A Preliminary Investigation Towards Detecting Heavy Metal Ions with a Cost-Effective Scheme

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Abstract: We report the findings of preliminary investigation corresponding to an optical detection technique implementing smartphone as our receiver towards quantitative assessment of heavy metal ions, namely, Cu, Zn, and Ni. Using intensity modulation, the optical responses are attained through a user-friendly app. The sensing region is made up of optical fiber whose cladding portion has been etched. Subject to varying concentrations of these metal ions, the modulated responses are attained, which reveal a declining trend. The absence of traditional parts such as a spectrophotometer makes the reported scheme cost-effective as well as field-portable.

1. Introduction

Aquatic pollutants in the form of heavy metal ions are of major concern when they exceed the permissible limit, as mandated by the World Health Organisation and Environmental Protection Agency [1-4]. The rampant industrialization, as well as mushrooming anthropogenic sources, has aggravated the problem of aquatic pollution. Starting from the ailments to causing the undesirable affects in flora and fauna, researchers have been engaged in constant efforts to curb this form of aquatic pollution. Accordingly, the first goal is to identify/select the heavy metal ions present in water bodies. Removal procedures then follow this. Until and unless there is an effective assessment of these hazardous metal ions, the diminution process remains ineffective. Arsenic, Cobalt, Zinc, Nickel, and Copper deserve specific mention [5-7]. Because of their inevitable nature of bioaccumulation, they pose a serious threat to living creatures, including human beings.

As far as the detection of heavy metal ions is concerned, there exist several standard techniques such as atomic absorption spectroscopy [8-9], atomic emission spectroscopy [10-12], inductively coupled plasma mass spectrometry [13]. These standard procedures require trained personnel and the designated labs, incurring huge expenditures in terms of cost and maintenance. On the contrary, colorimetric as well as optical detection techniques happen to have cost expensive. They can be assembled in a small space along with minimal logistics. Recently, Biswas and his group have done extensive research in detecting heavy metal ions implementing colorimetric, optical techniques as well as electrochemical techniques [14-15]. An optical detector was used in most of these implementations, which was then integrated with a readout system. Although cost-effective, the intensity fluctuations may induce certain errors

in the assessment thereof. In this regard, smartphone-based detection has of late grabbed the attention of researchers. When a laser source is used, there is another advantage of reducing intensity fluctuations. Considering all these, this work amalgamates intensity modulation with a smartphone-based detection. Accordingly, an optical fiber is declared in a certain portion to allow interaction of evanescent waves with analytes, leading to the modulated intensity, which can then be assessed via smartphone. Accordingly, this communication reports assessment of $CuCl_2$, $ZnCl_2$, and $NiCl_2$ with a concentration range from 1 ppb to 10 ppb.

2. Experimental Design

A 5 cm plastic-clad silica fiber of 600 µm core diameter has been taken. 0.5 cm of the fiber is chemically etched following standard protocol. The two ends of the fiber have been polished to avoid any impinging light anomalies. One end of the optical fiber has been connected to a Green Laser (λ=532 nm), whereas the other end has been connected to the ambient light sensor of a Smartphone. Meanwhile, the etched portion of the fiber has been readied for sample injection. The modulated response has been directly assessed through a Smartphone app.
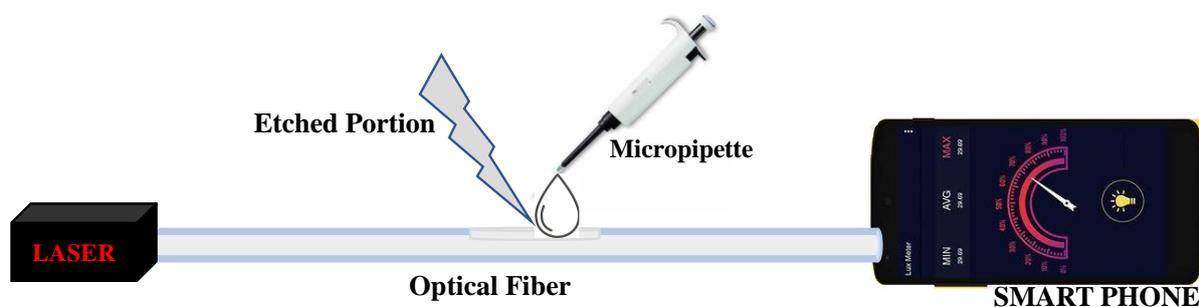

Figure 1. Schematic of experimental design for assessing heavy metal ion.

