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The detection of lead ion level in distilled water using 405 nm laser light and optical probe based on the Directional coupler

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Abstract

The development of lead ion detection systems is expected to have an advantage in terms of simplicity of the device and easy to trace the of level lead ion in the water. The level of lead ion in water that is allowed into the human body is 0.01 ppm. In this work, an alternative methode to detect the concentration of lead ion in water using 405 nm laser light and optical probe based on the directional coupler is proposed. The proposed methode to detect the concentration of lead ion is using directional coupler and flat mirror as a reflecting component. The performance of this new detection system that was developed will be shows: (i) sensitivity; (ii) linearity; (iii) operation range; and (iv) the limit of detection (LOD). To shows this performance, the system was tried to detect the concentration of lead ion in distilled water from 0.01 ppm to 0.07 ppm with four replication for each concentration. The performance of this alternative methode to detect lead ion has a 26.78 mV/ppm of sensitivity of with a linearity more than 99%, operation range operation range start from 0.01 ppm to 0.07 ppm, and LOD reaches 0.01 ppm.

Keywords: *directional coupler; laser light; flat mirror; lead ion*

1. Introduction

The water consumed by the community must be free from lead contamination, especially for drinking water. The lead content in the blood of children can cause decreased levels of intelligence, anemia, impaired reproductive function, kidney function, inhibit hemoglobin synthesis in bone marrow and trigger fetal defects. Children are particularly vulnerable to the health affects of unsafe drinking water, which include not only diarrheal disease but also diseases linked to inorganic pollutants such as lead. The exposure of lead contaminants for fetal and childhood can cause neurological damage and developmental impairments with lifelong consequences [1]. The allowable threshold for lead is 0.01 mg / l or equivalent to 0.01 ppm [2]. This study, developed an alternative method for detection of lead (Pb) in water. In this study we developed an optical fiber spectrophotometry technique based on the optical fiber displacement system. Development of lead (Pb) ions detection systems was expected to have advantages among others simplicity of the device and easy for the trace it content in water. In this work, an alternative methods to detect concentration of lead ions in water base on optical fiber spectrometry using directional coupler and flat mirror as a reflecting component is proposed. Optical fiber applications for sensors have been carried out by utilizing fiber-optic fiber - displacement systems. An optical fiber displacement system using a "bundled probe" can be used to detect medals [3]. The phenomenon of displacement between the tip of optical fibers has been successfully developed as a surface height sensor of a liquid material [4]. Studies relating to the development of fiber optic sensors for the determination of the concentration of a chemical has been carried out [5–8]. Optical methods developed to measure the concentration of these materials utilize the phenomenon of displacement between the ends of optical fibers. This developed technique is called optical fiber spectrophotometry techniques. With optical fiber spectrophotometry techniques it will be possible to measure the concentration of lead ions. The use of optical fiber spectrophotometry techniques to measure lead ion concentration is done by using a light source with a wavelength corresponds to absorbption wavelength of sample. If the absorbance of the samples detected using the optical fiber spectrophotometry technique is in the visible and ultraviolet (UV) region, the light source used must also be in the visible and ultraviolet region. For lead samples mixed with the ethylene tetra acetate acid (EDTA = $C_{10}H_{16}N_2O_8$) reagent, the absorbance is in the area of about 405 nm. For detection of this sample, a light source with a wavelength of 405 nm must be used. With optical fiber spectrophotometry techniques uses directional coupler and violet LED (405nm) source has been carried out with smallest detection limit of lead ions in water reaches a level of 0.1 ppm [9]. This study, we developed that system using violet laser diode (405 nm), flat miror and 2x2 directional coupler, so the smallest detection limit of lead ions in water reaches a level of 0.01 ppm. The experiment was begun with the preparation of samples of lead ions. The lead sample of nitrate Pb(NO3)2, dissolved in water. Samples of Pb(NO3)2 were fed ethylene tetra acetate acid reagent (EDTA = C10H16N2O8). Each sample was made variation of concentration from 0.01 ppm to 0.007 ppm.

2. Experimental setup

The use of optical fiber spectrophotometry techniques to measure concentration is done by using a light source with a wavelength that corresponds to the absorption wavelength of the sample passed by light. Some of the light intensity that is about the sample will be absorbed in proportion to the concentration of the sample. Some of the remaining light is forwarded to be applied to the optical detector. In this method, the

sample concentration is determined by the amount of light intensity absorbed by the sample. Description of the absorption mechanism in the sample can be explained through a model such as Figure 1.

