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Review Article

Progress in Development of Portable Colorimeters for On-Site Analyses

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Abstract

Humans favour visual information than any other formats. This can be easily understood from the inventions such as telescope, microscope, scanning electron microscopy, IR camera, colorimeters and many more. Colors play important role in our day-to-day life. The instruments based on color measurements such as colorimeter, are widely used in agriculture and fisheries sector. Colorimeters are used in several industries including biomedical research. There are several reagent-based testing kits available in the market for determination of water quality in aquaculture farms. However, the accuracy and the detection ranges are not comparable with the instrumental measurements. Meanwhile, instrumental techniques require relatively skilled persons to handle it due to its sensitivity and expensiveness. Portable colorimeters are best alternatives for this purpose since they are efficient, accurate, and economical. This review focuses on the progress in the development of portable colorimeters for on-site analyses.

Keywords: Colorimeter, portable, on-site analysis, LED, smart colorimeter, pocket colorimeter, water quality, fisheries

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Introduction

In human being, there are totally six senses. They are touch, sight with help of eyes, hearing, taste, smell due to nose and extrasensory perception. Among these, vision plays the most important role. Instead of hearing or smelling, the human beings are built to collect information only by what they see. Moreover people trust any incidents only by seeing rather than hearing or any other senses. Thus the eyes are the physical portal through which the data is collected from our environment and sent to the brain for processing. In brain, it converts the light that enters into our eyes into usable information.

Colorimeter is an analytical instrument designed for determining the concentration of the colored sample solutions by comparing the color of sample solution with the standard colors. The colorimeter was invented by Jules Duboscq in the year of 1854 and applied in analysis of urine and blood to determining the concentration of its components in medical diagnosis and physiological laboratories.

A colorimeter is a light-sensitive instrument which is used for the measurement of absorbance and also the transmittance of light travelling through the colored sample solution. Ultimately, this instrument can be used to measure the intensity of the color that was developed or concentration of the sample solution by introducing certain reagents into the sample solution. Densitometer is similar to the colorimeter to measure the density of the colors usually primary colors and photometer is more or less similar to colorimeter which measures the reflection of the color and also transmission.

In clinical laboratory, colorimetry is the most commonly used analytical techniques for biochemical estimation. Any substances to be colorimetrically estimated must be colored or it should have the ability to form chromogens (colored complexes) during the addition of any reagents. With respect to their color intensity, the colored substances absorb light and the concentration of the colored solution is directly proportional to their color intensity. Colorimeter, Photometer or absorptiometers are the instruments works on the basis of colorimetric technique. Colorimeters are used for determination of endless colored analytes.

Fisheries and agriculture are the major industry that uses analytical instruments. In most cases, portable instruments/gadgets are required for on-site determinations of analytes in these industries. For instance, measurement of dissolved oxygen in a fish pond or river has to be performed at the point of sampling. This is due to transportation of the sample which may influence the result. Therefore, portable or handy instruments could be beneficial for accurate analysis for these purposes. Aforementioned, colorimeters are useful for determination of water quality parameters. However, the conventional colorimeters cannot be taken to the field for analysis since they require power supply and skilled labour for handling.

Light emitting diodes (LEDs) are economical and best replacements for expensive light sources used in colorimeters. In the developing days of LED's, the emission wavelengths were narrower to near infra red region and slowly after the development of blue LED, and visible light region can also be covered now. Increase in their emission intensity reached several candelas. This is useful in colorimeter since an amplifier is more than enough because light intensity is normally strong. Therefore, development of portable colorimeters could be a better solution for on-site determination of analytes in any industry. Though colorimeter is a basic instrument used in chemical analyses, very few researches were performed on its portability. Indeed, the fundamental principle of colorimeter is Beer-Lambert's law. Hence, this review focuses only on development of portable colorimeters using different techniques and their wide spectrum of applications.

Discrete frequency colorimeter

Di Martini et al [1], described a compact and a portable colorimeter, which contained an integrally-formed probe having a solid-state monochromatic light source and a solid-state photodetector which was optically coupled. The light source was connected with a power oscillating gate. The light source comprises of a LEDs or a laser diode, it was passed into the chemical samples and the light emits from the samples was detected by the photodetector. The output of the photodetector was connected to the demodulating circuit and then the output of the demodulating circuit was converted to a signal and read-out indicated the concentration of the sample solution then the characteristics of the absorbance correlated with the wavelength of light source (monochromatic LED).

