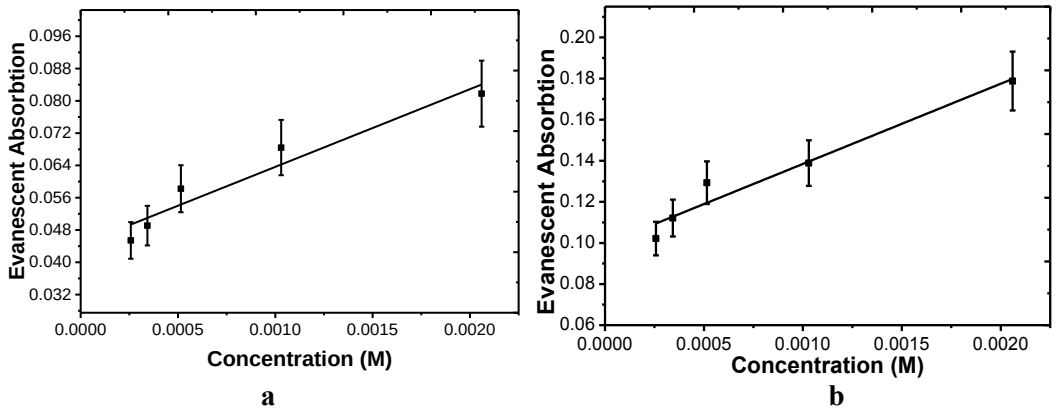

Figure 5. Graph absorbance *evanescent* as concentration function *lindane* at (a. 913nm b.1003 nm).

The results obtained graph shows that the greater the concentration of lindane that dissolved the greater the absorbance which occurs. The coefficient of absorption evanescent calculated based on the equation 2 is shown in Table 1.

Tabel 1. Wavelength and Coefficient absorption*Evanescent*

Wavelength (λ)	Coefficient absorption Evanescent (γ)
(nm)	($M\ cm^{-1}$)
913	5,97
1003	14,22

4. Conclusions

Biochemical fiber sensor works based on evanescent field has been demonstrated and used for detection evanescent absorption spectra from POPs compounds. The evanescent absorbance observed corresponds with the characteristics of POPs compounds**.**

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