3. Results and Discussion

As shown in Figure 1, standard solutions of $CuCl_2$, $ZnCl_2$, $NiCl_2$ are prepared through series dilution with concentrations ranging from 1 ppb to 10 ppb following [16-17]. The smartphone's ambient light sensor responds when varying concentrations of these precarious heavy metal ions are introduced in the etched portion. As we know, light propagates in an optical fiber via total internal reflection. As the cladding portion is etched, the light gets affected because a reduced amount of light reaches the other end—provided there is the air surrounding the etched region. Now, if heavy metal ions with specific concentrations are introduced in that etched region, the refractive index gets immediately changed. As a result, evanescent wave field intensity gets altered, which is detected through the smartphone app known as Lux Lightmeter.

Accordingly, different concentrations of heavy metal ions in the form of analytes are sensed through these schemes. Figures 2(a), 2 (b), and 2 (c) provide the modulated intensity as detected by the app. There is clear evidence that the response shows a declining profile. With rising concentration, we find the attenuated intensity. As compared to $CuCl_2$, the responses seem to be better stabilized, corresponding to the other two metal ions. In the case of $CuCl_2$, a slight deviation from the declining trend corresponding to higher concentrations may be attributed to absorption anomalies in the ambient light sensor.
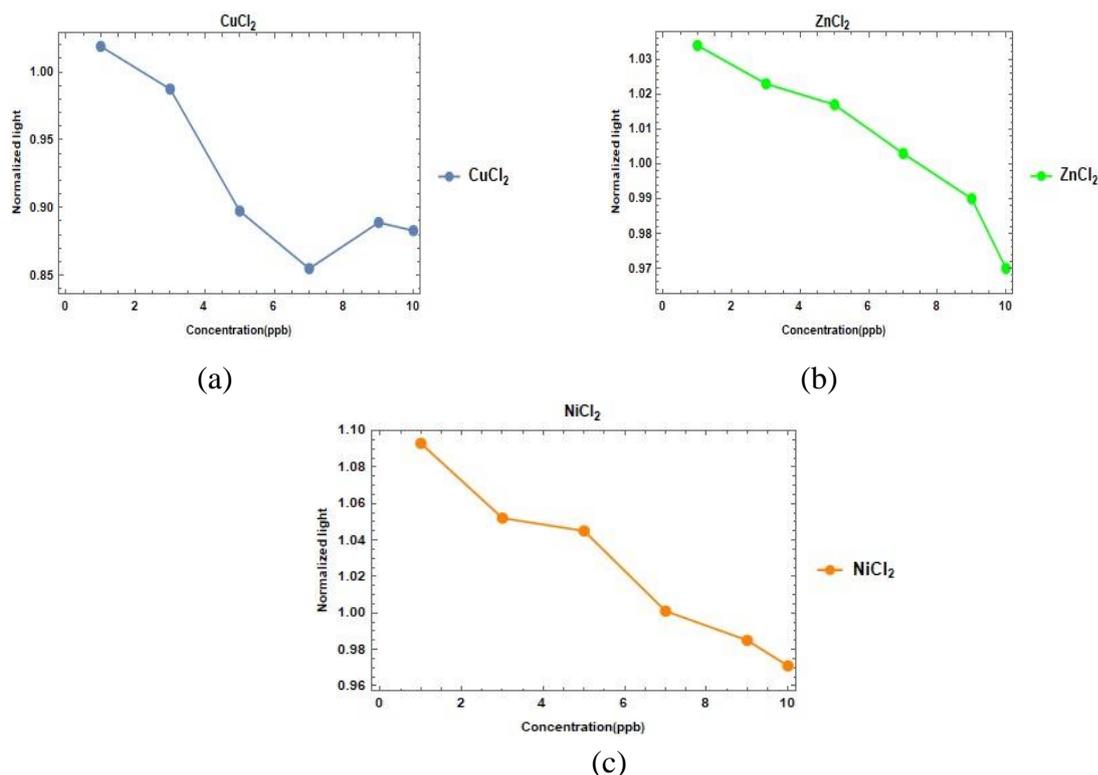
(a)

(b)

(c)

Figure 2. Modulated response corresponding to (a) Cu, (b) Zn, (c) Ni

4. Conclusion

This concise report briefs a preliminary investigation of detecting heavy metal ions through a very cost-effective scheme. Three prominent heavy metal ions, namely, Cu, Zn, and Ni, have been considered for the analysis. Using the affordable ambient light sensor from smartphones, the optical readout system has been designed. With varying concentrations of these heavy metal ions under consideration, the attained intensity exhibit a declining profile. With rising concentration, attenuated intensity emerges, which is readily achieved through the smartphone app Lux Light Meter. In summary, the scheme has been found to be robust in the light of its having proven capable of detecting concentrations of ppb level. More investigations are underway which will unleash considerable merits of this inexpensive scheme.

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Conflicts of Interest

There is no known competing interest with anyone.

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