Autoanalyzer for determination of nitrate and nitrite

Oudot et al [2], discussed about a high sensitive method for determining the presence of nanomolar concentrations of nitrite and nitrate in the seawater sample. The nitrate present in the seawater sample was converted into nitrite by the seawater sample was running in a column which consisted of cadmium granules combined with copper metal coating and ammonium chloride was used as a complexant and buffer. The resultant nitrite solution was mixed with sulphanilamide reagent and N-1-naphthylethylenediamine and it reacted to give a high colored azo dye. Then the colored solution was placed in the colorimeter to measure the concentration of nitrite in the seawater sample.

Hand held colorimeter for glucose estimation

Leveen et al [3], designed and developed a hand held colorimeter for measuring the concentration of glucose in the sample. This colorimeter consisted of LEDs (usually two or more) at one side for emitting the light and a photo transistor as a detector was placed at the opposite side of the LEDs. In between the LEDs and the photo transistor, an optic chamber was placed for inserting the glucose sample. A logic circuit was used to switch the correct LED depends upon the desired absorption band and the particular range of concentration of the sample. Therefore more absorption will take place in the particular range. In glucose estimation, optic chamber containing a strip was inserted in between LEDs and photo transistor. The light emits from the LEDs after passing through the strips placed in optic chamber was detected by the photo transistor, it produces the signal and directly connected to a computer and then the associated circuitry which was operated by the software gives the glucose concentration.

Colorimeter with fast-Fourier-transformation

Yasutada al [4], developed a colorimeter which was fitted with LED and two photodiodes. The LEDs (Blue and Green LEDs) was used as a light emitter and its wavelengths were 440 nm and 550 nm respectively. For cobalt determination, the sample solution was added with 2 M acetic acid-sodium acetate buffer solution and keeps undisturbed for 5 minutes. After 5 minutes it develops a color complex and then decomposes the complexes by adding hydrochloric acid. The cuvette containing sample with reagents was placed between the LED and the photodiodes (detector). In this work, the colorimeter was connected to computer for converting detected analog signals into digital signals. The analog signals received by the detector were converted into digital signal and fed into the computer for absorbance calculation. This colorimeter was mainly used to determine the cobalt content in the simulated water sample and nitrite ions in the river water.

Pen-shaped miniature colorimeter

Wagner et al [5], evaluated a colorimeter for the measuring the color of any object. This colorimeter consisted of a hand-held probe which looked like a large writing pen in shape and size. This probe has the capacity to measure the color of the targeted object. For any measurement, the tip of the probe was placing against or in close to the surface of targeted object. This colorimeter consisted of multiple LEDs (Blue, Green and Red) for emitting light of various colors towards the target. A light sensor was used for receiving light and from the multiple LEDs to target, and a light pipe was used for directing light. In this colorimeter, the reflection of the target measures the wavelengths of primary colors (RGB) and it generated three color (RGB) data points. A microprocessor tends to compare the measured value in a preloaded table and yields a single color value in the display. An electrical cable was used to connect the display module and probe.

Film Canister Colorimeter

James et al [6], described about the canister colorimeter which consists of a green LEDs (LEDs) for transmitting light and photo resistor for detecting the light waves. The voltage across the photo resistor was recorded by multimeter. The voltage measurement was substituted for transmittance. Dark voltage (V_{dark}) means the reading of the voltage during the canister closed with LED off. The measurement of voltage corresponding to 100% transmittance (V_{water}) value was made with the condition of LED on and also the cuvette was filled with water. This colorimeter was standardized by using potassium permanganate solution of concentration varying from (6.25×10^{-5} M to 5.00×10^{-4} M) were placed into the cuvette. After the placing of each solution, the cap was fitted on the top of the cansistor for providing a dark stable background and the multimeter can be used to measure the voltage value.

