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Development of Original Attachment and Application Software for Simple Fluoride Analysis Using Smart Device

Atsushi Manaka[1], Takahiro Ichida[1], Takeru Nakamura[2], Shoichi Fruyama[2], Makoto Satoda[3], Masamoto Tafu[1], Mitsuteru Irie[4], and Shukuro Igarashi[5]

1. Department of Applied Chemistry and Chemical Engineering, National Institute of Technology, Toyama College, Japan

2. Department of Electronics and Computer Engineering, National Institute of Technology, Toyama College, Japan

3. Satoda Science LLC 1046 Hitonose, Oogaki-chou, Etajima-shi, Japan

4. The Alliance for Research on North Africa (ARENA), University of Tsukuba, Japan

5. Department of Biomolecular Functional Engineering, College of Engineering, Ibaraki University, Japan

Abstract: An original attachment and application software were developed for simple fluoride analysis using a smart device such as a smartphone or tablet device, and the analytical performance of the proposed method was evaluated. Using a color reaction with lanthanum/alizarincomplexone, fluoride ion was determined in the concentration range from 0.5 to 1.5 mg/L; the relative standard deviation was 5.5% at the median of the calibration curve (5 determinations). Moreover, analytical results combined with date, time, and location information were obtained in the proposed method; the analytical results were then mapped using mapping software.

Key words: smart device, original attachment, application software, fluoride

1. Introduction

Fluoride contamination in drinking water is problematic because it causes tooth problems and born health problem such as mottled teeth. This problem is particularly serious in developing countries such as Tunisia because of the lack of fluoride analytical testing and removal technologies. Spectrophotometric determination with lanthanum/alizarin complexone (La-ALC), ion-selective electrode analysis, and ion chromatography have commonly been used as fluoride analysis methods. However, these methods require operator skill and involve complex operations and expensive analytical instruments. In addition, proper protection of the health of citizens requires analysis of the drinking water of each household. To meet these requirements, analytical engineers must analyze a large number of samples. Thus, the development and dissemination of analytical methods that citizens can easily handle are important. Recently, on-site fluoride remove technology [1-4] has been developed. However, confirming the effectiveness of the processing equipment also requires monitoring for fluoride in each household.

Colorimetry [5, 6] is one of the most effective on-site fluoride analysis methods because it does not require expensive analytical instrumentation for determining sample concentration. However, this method leads to differences in the analytical result because it requires subjective judgement of concentration on the basis of color contrast. Recently,

Corresponding author: Atsushi Manaka, Dr., Associate Professor, research areas/interests: analytical chemistry. E-mail: manaka@nc-toyama.ac.jp.

several types of portable analyzers [7-10] have been developed. However, analytical costs are increased with the introduction of such an analytical device. Simple analysis using a digital camera [11, 12] has been reported. This method effectively reduces analytical costs. However, for accurate analysis results, this method requires that the analytical conditions such as the irradiation conditions and distance between the camera and sample remain constant. Moreover, the method requires analysis of the photo using image processing software on a personal computer.

Smart devices such as smart phones and tablets are becoming ubiquitous. Such devices have rapidly spread on a global scale and perform several functions such as communications and taking photographs. Moreover, various features can be incorporated into these devices through application software. Therefore, we conceived that smart devices could function as measurement apparatuses according to their application software. On the basis of these findings, we attempted to develop a simple analysis method for fluoride using a smart device by developing an attachment and application software. Moreover, the proposed method was evaluated for on-site analysis.

2. Reagents and Instrument

All chemicals used were analytical-reagent grade. Fluoride solutions were prepared by diluting a commercial standard fluoride solution (Kanto Chemical Co., Inc.). A commercial test kit named Pack test® (Kyoritsu Chemical-Check Lab. Corp.) was used for chemical color analysis of fluorine. When this commercial test kit was used, the color of the sample changed from red to violet-blue with increasing fluorine concentration in the sample. A Nexus 7 F-8AT (Google) was used for measuring fluoride concentration. A Digital Pack Test Multi (Kyoritsu Chemical-Check Lab. Corp.), which is a commercial portable-type color analyzer, was used for comparison to the proposed method.