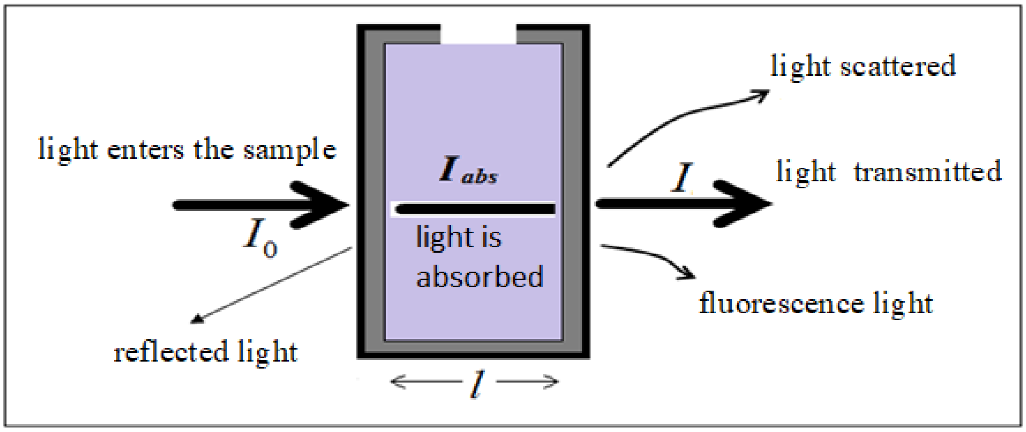

Figure 1: Model absorption mechanism on sample

According to the law "Beert-Lambert", the relationship between the intensity of light coming, the intensity that is forwarded and the concentration can be expressed as follows.

$$I = I_0 e^{-kcl}$$

Where *k* is a constant, c is the concentration and *l* is the thickness of the sample.

This equation, in other forms can be written as follows.

$$I - I_0 \cong -I_0 kcl$$

If the absolute value is taken to this equation, so it can be state as follows.

$$|I - I_0| \cong I_0 kcl$$

The absolute value of the difference intensity is proportional to the concentration of the sample. The absorption mechanism described above occurs in the cuvette component of the sensor probe for lead detection system as shown in Figure 2. The design of this optical system is a sensor probe that detects the concentration of lead ions (Figure 2) uses directional coupler 2 x 2 and flat mirror as a reflecting component. The tip of output-2 Diretional coupler is used to emit the light into flat mirror after crossing the sample. The light reflected by the mirror which crosses the sample is received by output-2 Directional coupler to be forwarded into input-2 directional coupler and optical detector. The tip of output-2 Directional coupler and mirror are integrated with the sample cuvette. In principle, experiment setup to detect the concentration of lead ion using a directional coupler (uses 2x2 directional coupler) and mirror is shown in Figure 3. The light source to detect lead (Pb) uses diode-violet laser (405 nm). The light from its source continued through input-1 directional coupler transmitting to output-1 directional coupler, which its output has been set to be a displacement system between the tip of it output and flat mirror. The tip of output-2 directional coupler is used to emit light towards the flat mirror and across the sample. The light reflected by the mirror and across the sample is received back by output-2 directional coupler to be forwarded on optical detector through input-1 directional coupler. The intensity of the light that coming at the optical detector will be converted into a voltage and detected using a millivolt meter.The displacement of the tip of output-2 directional coupler and a flat mirror must be chosen which produces the most optimum output. Here we will try the variations in displacement distances between 1,100 µm to 2,500 µm for the conditions: if the cuvette is not filled with samples and the cuvette is filled with water.