Graduated-cylinder colorimeter

James Gordon et al [7], studied that the graduated cylinder colorimeter that consists of 10-mL graduated cylinder for filling colored test sample. A cork stopper with LED was fitted in the top region of the graduated cylinder and the base portion having photoresistor as a detector. Both the LED and Photoresistor were connected with separate 9V battery. In LED connection, a potentiometer was used to regulate the voltage from 9V to 2V. A voltage divider circuit was used to measure the voltage from the detector (intensity of light exist from the colored test solution). As the light struck into the photoresistor, the voltage reading increased by decreasing resistance. Then the absorption value can be calculated from the voltage reading by using Beer-Lambert law. The green LED (emission λ_{max}=565 nm) used for potassium permanganate solution, which performs well with some significant absorbance for the ions of permanganate. Similarly, a yellow LED has emission λ_{max}=580 nm was used for $Cu(NH_3)_4^{2+}$.

Microprocessor Based Portable Colorimeter

Berstis et al [8], explain that the portable colorimeter was used for identifying or measuring the color of an any object. In this work, the portable colorimeter contains light emitters, it may be **a** LEDs (LEDs) or a laser and also contains one light sensor which the sample lights reflects from the object illuminated by light emitters. The sampling rate was almost twice the frequency of emitted light. A microprocessor was used for computation of fourier transform of reflected light intensity over a period of time, the fourier transform provides the intensity of light at each modular frequency and the relative contribution of the light reflected from the light emitter as well as the ambient light contribution were determined. A color value will be calculated and also selected a color name and given to the user.

LED based colorimetric system for flow Injection analysis

Yasutada et al [9], studied that the Flow injection analysis(FIA) was simplified by developing absorbance detector(four-channel). Four LEDs(Blue, Green, Yellow, Red and its wavelengths were 470,495,590 & 635 nm) as a light source. Their amplitudes were modulated electronically with various frequencies. Photo-diode (PD) was used to detects the light emitted from the LEDs after merged by fiber optics(plastic-core).The mixed signal was then passed through the lock-in amplifier(four-channel)which corresponding to their respective modular frequency(MF) and there was no need of monochromator and optical filter. This absorption detectors was mainly used to the detection of iron particles in the river water sample by flow-injection analysis (FIA), 1,10-phenanthroline were used.

According to Jiye Jin[10], residual chlorine in the enviro nm ent water sample was determined by developing a miniaturized FIA (flow injection analysis) system combined with a amperometric detector, that was based on two-electrode. The two-electrodes were gold and silver electrode, a gold and silver electrode were the working electrode and reference or counter electrode respectively. In this study, the results were determined or obtained by using N, N-diethyl-p-phenylene diamine (DPD) method. This developed method was successfully applied for determining the residual chlorine present in the sample water (either tap water or pool water).

Tristimulus colorimeter using digital still camera

Yasutada et al [11], also explained that the tristimulus colorimeter has been developed by using digital still camera. A dedicated light box made up of white acrylic sheet and it consists of white-color LED serves as a light emitter and the use of white acrylic was maintaining constant exposure of white light at each photograph. In tristimulus colorimeter, a digital photograph of both the sample solution and the standard solution were simultaneously taken by digital still camera, and the photograph was immediately transferred into the personal computer. On the personal computer, the colors of the standard solution and of the sample were analyzed. Finally L*, a*, b* (L*is the Brightness, a* was Red to Green components, b* was Yellow to Blue components) values were calculated with a software (Laboratory-made). Tristimulus colorimeter method was mainly used to determination of two components, (i) Iron particles in the sample of river water with 1,10-phenanthroline and (ii) Residual chlorine in the sample of tap water with N,N-diethylphenylenediamine (PDP).

Sequentially Reflective Colorimeter

Yang et al [12], studied about a colorimeter that contains three LEDs (LEDs) acts as a light emitter (source) and the light after reflected from the colored test object was detected by using silicon P-N photodiodes(it coverts light energy to electrical energy) with a amplifier (trans-impedance).The trans-impedance amplifier converts current into voltage. The light reflected from the test sample was recorded by using LF398 Integrated Chips and then the chromaticity coordinates were obtained and processed with a computer. The authors assumed a linear transformation (single) between the three color of CIE coordinates (i.e., X, Y, Z) and three values of measured reflectance during calibration. This transformations were initially characterized by a (3x3) matrix, totally 9 elements were found by the sample of four standards with their coordinates (chromaticity coordinates-x, y) were measured with a well-calibrated instrument. They successfully demonstrated their calibrating methods to conventional illuminants: (i) a bulb and (ii) a fluorescent lamp.

