The possibility of smartphone camera to determine iron(III) in solution

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Abstract. Determination of iron in solution is usually done by using instruments, such as Atomic Absorption Spectrophotometer (AAS) and UV-Visible Spectrophotometer. However, the availability and the use of these instruments in Indonesia is limited due to the expensive price. Nowadays everyone has smartphone with advanced camera features. This study focuses on the determination of iron (III) using a non-instrument method, namely digital image colorimetry. This method is using smartphone camera to capture the digital image of sample. Smartphone cameras used on this study are based on Android operating system with the specification of 16-megapixel and OS operating system with the specification of 12-megapixel. Digital images that has been captured by smartphone camera are processed using MATLAB to determine the RGB intensity. The image processing results then compared with the results from UV-Visible spectrophotometer. The result shows the linearity of the RGB color calibration curve from the smartphone camera is on a part with the calibration curve that generated by the UV-Visible spectrophotometer. This indicates that smartphone camera has a possibility to determine iron (III) in solution by using digital image colorimetry.

1. Introduction
Heavy metal is a type of metal that can cause environmental damage and cause many diseases such as cancer, if consumed by humans. Heavy metals are non-biodegradable so they cannot be decomposed even for very long periods of time. Heavy metal in the environment will cause water and soil pollution, so that it can enter the human food cycle. Generally, many industries use various kinds of heavy metals for their production processes such as Pb, Cu, Zn, Cd and Fe.

Iron (Fe) is the fourth largest metal on earth. In nature, iron is present in the form of compounds such as hematite (Fe₂O₃), magnetic (Fe₃O₄), pyrite (FeS₂), and siderite (FeCO₃). Pure iron is obtained from the electrophoresis process of iron sulfate solution [1]. Pure metal iron is chemically reactive and corrosive, especially in humid air or when there is an increase in temperature. The river contains an amount of iron of 0.5-1 ppm, while ground water contains iron of 100 ppm. Iron is widely used in various industries and household appliances.

Small amounts of iron compounds in the human body functioned to form red blood cells. But if it exceeds the dosage needed by the body it will cause health problems that can damage the intestinal wall. Death is often caused by damage to the intestinal wall, iron can also accumulate in the alveoli and can cause reduced lung function [2].

Generally, the methods that used to determine iron content are Atomic Absorption Spectrophotometry (AAS). Determination of iron content using other instruments has also been carried out. The instruments used include High-Performance Liquid Chromatography (HPLC), flow injection...
analysis (FIA), and voltammetry. The High-Performance Liquid Chromatography method conditions the column first using 1- (2-pyridylazo) -2-naphtol (PAN). Determination of iron content using flow injection analysis is based on measuring the effect of iron quenching on salicylic acid fluorescence. The voltammetry method for determining iron was developed using Pyrolytic Graphite (EPPG) Edge Screen Electrodes and screen printed electrodes [3] [4] [5].

However, the availability of instruments is still limited due to expensive prices. The SSA method requires high expertise and accuracy in its use. Fe analysis can also use the colorimetric method with UV-Vis spectrophotometer which is through the reaction of Fe using thiocyanate in an acidic atmosphere resulting in the red-orange Fe-SCN complex detected at wavelengths of 470-530 nm [6]. However, the analysis using this spectrophotometer also requires expensive costs because the instrument is relatively high so that not all agencies and laboratory can have it.

Therefore, in this study, the method of determining iron content analysis using a simple colorimetric method utilizes digital images that can be obtained from smartphone cameras [7]. The smartphone camera can be used as a sensor, reader and recorder instrument for the complex color intensity from each pixel, then processed with digital image techniques using Matlab. The advantage of the measurement using digital imaging method is that the amount of material used for research becomes less and more efficient and does not require expensive and complicated instruments.

2. Materials and method

2.1. Materials

Materials used in this study were concentrated HCl solution, concentrated HNO3 solution, NH4Fe (SO4) 2.12H2O solids, potassium thiocyanate (KSCN) solids, metal-free distilled water, and packaged drinking water samples.

