# Mercury (II) Ions Assessment as a Toxic Waste Hazard in Solution Based on Imagery Data for a Part of Environmental Disaster Management

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**Abstract.** It has been made and calibrated a device to detect dissolved mercury (II) ions as a toxic hazard using Arduino Uno and color sensor TCS3200. The purpose of this design was to realize a device for detecting dissolved mercury (II) ions as heavy metal pollution based on the relation of soluble mercury ion concentration to the liquid from the imagery data. Conjoint natural and technological disasters like the Mercury may pose tremendous risks to regions which are unprepared for such disasters. The results could be an environmental disaster, particularly when these occur in a highly populated area. Controlling the levels of dissolved mercury ions on a regular basis is a part of the environmental disaster management. The device works by converting any light by the photodiode optical sensor when the output is such a magnitude of an electrical current which proportional to the received light color level. The currents that are processed using the Arduino IDE software to extract the RGB values of the dissolved mercury (II) ions image data. Dissolved mercury ions generally do not have the necessary color, therefore, biocatalyst as reagents to generate color in a solution containing the mercury and this study using the Silver Nanoparticles. After reacted with a solution of known concentration of mercury in the value of the solution then carried out on a sample data collection to determine the RGB color values in the solution. In general, the device can be used as a color calibrator applied to the detection of dissolved mercury (II) ions by the obtained image data.

## 1. Introduction

Mercury is considered one of the most harmful metals found in the environment as a toxic hazard [1]. Combining natural and technological disasters such as the Mercury may pose tremendous risks to regions, which are unprepared for such disasters. The results could be an environmental disaster, particularly when these occur in a highly populated area. Controlling the levels of dissolved mercury ions on a regular basis is a part of the environmental disaster management [2].

Environmental pollution is a serious problem for developing countries like Indonesia. One is pollution by heavy metal ions. Mercury (Hg) is one of the most dangerous heavy metals. In nature, we can see the mercury in three forms: elemental (Hgvapor0toxic), inorganic mercury (Hg22+ and Hg2+) and organic mercury (methyl mercury, ethyl mercury and phenyl mercury). Hgions2+ dissolved in water is pollutant mercury is the most common and most stable. This means that the Hg2+ may accumulate in vital organs of humans through the food chain and can cause damage to the brain, nervous system, kidneys, heart and endocrine system[2].

Currently, there are a lot of measuring instruments used to detect mercury such as Atomic Absorption Spectroscopy (AAS), Inductive Coupled Plasma-Mass Spectrometry (ICP-MS) and Atomic Fluorescence Spectrometry (AFS), however, these instruments are high cost, and requires special skills to be able to operate, relatively long time and not portable [3]. Therefore, it is very necessary means to detect the dissolved mercury ions with a fast, simple, economical, effective and portable.

One promising method is detection based on color or colorimetric sensors due to the simplicity of its operation, the process of rapid, high sensitivity, effective and easily observed with the naked eye. One example of a colorimetric sensor that is widely used today is the TCS3200 color sensor. TCS3200 color sensor with Arduino-Uno can also be used to detect any number of colors. The sensor changes color in the form of a stream and converted into a frequency signal. Values obtained from the frequency of the color sensor readings are processed by using a microcontroller and displayed on a computer or screen.

The basic principles of color are grouped into three basic colors, namely red, green, and blue (RGB). The color is referred to as primary colors. The combination of the two primary colors will produce a new color or referred to as a secondary color, for example, green and red color mixing will produce a yellow color. Primary colors are red (like blood), blue (like the sky or the sea) and yellow (such as egg yolk). The secondary color is the color of the merger of two primary colors with the composition of 1: 1. Tertiary colors are the result of merging the primary color with a secondary color or the merging of the three colors either two primary and secondary colors as well as the incorporation of other secondary colors [4].

Arduino-Uno is a board microcontroller based ATmega328, this is a single-board microcontroller that is open source support, derived from the Wiring platform, designed to facilitate the use of electronics in various fields. Hardware is an Atmel AVR processor and software it has its own programming language [5]. Arduino can be programmed using the Arduino IDE software. The microcontroller of ATmega328 on the Arduino Uno is bootloader that allows uploading the generated code without having to use an external hardware programmer. Arduino software can be installed on a variety of operating systems (OS) such as Linux, Mac OS, and Windows.