A Simple Portable Colorimeter

Mohammad-Hossein et al [13], designed a system which employs an green LED, emitting a spectrum ranges from 520-620 nm and λ_{max}=565 nm, was operated by 2 dry battery(1.5 V each),was used as a light source. A common photoresistor (photocell) serves as a detector. The photocell detects the light intensity which emitted from the LED and passed through the cuvette containing test sample(colored).The photocell was directly connected to the multimeter to measure the resistance value during the transmission of light. The absorption values were calculated from the resistance value by using resistance to absorption conversion formula. Standardizing this portable colorimeter by using the concentration of permanganate, eriochrome black T (ECBT) and Fe-1, 10-phenanthroline complex solution. The value of resistance was inversely proportional to the light transmittance. The same authors [14], demonstrated a simple colorimeter which consists of LED (Red LED which emits the continuous spectrum of ranges from 550-680 nm) as a light source. This LED was operated by 2 dry batteries (1.5 volt each) and the common LDR (light dependent resistor) as a detector. The colored sample was inserted in the cuvette and was placed in between the LED and the LDR so that the light emitted from the LED after crossing through the cuvette was detected by the light dependent resistor and the LDR was directly connected to the multimeter to measure the value of resistance for the particular detection of light. The multimeter was also driven by a separate 9V battery for measuring the resistance reading. The resistance reading increase with increasing the light absorption by the colored sample solution. This colorimeter was mainly used for estimation of to determine the concentration of copper in the water sample and also urine sample. In urine sample or water sample, the copper determination was based on the chemical reaction with SPAQ (sodium-8-aminoquinoline-5-azobenzene-4'-sulfonate). Using this colorimeter, molar absorptivity of complex (Cu(II)-SPAQ) were also determined.

Photometric determination of Iron by discrete flow system

Yasutada et al [15], described a photometric system for estimation of iron present in the river water sample. The photometric system consisted of a LED light source, a photodiode detector, a glass syringe and also two optical fibers. The reagents were used to mix with the sample water and the absorption values will be calculated. They were following two types of methods, at first the sample water was taken from the river and filtered by using PTFE membrane filter, methyl orange (MO) was added to the water sample and then the absorption value was calculated by using blue LEDs (Blue-LED) of 470 nm and the another method was that the filtered water sample of 100μL was taken in the glass syringe and mixed with some reagents such as 10μL of 1, 10-phenanthroline, 25μL of sodium acetate and 10μL of 1% hydroxyl ammonium chloride. These solutions were properly mixed by the plunger was moved at several times and then the absorption value was calculated by using a blue LEDs of 470 nm (Blue-LED) and analog to digital converter. The proposed system was readily applied for determining the iron in the river water sample.

The same authors [16], described determination of the selenium content in the river water sample. In this work, a spectrofluorometer device which comprises an UV LEDs (LED-380 nm) which serves as a source of light and a microsyringe was used as a cell, a CCD (charge coupled device) spectrometer and a computer and this setup can be used on the site. This device has the ability to works continuously with the help of battery for 3 hours. In this work reduces the consumption of required reagents and also the solution (sample). The performance of the spectrofluorometer was compared with some bench-top spectrofluorometer. The selenium in the water sample reacts with 2,3-diaminonaphthalein and its form a piazselenol, which was extracted with the cyclohexane. The developed spectrofluorometer was mainly applied to determine the presence of selenium in the river water sample, it was one of the hazardous element model in the enviro nm ent and the recovery of selenium ranges from 104-112% and the limit of detection was 0.5 μg L^{-1}.

