Study of Evanesence Wave Absorption in Lindane

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Abstract. Evanescent wave field has been studied for the purpose of tailoring fiber sensor capable of detecting lindane concentration in a solution. The mounted fiber was optically polished such that part of the fiber clad is stripped off. To study the evanescent wave field absorption in lindane solution, the unclad fiber was immersed in the solution. Light coming out of the fiber was studied at different wavelength each for different lindane concentration. It was shown that evanescent wave field absorption is stronger at wavelength corresponding to lindane absorption band as has been shown from absorption studies lindane in UV-VIS-NIR spectrophotometer.

1. Introduction

Farming efficiency have introduced not only modern farm machinery but also the use of fertilizer and pesticides. Applying this modern method, farmers have become capable of increasing the land productivity using less labor and land. The biggest issue is improper and excessive use of chemical fertilizers and pesticides can endanger our environment. Among many pesticides used by famers, lindane is one that have been used excessively in rural country. To ensure that the disposed lindane in our environment is still under the allowed level, frequent monitoring of lindane concentration level in our environment is required.

So far, lindane and other persistent organics pollutants (POPs) concentration in a groundwater is obtained from expensive lab work. Many sensors capable of measuring POPs concentration have been developed. Among them are optical fiber sensors. In last few decades, these sensors have received much attention because of many reasons. Among them are small size, low cost, no electrical risk, and immune from interference. Taking these advantages in mind, many optical fiber sensors have been developed. Few of them are mechanical fiber sensors [1, 2, 3], thermal fiber sensors [4, 5], and biochemical fiber sensors [6 - 9]. The main advantage of using optical fiber for biochemical sensors is the capability of light to reveal the finger print (unique absorption or emission spectrum) of a compound. Aimed at designing fiber sensor to measure lindane concentration, this paper presents the analysis of light-lindane interaction in term of the amount of the evanescent wave field light absorbed as unclad fiber optic is immersed in different concentration of lindane solutions.

2. Experimental

Lindane used in this experiment was that purchased from Sigma-Aldrich with purity of 99 %. Lindane was then dissolved in methanol 70% so that different concentrations of lindane solutions were
obtained (2.06x10^{-3} M, 1.06x10^{-3} M, 5.15x10^{-4} M, 3.43x10^{-4} M, and 2.58x10^{-4}M). Standard absorption spectrum of each lindane solution was recorded at room temperature using UV-VIS-NIR spectrophotometer. In order to study the absorption spectrum of lindane resulted from its interaction with the light propagating along the fiber sensor, polymer optical fiber was mounted on a resin block surface. Polishing this surface gently will strip part of the fiber clad away. Figure 1 is the experimental setup. The optical fiber sensor was immersed in lindane solution. As the polychromatic light was launched from one end of the fiber, light will propagate in the fiber core with multiple total internal reflections (TIR). Evanescent wave field resulted on unclad fiber might be absorbed by lindane solutions. The absorption strength will then be detected by spectrometer and displayed by personal computer (PC).

3. Results and Discussion

Figure 2 is absorption spectra of many different concentrations of lindane solutions recorded at room temperature. Two unique absorption bands corresponding to absorption peaks at 913 nm 1003 nm are observed. Absorbance peaks at 913 nm corresponding to lindane solutions of 2.06x10^{-3} M, 1.06x10^{-3} M, 5.15x10^{-4} M, 3.43x10^{-4} M, and 2.58x10^{-4}M are 1.55x10^{-2}, 1.67x10^{-2}, 1.71x10^{-2}, 1.74x10^{-2} and 2.30x10^{-2} arbitrary units, respectively. While for band peaks centred at 1003 nm, their corresponding absorbances are 9.25x10^{-2}, 9.37x10^{-2}, 9.53x10^{-2}, 9.58x10^{-2}, and 9.71x10^{-2}, respectively. It is clearly seen from figure 3 that the absorption peaks increase linearly with the increase of lindane.
concentrations. Both curves give good linearity ($R^2 = 0.91$ for absorption band at 913 nm and $R^2 = 0.93$ for that at 1003 nm). No such relation can be observed for absorbance beyond these two absorption bands. Good correlation between absorption peak and its corresponding concentration of a solution has also been observed by other researchers [10, 11] implying that a unique absorption band strength can be used as a measure a compound concentration presents in a solution.

**Figure 3.** Absorbance peaks of lindane solution at wavelength (a) 913 nm and (b) 1003 nm

**Figure 4.** Light intensity spectra expressed in voltage detected from the end of the fiber sensor as the unclad part of the fiber were immersed in different concentrations of lindane solutions. Higher voltage as shown in this figure means that more light is transmitted through fiber optic while less voltage means more light is absorbed. Absorption at 913 nm and 1015 nm as shown in figure 4 corresponds to absorption at 913 nm and 1003 nm, respectively. There was a slightly shift of the peaks positions of the light spectra recorded by our evanesence wave field spectrometer compared to that recorded by direct measurement of absorption by UV-VIS-NIR spectrophotometer. This shift however is still within the tolerated error.

Figure 4 is light intensity spectra expressed in voltage detected from the end of the fiber sensor as the unclad part of the fiber were immersed in different concentrations of lindane solutions. Higher voltage as shown in this figure means that more light is transmitted through fiber optic while less voltage means more light is absorbed. Absorption at 913 nm and 1015 nm as shown in figure 4 corresponds to absorption at 913 nm and 1003 nm, respectively. There was a slightly shift of the peaks positions of the light spectra recorded by our evanesence wave field spectrometer compared to that recorded by direct measurement of absorption by UV-VIS-NIR spectrophotometer. This shift however is still within the tolerated error.

Strong absorptions observed at 918 nm and 1015 nm as shown in figure 4 imply that part of the evanescent wave field penetrate out of the fiber core within the unclad fiber is strongly absorbed by lindane solution using mechanism outlined in figure 5. Light is launched from one end of the optical
fiber and propagating toward the other end with total internal reflection (TIR). As the light strikes the core-cladding interface, light will be reflected back to the core. At the striking point, part of the light penetrates in the cladding area, but because the cladding material is not designed to absorbed light, the light will keep moving forward. In term of field distribution, strong field is confined within core region with weak tail penetrates within very depth skin in clad region. As the clad is removed and replaced with lindane the evanescent wave field might or might not be absorbed. If light with wavelength beyond the absorption band is launched into the fiber optics, light will not be absorbed. While if it is within the absorption band, light will be absorbed.

![Figure 5](image.png)

**Figure 5.** Absorption mechanism of evanescent wave field within unclad fiber by lindane solution. (1) fiber clad, (2) evanescent wave field penetrating in fiber clad, (3) evanescent wave field penetrating in lindane solution, (4) light propagation in fiber core.

4. Conclusions
Absorption spectra of different concentration of lindane at room temperature have been measured using UV-VIS-NIR spectrophotometer. Two absorption peaks corresponding to wavelength of 91 nm and 1003 nm have been shown to linearly increase with the increase of lindane concentration in solution. Absorption of evanescent wave field observed from the immersed unclad fiber into lindane solution also showing similar results. This suggest that optical fiber sensors to measure lindane concentration in a solution that work based on absorption evanescent wave field might be designed.

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