Mercury as an element or the ion in solution is toxic or hazardous materials. Therefore, the waste containing mercury with all forms is also a toxic waste. Mercury contained in the waste disposal in public waters or modified by the activities of microorganisms into components of metal mercury (CH3-Hg) which have toxic properties and a strong holding capacity in addition to its high solubility. This resulted in mercury accumulated through the process of bioaccumulation and biomagnification in the body tissues so that the levels of mercury can reach levels dangerous for the lives of aquatic animals as well as human health, eating the aquatic animals [6].

## 2. Material and Methods

All chemicals used in the present study were of the highest purity (p.a). Chitosan of medium molecular weight and sodium borohydride purchased from Aldrich (USA). Silver nitrate, acetic acid, methanol, salt of additional cation tested and all other chemicals bought from Merck (Germany). Characterization of size and shape of the synthesized silver nanoparticles was carried out using Transmission Electron Microscopy (TEM) recorded on JEOL JEM-1400 operating at 100 kV [7].

### *2.1 Synthesis of Silver Nanoparticles*

Colloidal silver was prepared by reduction of AgNO3 using sodium borohydride as our reported method with slight modification [8]. All glassware was washed with a mixture of nitric acid and

hydrochloric acid (1:3) before use. Distilled water was used throughout the experiment. Silver (I) stock solution was prepared 10-4 mol/mL from silver nitrate as a precursor. In the typical experiment, 5.6 x 10-4 mol (0.0900) was dissolved in 88.8 ml acetic acid (1.5%) and the mixture was stirred overnight to obtain a homogeneous solution. Furthermore, 90 ml of methanol slowly added with vigorous stirring. Afterward, 1.12 ml (1.12 x 10-4 mol) of the silver stock solution was added little by little to the mixture. Then 0.0265 g of sodium borohydride was added slowly while kept stirring vigorously to reduce the silver ions to silver particles to yield brown yellowish colloid. These silver nanoparticles were characterized with TEM.

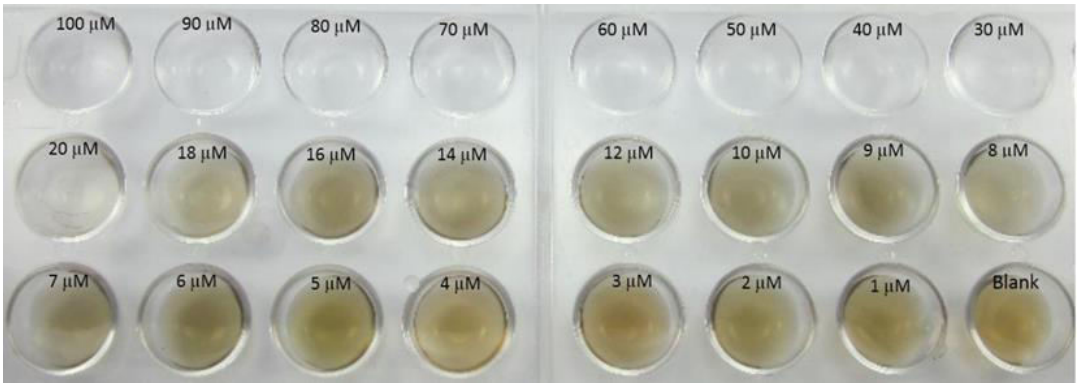


**Figure 1.** Sensitivity of Chi-AgNPs toward $Hg^{2+}$ ions at different concentration.

*2.2 Color Level Identification*

The main sensors used was the TCS2300 which is attached on the board. It is an RGB light to frequency sensor which generates an output frequency (1 Hz and 600 kHz) proportional to the measured light intensity of the selected channel (red, green, and blue or clear) [9]. In this study, the color reflectance of sixteen different concentrations of mercury ion for several treatments is shown in Figure 1. Based on the flowchart programming using Arduino-Uno (Figure 2), any number of color mercury can be determined by TCS3200. The data that was detected on the TCS3200 sensor will be sent to the Arduino. Furthermore, the Arduino will transmit the data to the computer via serial communication of Universal Synchronous Bus (USB) in form of the RGB values. After the data entered into the computer the data will be processed for statistical regression analysis using Microsoft Excel.