LDR based field kit for nitrite estimation

Ajayi et al [17], developed a colorimeter consists of tungsten light source combined with three filters for 710 nm (red), 580 nm (yellow) and 520 nm (green) regions for the selection of wavelength and a LDR (light dependent resistor) which was used as a detector. The resistance of the light dependent resistor varies depends upon the various concentration of the given colored sample solution and the absorption values was measured from the LDR's resistance value. Before the determination of nitrate in the sample solution, calibrate the colorimeter with the standard solution of nitrite. The color developed by the standard solution or the sample solution of the nitrite estimation was based on mixing the solution with two reagents namely N-(1-napthyl) ethylenediamine dihydrochloride and Sulphanilamide. After the reagents were mixed, it gives pink colored solution then, they can easily measure the resistance of the sample solution and finally it was converted into absorption value.

On-site Determination of trace manganese

Junpei et al [18], developed a method for determining the manganese ion using manganese-catalyzed which oxidation of malachite green with the presence of potassium periodate. The size of this portable colorimeter was 10×7×5 cm and its weight was 280g and equipped with a glass cell of 10 mm thickness. This colorimeter has LED which can perform as a light source (totally three light emitters-Red, Blue, and Green) and a photodiode was used for absorbance measurement. Liquid Crystal Display was used for displaying the value of absorbance. The sample was taken in the cuvette and mixed with regents and then placed in between the LEDs and the detector (photodiode). The detector receives the light signal was converting into electrical signal and the absorption of the particular LEDs was displayed in the LCD. The proposed method was used to determining the concentration of manganese ranges from 2-20 μg L^{-1} and it was successfully applied for trace the manganese concentration in the lake, river and tap water samples.

Analysis of sodium in vegetables

Murugananthan et al [19], had developed a colorimeter to determine the various concentration of the sodium ion present in the vegetable sample. The colorimeter consisting of LED has the wavelength range of 530 nm which provides a light source (light emitter), a simple photodiode was used as the light detector. Inbetween light emitter and detector, a vegetable sample was placed and the absorption value will be calculated from the voltage reading. ATmega16 microcontroller was used to read the value of voltage for the standard, blank and the sample solution. At first, the required vegetable sample was bought from the local market. Fresh sample (vegetables) was cleaned with water properly and wiped with a clean dry cloth. Then the edible portion of the sample vegetable was separated and allowed for drying in a oven (Hot air oven-50^{o}C for an hour) after that the dried vegetable was boiled in water bath, it was then extracts in the test tube and filtered by using filter paper and finally, the filterd sample was centrifuged at 2000-3000 rpm for obtaining clear sample solution. The sample solution was added with the color reagent (1mL) and a precipitating reagent (0.02mL). Mixed well and transferring this solution into the cuvette and the detector detects the light after travelling from the sample solution.

Colorimetry based Calcium Measurement

Rupali et al [20], has developed a colorimeter for determining the concentration of calcium. In this colorimeter contains LED of 650 nm as the emitter (light source) and a photodiode BPW34 (high speed) serves as a light detector. The light emitted from the LED after passing through the cuvette having colored sample was detected by BPW34 photodiode, the output voltage was amplified and then given to the DAS (data acquisition system). A microcontroller (ATmega644) was used for data acquisition system and finally the analog signal was converted into digital signal by 10 bit A/D converter. Analysis of calcium was one of the important parameter in the field of clinical diagnosis. Normally, the range of calcium in the human serum was between 8.5 to 10.5mg/dl. The calcium ion reacts with ArsenazoIII and forms a complex solution (colored). By using Beer-Lambert's law, the absorption value of the colored sample will be measured from the measurement of concentration of calcium.

Colorimeter based on photometer for chromium speciation

Mohammad-Hossein et al [21], discussed about a simple method of spectrophotometric for determination of chromium in the water sample. This spectophotometric method containing a white color LEDs (LED) served as the light emitter and the light after passing through the sample was converted into frequency by pre-programmed light into frequency converter(photodiodes were arranged in three arrays with blue, green or red filter) which was used as a detector. The Chromium (VI) was reacted with 1,5-diphenylcarbazide to form a complex formation of chromium. By using the green filter detector, the maximum range of absorption wavelength for the chromium complex formation was determined. This developed method was mainly implemented for the chromium speciation in the water sample.

