Progress Report (1st Phase)

Project Title: "**Smartphone Based Instrumentation for Water Quality Monitoring with Reference to Resource poor Regions**"

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Awardee name: Ifatk Hussain, PhD scholar, Department of Physics Tezpur University.

Project Assistant: Diganta Hatiboruah, Department of Physics, Tezpur University.

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Date of Start: 1 June 2017

Duration of the Progress: 10 months (As on April 30 2018)

Project introduction: The plan of this research is to develop a compact, portable and user-friendly smartphone sensing system to monitor water quality for resource poor regions. The working principal of this sensing platform will be based on colorimetric method. It is proposed to design a compact optical set-up using 3-D printer which would hold the necessary optical components to be attached to the smartphone. Regular monitoring of water quality could prevent water related diseases among the common masses. The proposed sensing platform will provide easy access to water quality data in resource poor regions and ensure safe drinking water. The social view of this research project is to ensure safe drinking water for all.

Milestones:

- To study the societal impact and need of the innovation.
- Complete development of the laboratory facility from prototype to manufacturing.
- Fabrication of the sensors.

Progress of the project work:

- Appointment of project assistant: On June 5th 2017, Mr. Diganta Hatiboruah, (M.Sc in Physics) was appointed as Project Assistant (PA) in the project at a monthly fellowship of 12,500 rupees for a period of 2 years.
- Establishment of Laboratory facility: In this project period necessary chemicals and equipment are procured and stored. A 3-D printer (Raise-N2) with a 3-D model design software (ZW3D) has been installed in the laboratory. A digital balance (ME204) and a 1 KVPS UPS (Orion) system have been procured from the grated project fund.
- Literature review: In the first two months PA has done extensive literature work related to the project work and societal impact of the innovation. A huge portion of the world population is affected due to the consumption of contaminated water. Estimation of pollution level in drinking water with reference to remote and resource poor regions are lagging behind due to the

unavailability of proper laboratory facilities. Proposed sensor has the potential to work in such environment and ensure the quality of water before consumption.

- Learning of perquisite courses: Currently the PA is learning on Optics layout design, 3-D drawing, 3-D printing technology and android application development courses which would be required for the proposed work. ‘Google Sketchup’, ‘ZW3D’ software are being used to design the sensing set-up. ‘IdeaMaker’ software is used to produce the g-code for the 3-D printer for efficient printing. The cloud based application development platform ‘MIT appinvetor-2’ has been used to develop the application for the present work. In future, the application will be developed using ‘android studio’ software.
- Fabrication of the set-up: Prior to the project approval, the nylon cradle for holding optical components, sample cuvette to the smartphone were fabricated using CNC machine. In this project period all the necessary components are printed in a 3-D printer (Raise N2). 3-D printing results in increasing robustness of the set-up with accuracy in alignment and position of the optical components. Usage of black coloured material to print the whole set-up minimizes the effect of ambient light on proposed sensor.

Summary of the work that has been done within this project period: According to Indian Standard of drinking water specification (adopted by the Bureau of Indian Standards (BIS)) the parameters related to the water quality measurement are classified in different categories. The permissible limit and detection procedures for each individual parameter are well adopted by BIS in the documents prepared by Drinking Water Sectional Committee and approved by the Food and Agriculture Division Council. Some of the classifications are given as follows-

1. Physical parameter: The colour, hardness, taste, turbidity and total suspended solute (TSS) are considered as physical parameters of a water sample collected from any drinking water resources. There is a permissible limit for each parameter for safe drinking water.
2. General parameters concerning substances undesirable in excessive amounts: In this classification those substances are included which are necessary for human consumption of minimum amount. If the amount of these substances is above the permissible limit then various health issues may occur. Some of the substances are chloride, fluoride, iron, copper, sulphate etc.
3. Parameters Concerning Toxic Substances: Substances under this classification are highly undesirable in any amount. These substances are highly hazardous to human health. Absence of such substances possesses quality water. That is why the permissible limit of such substances is kept as low as possible. Cyanide, lead, mercury, pesticide are fall in this category.

The primary objective of this project is to develop a standard smartphone based water quality monitoring platform, which will estimate almost all the necessary parameters of drinking water to ensure the quality of it. If the water quality parameters are above the permissible limit then they can cause severe problems to human health. So it is necessary to monitor those parameters of any water resources in a regular basis. For that a compact, user-friendly and low cost portable device is required so that any common people can measure those parameters prior to drinking from any water resources. The instrumentation of the platform is focus on the reliable estimation of target parameters, reliable estimation in ambient conditions (in-field testing), and user-friendly estimation procedure and minimise the manufacturing cost.

The working of the instrumentation of the water quality monitoring platform can be divided into two parts Detection and Estimation. In both the cases smartphone will be used as a detector and an analyser of the detected signal to estimate the target parameter.