2.2. Apparatus and software

The apparatus that used in this research are chemical glass equipment, pH meters, filter paper, Labtech SPECTROstar Nano UV-Visible Spectrophotometer, microplate costar 3590, 0.5 mL micropipette, OPPO F1s smartphone with 16-megapixel camera specifications, iPhone 6 smartphone camera with 12-megapixel specifications. Potoshop (Adobe System Inc.), Matlab (Mathwork Inc.) and Excel (Microsoft Inc.) were used for digital image data processing.

2.3. Preparation of 1000 ppm iron (III) stock solution

Iron (III) 1000 ppm stock solution was made by dissolving 8.63 grams of NH4Fe (SO4) 2.12H2O solid using distilled water and then putting it in a 1000 mL volumetric flask. A total of 4 drops of concentrated HCl are added to the volumetric flask then the solid is dissolved while being shaken until it is dissolve perfectly. Then distilled water is added to the measuring tube until the boundary mark and shaken until it is homogeneous.

2.4. Preparation of 100 ppm iron (III) stock solution

100 ppm iron (III) stock solution was made by dissolving 0.0863 grams of NH4Fe (SO4) 2.12H2O solids using distilled water then put it in a 100 mL measuring flask. A total of 4 drops of concentrated HCl are added to the measuring flask then the solid is dissolved while being shaken until it dissolves completely. Then the distilled water is added to the measuring flask until the boundary mark and shaken until homogeneous.

2.5. Preparation of standard iron (III) solution 0 - 70 ppm

Standard solution of iron (III) 0-70 ppm is made by inserting a standard iron (III) 1000 ppm solution as much as 0; 0.25; 0.5; 0.75; 1; 1.25; 1.5; and 1.75 mL each into a 25 mL measuring flask. As much as 0.25 mL of 1 M HNO3 solution and 2.5 mL of 1000 ppm KSCN solution were then added to each measuring flask and then shaken until homogeneous. Distilled water added to the measuring flask until the boundary mark and shaken until homogeneous Fig. 1.
2.6. Measurement of iron content (III) using UV-visible spectrophotometer

A standard solution of iron (III) 0-70 ppm was taken as much as 100 µL with a micropipette then put into the micro-plate chamber. The absorbance is then measured for absorbance at a wavelength of 480 nm. Calibration curves are obtained from the absorbance value of the standard iron (III) solution.

2.7. Measurement of iron (III) content using the digital image colorimetric method

Standard and sample solutions were placed in testing tube in a white background opaque cabinet to maintain the same environmental light and photographic conditions. Detail of smartphone camera set up using automatic mode. Digital images were transferred to a computer using Adobe Photoshop software. Colors were obtained from a representative square region of approximately 100 pixels located in each sample. The average RGB values were measured using Matlab's image processing tool box. Digital image capture and Matlab processing of sample were performed in 3 replicates. Further analysis of RGB data were made by Microsoft Excel for simple linear regression (SLR), respectively.

The RGB intensity data is then converted to absorbance using the Lambert-Beer equation.

\[ A = \log \frac{i_o}{I} \]  

The symbol I is the intensity of the actual color of the sample (the intensity of the color of the RGB) and \( I_o \) is the intensity of the RGB color of the blank solution. After obtaining the absorbance value, a calibration curve is made by creating a relationship curve between absorbance (A) and concentration of solution (C).

3. Results and discussions

3.1. Calibration curve of iron (III)

Iron (III) content determination using UV-Visible spectrophotometer and digital image colorimetry has been carried out. At first, the standard iron (III) solution with concentrations of 0 - 70 ppm was made. Each solution is added with 1 M HNO₃ solution to create an acidic atmosphere, which is at pH 2, to form complex compound [Fe (SCN)]⁻².
The absorbance of iron (III) then measured using a UV-Visible spectrophotometer. The absorbance curve of standard iron (III) solution 0 - 70 ppm is shown in Fig. 2. The calibration curve produces the equation $y = 0.0083x$ with linearity shown by $R^2$, which is equal to 0.9209.