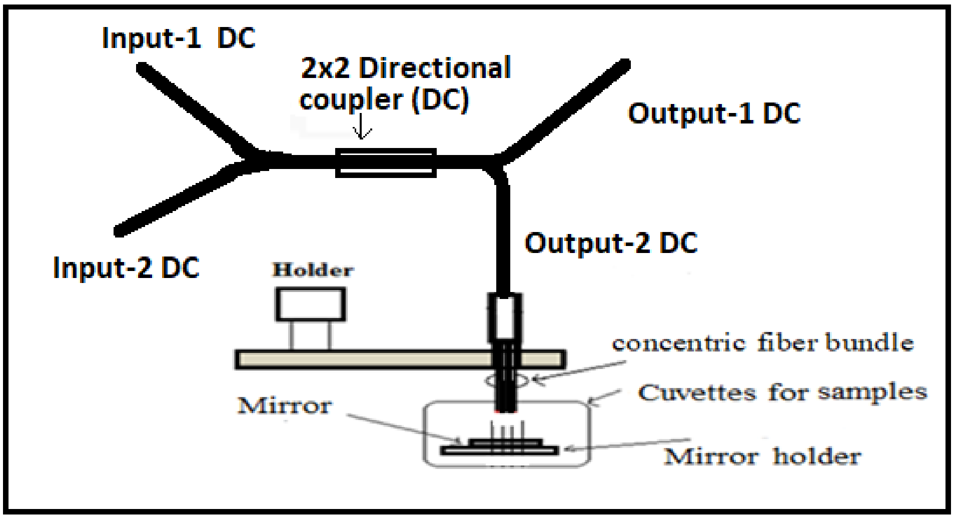

Figure 2: Scheme of sensor probe for lead (Pb) detection system

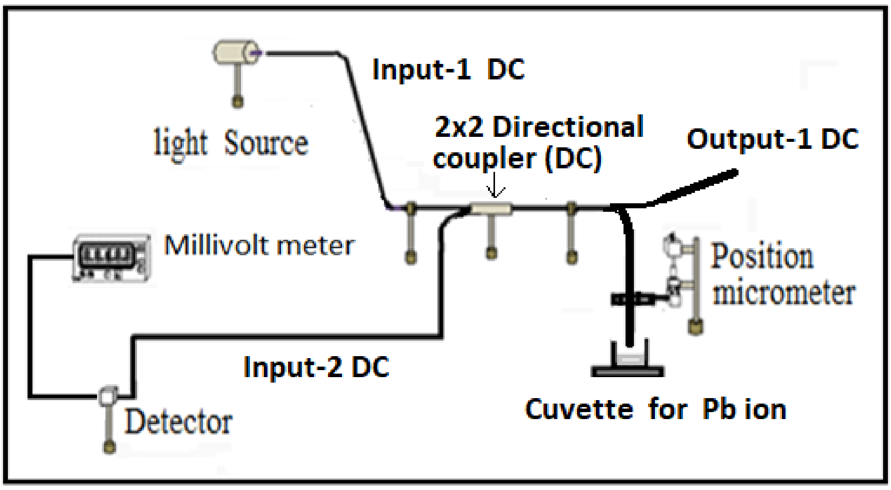

Figure 3: The set-up experiment detection of Pb ions in water

3. Results and discussion

The output voltage detector as the function of displacement probes (1,100 µm to 2,500 µm) if the cuvette is not filled with samples and the cuvette is filled with water has been carried out. Graph of output voltage detector as a function of displacement probe is presented in Figure 3. The optimum value of the detector output voltage occurs at a displacement value: 1,600 µm to 1,700 µm. To detect the concentration of cadmium in water a displacement of 1,650 µm is used. The absolute value of the output voltage difference (Vo) with reference voltage (Vr) as function of a cadmium concentration is presented in Table 1. Linier regresian voltage $|V_o - V_r|$ as a function of concentration for lead ions in water is presented in Figure 4. Based on the graph in figure-4, it appears that the relationship between voltage $|V_o - V_r|$ to the concentration of lead ion can be approximated by a linear function with the value R^2 = 0.9964 with the equation: y = (26.786 x - 0.2464) mV. In this case y represents the voltage $|V_o - V_r|$, while *x* represents the lead ion concentration c. This value of R^2 = 0,9964 means that the correlation between the voltage $|V_o - V_r|$ with lead ions concentrations is linear. The smallest concentration of lead ions that have been carried out in this

study is 0.01 ppm. Referring to the data above, it can determine the performance of the detection system of lead ion in water. The performance of the detection system obtained is presented in Table 2.