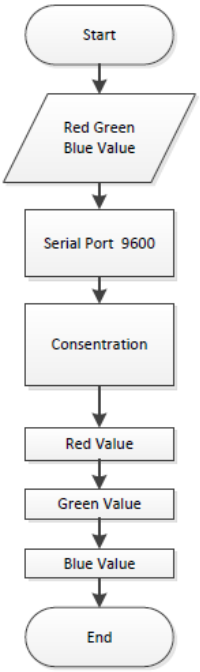


**Figure 2.** Sensitivity of Chi-AgNPs toward $Hg^{2+}$ ions at different concentration.

The codes for color sensor TCS230 using Arduino-Uno Microcontroller are shown in the Figure 3.

FDUEUJ8IVA4KQNO

```
#include <TCS3200.h>

uint8_t RGBvalue[3];

TCS3200 colSens;

void setup()
{
  Serial.begin(9600);
  Serial.println("BEGIN");
  colSens.begin();

  Serial.begin(9600);
  Serial.println("CLEARDATA");
  Serial.println("LABEL,Red,Green,Blue");
}

void loop()
{
  colSens.loop();
  colSens.getRGB (RGBvalue);
  //colSens.getRGBtoMaxCorrection (RGBvalue);
Serial.print("DATA,");
      Serial.print("\tR:\t"); Serial.print(RGBvalue[0]);
Serial.print(",");
      Serial.print("\tG:\t"); Serial.print(RGBvalue[1]);
Serial.print(",");
```

**Figure 3.** The codes for an interface between the Arduino-Uno and the TCS230 color sensor.

## 3. Results and Discussion

The dissolved mercury ions generally do not have the specific color, therefore, biocatalyst as reagents was used to generate color in a solution containing the mercury. In this study, the Silver Nanoparticles

was used as a reagent. After reacted with a solution of known concentration of mercury in the value of the solution then carried out on a sample data collection to determine the color reflectance of the solution in RGB values. There were sixteen samples made and tested in this study. Collecting data on the sample are acquired from two conditions that have been arranged, namely at the open and enclosed spaces.

In order to obtain the basic assumption of these components, therefore, it was important to test a relationship between sixteen samples of mercury ion concentrations and the RGB values of the color reflectance of samples. Correlation analysis has been the most commonly used in statistical tests to find the relationship among variables. This test can be performed in order to determine that the relationship between these data is linear or nonlinear. Assessments of the correlation ($r^2$) between the concentration of mercury ion in micro Molar (μM) and blue values from TCS230 color sensor were correlated to the concentration, except for the green and red channel of TCS230 color sensor. There were no significant correlations between the mercury concentration and R, G values (mercury to R & G). In the samples, the correlation for mercury to R & G was very weak, either from the color reflectance of samples that acquired in open and enclosed spaces.

The regression analysis between mercury concentration and blue values of TCS230 color sensor acquired from open space are presented in Figure 4. The maximum value of the $r^2$ between the concentration of mercury and the blue channel was 0.66. This means the light intensity of the blue channel had better correlations with concentration than the red and green channel. The open spaces testing showed that there was the ambient light contribution for color reflectance deviation of the TCS230 sensor. In spite of the correlation between them is moderate but significant correlated in this case study.