Mobile based Colorimeter for chlorine estimation

Sarun et al [22], experimentally demonstrated that the concentration of chlorine was determined by using mobile or tablet embedded with a 2D digital camera. This colorimeter containing a reference scene, a small transparent glass bottle(sample bottle), a smart mobile or tablets and this setup having uniform light illumination(White light). The reference scene was usually a cheap white paper and the transparent glass bottle was filled with sample solution and tightly closed with their lids. Then, the transparent glass bottle was placed in front of white paper reference scene and the camera was placed where the reference and also the transparent glass bottle was clearly focused in the digital camera (2D). First of all, they prepared the KI-starch solution by iodometric method, KI powder (30g) was dissolved in the water of 200mL, and then starch powder (2g) was dissolved in the water of 50mL. After that, 30mL of starch solution was properly mixed with the above prepared KI solution (200mL). The prepared KI-starch solution was added to the water sample contains chloride. The potassium starch solution and chlorine in the sample water reacts and then the color of sample solution changes from white to dull blue color and this color varies depends upon the concentration of the chlorine available in the water sample. Finally, the color ratio (CR) was calculated for the reference scene and also the sample in the glass transparent bottle.

A Portable Spectrophotometer for Water Quality Analysis

Xiaomin et al [23], designed and developed a spectrophotometer for analyzing water quality. The developed system embedded with a module of LEDs(6 No's) as a long-life source (light emitter), a photodiode acts as a detector, the main role of the photodiode was to convert electric signal from the light received from the emitter after passed from the sample. A microcontroller (C8051F410) plays an important role in the water quality analyzer, it controls the LEDs (LEDs ON/OFF), LCD, data acquisition and processing of signals. Water quality parameters such as nitrite, ammonia etc., and the measurement of this concentration were based on the principle of colorimetry. According to this principle, the intensity of the light which was transmitted through the colored solution and the intensity of the light entering into the medium were measured by colorimeter and % transmission of the solution was measured by a detector then it will be converted into absorbance.

Monitoring chlorine on mobile-platform based colorimeter

Sarun et al [24], has developed a colorimeter to determining the residue chlorine concentration in the water sample by adding some indicating chemicals to the water sample. This system was also known as mobile platform colorimeter method. There were two main parts in the proposed mobile platform colorimeter. The First part contained a white light source with a white diffuser (sheet), a reflective surface (flat), batteries and a switch. In the second part a mobile phone or a tablet that was embedded with algorithm was used. The indicating chemical solution such as o-tolidine was mixed with the sample solution and they get a colored sample solution then the colored sample solution was inserted in the glass bottle and closed with their led and the glass bottle was fitted in the field of clear focus to the camera (2D). The 2D camera analyzed both the reference material and also the sample solution placed in the glass bottle. The authors used an already developed java based application called "ClApp" for determining the concentration of the chlorine in the sample water.

A simple LEGO colorimeter

Jonas Asheim et al [25], described the construction of a robust colorimeter from Lego bricks. This Lego brick colorimeter containing two LEDs in which one LED emits light when a current was applied so it was called as emitter LED (source of light) and the other LED serves as a detector. The detector LED was usually a Red LEDs (Red LED) because it was very much sensitive to all the colors available in the region of visible spectrum. The minimum necessary of this colorimeter consisting of two LEDs, a 3 volt battery, few wires, a resistor and a voltmeter (mV). The resistor was necessary to keep the voltage in the optimal working range of LED. Jonas Asheim et al [25], successfully demonstrate the Beer-Lambert law from the solution of $Cu(NO_3)_2$ with ranges varies from 0.010-0.70 M. This solution was taken in the cuvette and placed in between the emitter and detector LED. The detector red LED) was directly connected to the digital multimeter. The detector which was connected to the multimeter yields voltage reading in mill volt. The absorbance value was measured by substituting the voltage reading in the Beer-Lambert's law and calculated the transmission value first and then calculated the absorbance value from the transmittance value. The percentage transmission was measured by the given formula:

$$\%T = \frac{Vsolution}{Vwater} \times 100\%$$

Where, Vsolution – Voltage reading when the analyte (sample solution) was used. Vwater – Voltage reading when water (blank solution) was used.