3. Attachment and Application Software

We designed an attachment for measurement with a smart device. A schematic of the attachment is shown in Fig. 1. Using this attachment, the bottom part of the sample cell was fixed onto the camera of the smart device, and the sample was photographed. The attachment manufactured by Satoda Science was placed on the camera of the smart device to affix the sample cell. The bottom of the sample cell was simply placed on the lens of the camera, guided by the attachment.

We also developed original application software for the measurement of fluoride by color information obtained from sample photos. The principal of application software is shown in Fig. 2. After selecting "calibration" from the initial screen, we entered the concentrations of three different fluoride standard solutions (0, 0.5, and 1.5 ppm). Using the attachment, we took a photo of each coloured standard solution. The colour information of each standard solution (*y*, *u*, and *v* values) was automatically obtained from the photo data. A linear line between the *v* value and fluoride concentration was then defined. The *y* value indicates the brightness, *u* value indicates the degree of blue, and *v* value indicates the degree of red. In case of the proposed fluoride analysis, we used the *v* value to establish a relationship with the fluorine concentration.

As mentioned previously, the developed colorimetric system shows a change in colour from red to violet-blue, which means that the intensity of the red colour is reduced depending on the fluoride concentration. We

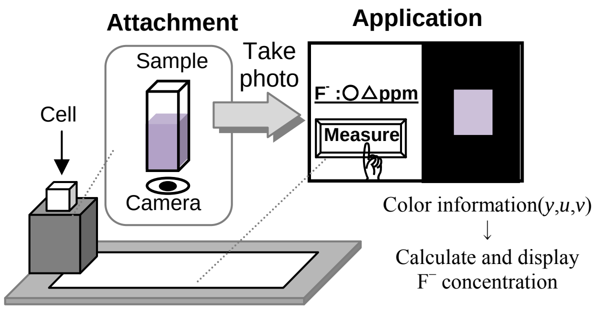

Fig. 1 Schematic of the original attachment.

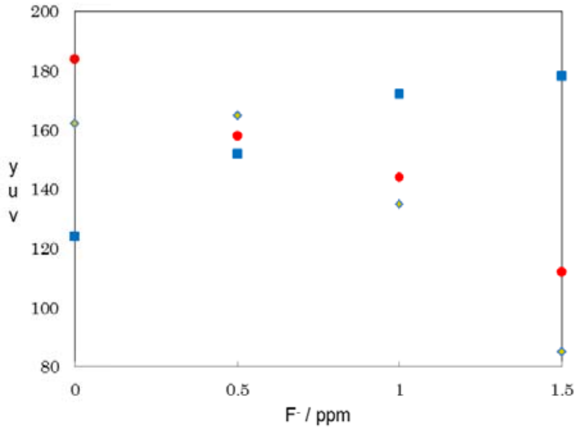

Fig. 2 Outline of the original application software for measurement of F-ion.

therefore expected the *v* value to decrease with increasing fluoride concentration.

A picture of the coloured sample was subsequently taken in the measurement mode, and the fluoride concentration was measured by substituting the *v* value determining from the sample photo into the calibration equation. Furthermore, by linking to the clock and GPS function of the smart device, date and location information were recorded along with the analytical data.

4. Procedure

The reagent from the commercial pack test for fluorine colorimetric analysis was added to 2 mL of sample. After dissolving the reagent, we added the solution to the plastic cell for commercial absorption spectroscopy. The cell was placed in a dedicated attachment mounted onto the smart device. After 10 min, the fluoride ion concentration was determined by measuring the *v* value of the solution in the cell using our application software.

5. Results and Discussion

The relationship between the *y*, *u*, and *v* values and the fluoride ion concentration is shown in Fig. 3. The *y* value was constant irrespective of the fluoride concentration for concentrations from 0 to approximately 0.5 ppm; at higher fluoride concentrations, the *y* value exhibited a sudden decrease. The *u* and *v* values changed in accordance with the fluoride ion concentration. The *v* values, in particular, substantially changed in response to changes in the fluoride ion concentration. Consequently, in the proposed method, the fluoride ion concentration was determined on the basis of the *v* value. As a result, 0.5 to 1.5 ppm of fluoride ion could be determined, and the relative standard deviation at 1 ppm of fluoride ion was 5.5% (five determinations).