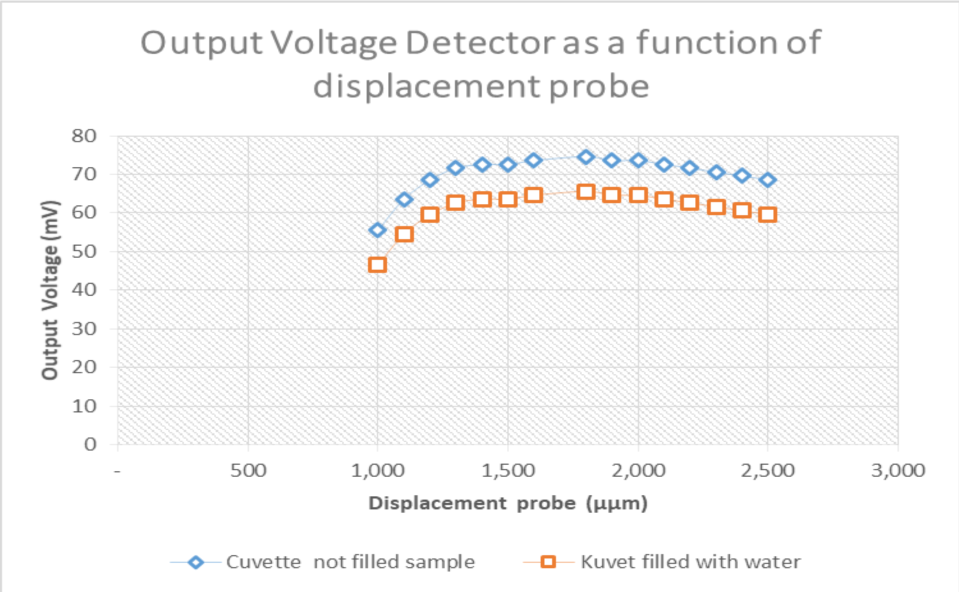

Figure 4: Graph of output voltage detector as a function of displacement probe

Table 1: The absolute value of the output voltage difference (Vo) with reference voltage (Vr) for lead ions

No	C (ppm)	Voltage (mV)				Average (mV)	Vr (mV)	(Vo-Vr)	/Vo-Vr/ (mV)
		I	II	III	IV				
1	0.01	65.7	65.5	65.6	65.4	65.55	65.6	-0.05	0.05
2	0.02	65.4	65.3	65.3	652	65.3	65.6	-0.30	0.30
3	0.03	65.1	65.0	65.0	65.1	65.05	65.6	-0.55	0.55
4	0.04	64.9	64.7	64.8	64.9	64.825	65.6	-0.77	0.77
5	0.05	64.6	64.4	64.5	64.7	64.55	65.6	-1.05	1.05
6	0.06	64.4	63.9	64.2	64.3	64.2	65.6	-1.40	1.40
7	0.07	64.1	64.0	63.8	63.9	63.95	65.6	-1.65	1.65

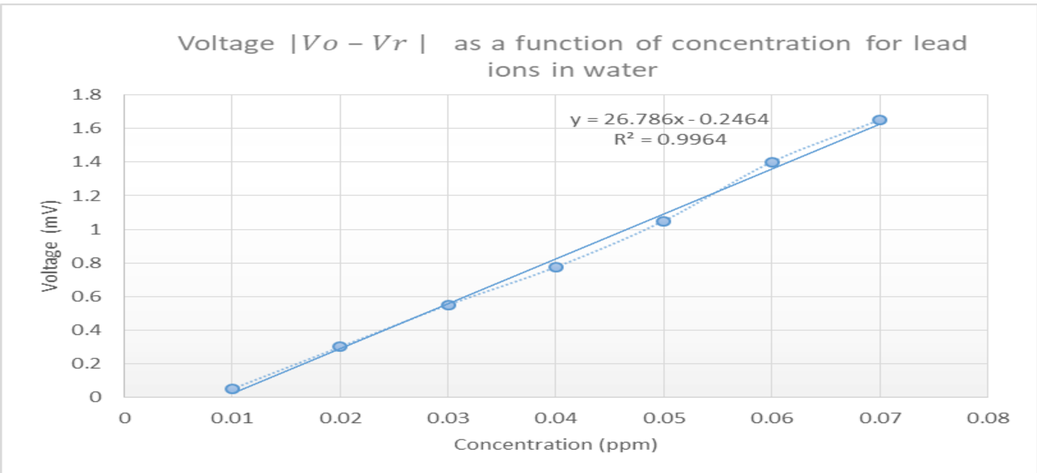

Figure 5: Graph of voltage Va as a function of concentration for lead ions in water

Table 2: The performance of the detection system of the lead in water

No	Performance	The values of detection performance of cadmium ions
1	Sensitivity	26.78 mV/ppm
2	Linearity	> 99%,
3	Range of measurements	0.01 ppm to 0.07 ppm
4	The limit of detection	0.01 ppm

4. Conclusions

In this study, detection lead ions in water was carried out. The experimental results show that the performance of this alternative methode to detect lead ion has a 26.78 mV/ppm of sensitivity of with a linearity more than 99%, operation range operation range start from 0.01 ppm to 0.07 ppm and LOD reaches 0.01 ppm.

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