### 3.2. Digital image quantification

The standard iron (III) solution of 0-70 ppm is put into a test tube and placed in a place with a white background. Each sample was photographed using the OPPO F1s smartphone camera and the iPhone 6 smartphone camera. The digital image was then transferred to the computer to be cropped by 100 x100 pixels. The cropping image process is done by using an Adobe Photoshop device on a homogeneous image location. Based on the type of color, digital images can be grouped into three, namely RGB image, grayscale image and binary image [8]. In relation to colorimetry, the elements processed are RGB color elements because the basic principle of colorimetry is the analysis of sample concentrations by utilizing dispersion from visible light sources. The digital image results are then converted in the form of the $M \times N$ pixel matrix by utilizing the existing Image Processing Toolbox in MATLAB. The matrix is then reconstructed so as to produce the intensity of the RGB image value of each sample. The average intensity of RGB is shown in Table 1.

![Figure 2. Calibration curve of standard iron (III) solution 0 - 70 ppm.](image)

### Table 1. Average Intensity of RGB.

| Concentration (ppm) | Oppo F1s | | | | Iphone 6 | | |
|---------------------|----------|---|---|---|---|---|---|
|                     | $R$ | $G$ | $B$ | $R$ | $G$ | $B$ |
| 0                   | 164 | 174 | 186 | 175 | 177 | 177 |
| 10                  | 166 | 162 | 148 | 188 | 168 | 138 |
| 20                  | 169 | 142 | 95  | 194 | 160 | 107 |
| 30                  | 179 | 130 | 73  | 204 | 148 | 79  |
| 40                  | 189 | 121 | 69  | 199 | 146 | 71  |
| 50                  | 190 | 105 | 47  | 199 | 131 | 64  |
| 60                  | 183 | 108 | 43  | 183 | 118 | 59  |
| 70                  | 188 | 98  | 42  | 183 | 115 | 54  |
The result of plotting the RGB value produce a hyperbolic curve. For that reason, to obtain a linear line plot the RGB values obtained are converted into logarithmic curves according to equation (1). A calibration curve is made by plotting the absorbance value to the concentration. Processing data by digital imaging will produce three calibration curves of standard iron (III) solution for RGB color components in each digital camera as shown in fig.3 and fig.4.

For component R (Red), the value of absorbance tends to lead to zero and negative positions. This fact shows that the solution does not absorb the color of the red complement from the radiation source of light emitted by a digital camera. The number of energy packages (photons) absorbed by the colored solution causes the amount of visible light intensity (I) to increase so that the absorbance value becomes large. According to the Lambert-Beer equation, the absorbance value at this concentration will be positive so that the component calibration curve R (Red) can be used to predict iron (III) levels in the sample.

Data from the measurement of iron (III) concentrations resulting from each color component G (Green) and B (Blue) have regression coefficients above 0.96 and 0.93 for cameras OPPO F1s, 0.97 and 0.90 for iPhone 6 cameras. Overall, the calibration curves resulting from digital imaging with UV-Visible spectrophotometers are relatively the same. These results indicate that smartphone cameras and data processing with digital imaging techniques can be used as an alternative instrument-free method in quantitative analysis with colorimetric methods.

There are several ways that can be done so that the results of the obtained image are better so that the processing can replace the spectrophotometer method. The first way is to increase the sensitivity of digital image colorimetry. Sensitivity enhancement can be done by using a camera that has better
specifications such as a DSLR camera or higher smartphone camera specification. The second way to increase sensitivity is to first filter the incoming light before taking digital images.

4. Conclusions
Iron content (III) using the instrument-free method, namely digital image colorimetry is determined by taking photos of sample using smartphone cameras. The photo results are then processed using the MATLAB to obtain RGB color. The calibration curve of RGB color was then compared with the calibration curve of the UV-Visible spectrophotometer instrument. The linearity of the RGB color calibration curve from smartphone cameras is not inferior to the linearity produced by the instrument calibration curve. This shows that digital image colorimetry has possibility to be used as an alternative processing of data from the measurement of iron (III) levels in solution.

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