Moreover, the proposed method was used to determine the fluoride ion concentration in tap water spiked with a known amount of fluoride ion. These results are shown in Table 1. Compared with the reproducibility of the commercial simple method (Digital Pack Test), that of the proposed method was satisfactory. Furthermore, as shown in Fig. 4, the proposed method also enabled the mapping of measurements by obtaining information related to the measurement time and location at the same time. This function would be effective for mapping the contamination status in developing countries that contain regions with clear address.

Furthermore, the proposed method was evaluated from three perspectives (simplification, software, and analytical time) by user test of Tunisian people. The questionnaire results are shown in Table 2. Almost all the users were satisfied with the analytical performance of the proposed method. However, the

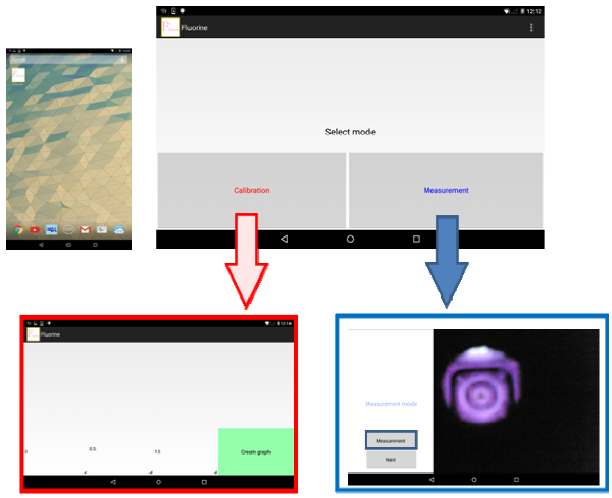

Fig. 3 Relationship between *y*, *u*, and *v* values and the F-concentration (◆ : *y*, ■ : *u*, ● : *v*).

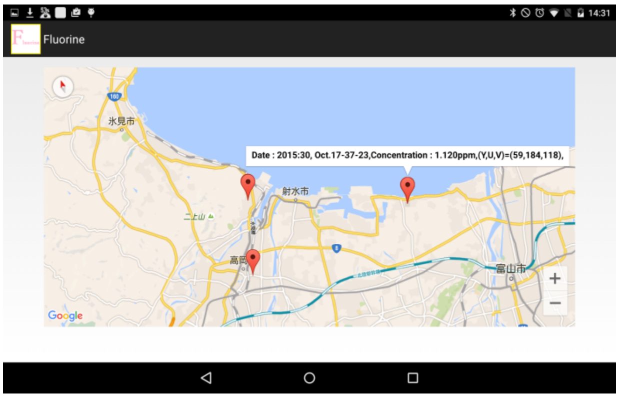

Fig. 4 On-site analysis mapping data.

Table 1 Results of the developed method applied to the analysis of tap water.

Sample	Added (mg/L)	Found	
		This method (mg/L)	Digital Pack Test (mg/L)
1	0.50	0.45	0.55
2	1.0	1.05	1.03

Sample: Tap water at the National Institute of Technology, Toyama college.

Table 2 Questionnaire result for Tunisian people.

No.	Question	Good	Slightly good	Slightly bad	Bad
1	Simplification	10	0	0	0
2	Application software	3	7	0	0
3	Analytical time	5	4	1	0

Number of people: 10

proposed method is influenced by the irradiation conditions. Therefore, in the proposed method, the measurement position should be fixed and calibration should be performed before each measurement. User comments on the questionnaire indicated this problem. Thus, for improvement of the analytical performance of the proposed method as on-site analysis, the influence of irradiation conditions should be overcome.

6. Conclusion

Fluoride analysis using a smart device was successfully conducted through the development of an original attachment and application software. In addition, in case of fluoride analysis in tap water, statistically valid results were obtained. In comparison with a commercial portable fluoride analytical device, the proposed method has the advantages of being economical because a hand-held smart device is used as the measuring device. Moreover, mapping of the analysis results can be easily performed in a wide range of field analyses. Furthermore, the proposed method is applicable to analyze not only fluoride but also other materials because it can use other color reactions. This fact indicates the proposed method can contribute to not only developing country such as Tunisia but also other countries. As on-site analysis in developing countries, it is necessary to conduct the trial under outdoor conditions in the future. However, because smart devices such as smart phones and tablet devices have been worldwide spread rapidly, the proposed method is expected as highly versatile technique.

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