A DIY photometer for pH measurement

Bo et al [26], developed a portable photometer which was used for measuring the pH present in the sample solution (mainly seawater sample). The portable photometer consists of two LEDs acts as a light emitter and its wavelength was 434 nm and 578 nm. The light detector was a photodiode combined with a trans-impedance amplifier on a CMOS (Complementary metal-oxide-semiconductor) single monolithic circuit (integrated). A sulfonephthalein indicator with meta-cresol purple was added in the sea water sample so the changes of color in the sample depend upon its pH value. The sample solution with the reagents was inserted into the cuvette and the cuvette was placed inside between the LEDs (LEDs) and the detector (photodiode with transimpedance amplifier). The light after transmitting from the sample solution was detected by the detector with transimpedance amplifier and it converts the light signal into voltage value. An open source microcontroller (Arduino) was used for control of system and the processing of data. The proposed system was mainly used for measuring the value of pH value in the sea water sample.

Optical Density Meter

Ankit et al [27], has been developed a colorimeter for the identification of analytes (Biological marker) and it was very helpful to the confirmation of any diseases and overdose of any drugs. It was very helpful for the treatment of patients. This colorimeter consists of normal LEDs (LEDs) acts as a light emitter (light source). Usually 5mm LED with the wavelength ranges from 400-700 nm and the light emitted light after crossing from the sample was detected by a simple light detecting resistor (LDR). Remaining components in this colorimeter were a 10 kΩ resistor and a cuvette. The sample solution was poured inside the cuvette and this cuvette was madeup of white acrylic material. This colorimeter was mainly applied to the measurement of Optical Density (OD) in the sample solution. Using arduino microcontroller, they programmed to get a optical density value from the transmission value. The developed device was suitable for estimating potassium indigo sulphate, rhodamin-B dye and also salicylic acid by creating a standard plot curve.

Smart phone-based Estimation of Iron, Fluoride, and hexavalent Chromium content in drinking water

Debmalya et al [28], discussed that the cost effective techniques for determining the presence of fluoride, iron and hexavalent chromium in the drinking water. The low cost portable instruments used for multiple analyte detections include Colorimeter or Ion Selective Electrodes (ISE). In this work, three LEDs (Blue, Green and Red) were used as a light source and using smartphone application "Spectruino" for determining the concentration of the analyte. For chromium estimation, 1,5 diphenyl carbazide was used for the development of the color and absorbance was measured by using portable colorimeter. In case of fluoride estimation, the reagents used were AR grade (4, 5-dihydroxy-3-paraslfophenylazo- 2, 7-naphthalene disulfonic acid and trisodium salt) SPADNS and zirconyl chloride octahydrate ($ZrOCl_2.8H_2O$) and reagents used for iron estimation were 1, 10 phenanthroline and hydroxylamine hydrochloric acid and a calibration curve was plotted.

A Miniaturized Colorimeter for water quality detection

Jun-Chao et al [29], studied that a miniaturized colorimeter can used for the water quality detection. In this work, colorimeter was developed on the basis of beer-lamberts law for high precision detection of chemical elements in the water sample. Ammonium molybdate and potassium antimony tartrate reagents were mixed with the sample solution and absorbance value was measured by using colorimeter. A laser light of 880 nm was used as a light emitter (source) and a photodetector was used as a detector. In another study, the authors [30] described about a portable colorimeter for determining the presence of phosphate ion in the natural water. In this study, the light source was a laser of 880 nm and an integrated photodetector was used as the detector. The sample phosphate solution was mixed with ascorbic acid and ammonium molybdate reagents to form a blue complex. Then the colored sample solution was loaded in the colorimeter, it was connected to the computer and programmed (ZigBee module and also GSM module were used) to obtain the absorbance value.

Prospective and Conclusions

The basic components of a portable colorimeter are a light source, signal receiver, and a digital display unit. In some cases employment of microcontroller is also observed in the above discussion. The key for the development of a modern day colorimeter are (i) portability, (ii) display of digital and accurate value, (iii) economy, (iv) less operational procedures, and (v) on-site determination. By considering these key parameters in the design aspects, an economical colorimeter with the function of real-time monitoring for on-site analysis is possible. In most of the studies, the light source and the microcontroller are the expensive components in the colorimetric system. By carefully selecting economical and efficient light sources such as LEDs and other components, the cost of the portable colorimeters could be lowered.

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