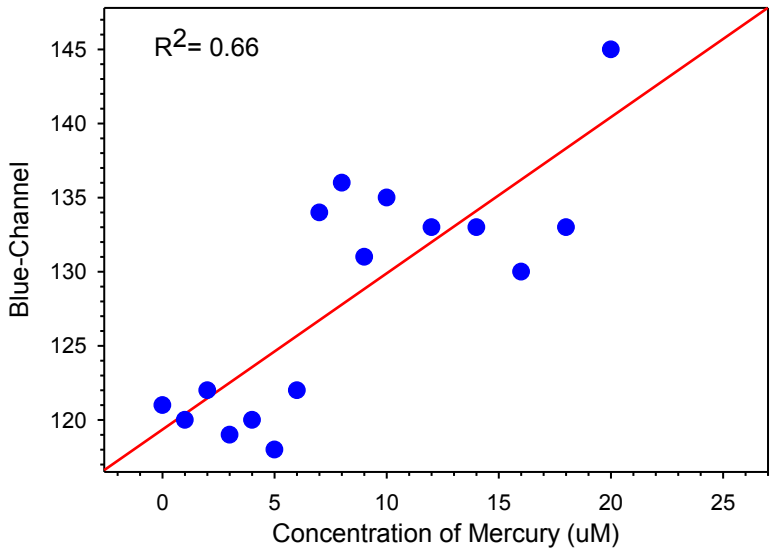


**Figure 4.** Scatter plot of mercury concentration and Blue Channel in open spaces testing.

Next, mercury concentration was derived using the blue channel for testing at enclosed space. The results show that the accuracy of concentrations was 0.72 (Figure 5). It indicates that the variation of concentrations is also significantly correlated to the blue channel of TCS230. These results also demonstrated that the accuracy of the mercury concentration estimation using enclosed space has improved the retrieval accuracy than using the open spaces testing. This is because the influence of light noise from the outside is negligible in the enclose space so that the sensor only detects the color reflectance possessed by the image. In the state of open space, color possessed by the sample is affected by the light from the outside which causes the color reflectance in the sample experienced a slight discoloration.

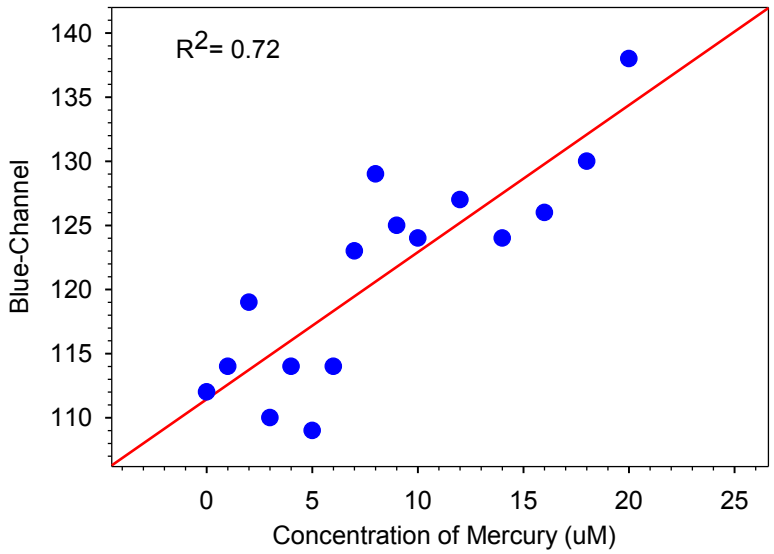


**Figure 5.** Scatter plot of mercury concentration and Blue Channel in close spaces testing.

## 4. Conclusion

TCS3200 color sensor can be used to detect the toxic hazards of mercury ions in solution through the imagery data. This tool could be applied to detect mercury ions dissolved in the environment with the support by the biocatalyst as color reagent in a solution containing mercury ions.

## References

[1] Kadirvelu K, Kavipriya M, Karthika C, Vennilamani N and Pattabhi S 2004 Mercury (II) adsorption by activated carbon made from sago waste *Carbon* **42** 745-52
[2] Wang X, Gartia M R, Jiang J, Chang T-W, Qian J, Liu Y, Liu X and Liu G L 2015 Audio jack based miniaturized mobile phone electrochemical sensing platform *Sensors and Actuators B: Chemical* **209** 677-85
[3] Gao Y, Shi Z, Long Z, Wu P, Zheng C and Hou X 2012 Determination and speciation of mercury in environmental and biological samples by analytical atomic spectrometry *Microchemical Journal* **103** 1-14
[4] Aruan N M, Andjani D and Yuliora E 2016 Pembuatan album warna dengan menggunakan sensor warna jenis TCS230. In: *PROSIDING SEMINAR NASIONAL FISIKA (E-JOURNAL),* pp SNF2016-CIP-47-52
[5] Badamasi Y A 2014 The working principle of an Arduino. In: *Electronics, computer and computation (icecco), 2014 11th international conference on*: IEEE) pp 1-4
[6] Comission E 2017 Tackling mercury pollution in the EU and worldwide
[7] Zarlaida F, Adlim M, Surbakti M S and Omar A F 2018 Chitosan-stabilized Silver Nanoparticles for Colorimetric Assay of Mercury (II) Ions in aqueous system. In: *IOP Conference Series: Materials Science and Engineering*: IOP Publishing) p 012049
[8] Adlim A 2012 Preparation of Chitosan-Stabilized Silver (Chi-Ag) Nanoparticles Using Different Reducing Agents And Techniques *Jurnal Sains MIPA Universitas Lampung* **4**
[9] Berns K and Luksch T 2008 *Autonome Mobile Systeme 2007: 20. Fachgespräch Kaiserslautern, 18./19. Oktober 2007*: Springer-Verlag)