- *Detection:* In this project the physical parameters, substances which are undesirable in excessive amount and toxic substances are major concern of determination. The working of the platform is based on optical method of detection of water quality parameters. In general, water quality parameters which are responsive to light will be detected and estimated using this platform. The detection part of the target parameter or substance can be divided into three parts as follows-
    - Method of sample preparation: The detection of the water quality parameters starts with the proper preparation of the test sample. Sample preparation includes the chemical treatment of the collected water samples. For each parameter, there is specific and highly sensitive chemical procedure of determination. These chemical methods can be adopted from the documents prepared by Bureau of Indian for water quality standard in India. In the designing of the proposed sensing platform the chemical procedure we have chosen are optical based methods. Here, colorimetric, turbidimetric and fluorescence method are primarily chosen to investigate the water quality parameters. *Colorimetric* methods refer to the absorbance of incident light of a coloured test sample. A light source of emission wavelength equal to the peak absorbance wavelength of the test sample is used for investigation. In this method as the concentration of target elements changes in the test sample the absorbance value also changes proportionately. *Turbidimetric* methods refer to the collection of scattered light intensity from a turbid test sample at a specific angle to the direction of the incident signal. The emission wavelength of investigating light source depends on size of the particles present in the turbid test sample. As the concentration of target elements increases the amount of scattered light signal also increases. *Fluorescence* method refers to the collection of fluorescence emission from a fluorophore on excitation. To excite it, illumination of the fluorophore by a proper light signal is necessary. The presence of some target elements quenches the fluorescence property of a certain fluorophore. Hence by collecting the emitted light signal from the fluorophore the amount of target element in the test sample can be calculated.

Reference of some research work of highly selective chemical procedure for the determination of dissolved substances in water based on optical approach are listed below-

[1] American Public Health Association, American Water Works Association, Water Pollution Control Federation, & Water Environment Federation, “Standard methods for the examination of water and wastewater (Vol. 2),” American Public Health Association (1915).

[2] Ramakrishna, T. V., Aravamudan, G., and Vijayakumar, M., “Spectrophotometric determination of mercury (II) as the ternary complex with rhodamine 6G and iodide,” Analytica Chimica Acta 84(2), 369-375 (1976).

[3] Yang, Y. K., Yook, K. J., and Tae, J., “A rhodamine-based fluorescent and colorimetric chemodosimeter for the rapid detection of $Hg2^{+}$ ions in aqueous media,” Journal of the American Chemical Society 127(48), 16760-16761 (2005).

- Optical set-up: The project proposes to design and develop a sensing platform to detect heavy elements in water utilizing the embedded optical sensor of smartphone. 3-D printing technology will be used to develop the proposed sensing platform. ZW3D software will be used to design the 3-D model of optical component holders, sample holder and attachment setup for the smartphone. For the designing of the optics of the proposed sensing platform, Zemax software will be used. The usage of optics designing software will optimise the optical performance of the proposed sensor. The smartphone battery will be utilised to give power to the light source results in elimination of external power supply. Finally, an android application will be developed to analysis the optical signal received by the smartphone camera and ALS to investigate the concentration of the target element. The application will be developed in android studio software.
- Signal detection: In optical sensor there is an optical source which illuminates the test sample and there is an optical detector which collects the light signal coming from the test sample. The collected light signal arises due to the interaction between the test sample and incident light signal. Camera and ambient light sensor (ALS) of a smartphone are used as light signal detector in this proposed platform. Now a day these sensors, embedded with each smartphone are technologically highly advanced that can detect small amount light signal in greater precision. Technological advancement of smartphone sensors and integration of simple optical setup to it, enable us to detect water quality parameters as precisely as laboratory equipment.

- *Estimation:* Estimation of target parameter of water quality is depends on the proper analysis of the collected light signal. To analyse the light signal the smartphone itself can be considered as an analysing tool. The required software for the analysing purpose can be developed and easily installed in a smartphone. An android application which can analyse the collected light signal for each quality parameter will be developed using the cloud based platform "MIT app-inventor 2". The same application can also be used to collect and share data, using the memory element and networking system of a smartphone respectively. Sensor calibration can be included in the application. Installation of android application in an android smartphone can be done easily. The primary task of analysing the collected data by smartphone photo-sensors is to develop an android application.

Work that has been done within this project period:

Fluorescence based smartphone sensor: smartphone based fluorescence emission detection sensor has been designed in this period of the project work. Fluorescence based Mercury level estimation has been evaluated using the designed sensor so far. Mercury is a very toxic substance dissolved in drinking water. It has a very low permissible limit of 0.001 mg per litre of water. Human activities which are related to the exploration of natural resources and also natural deposition increase the mercury level in water resources day by day. Consumption of mercury contaminated water causes Loss of vision and hearing, intellectual deterioration, kidney and nervous system disorders. Excess accumulation of mercury in human health leads to death. A highly sensitive fluorescent method has been adopted to estimate mercury in aqueous solution. Mercury (II) in aqueous solution behaves as a linker between a rhodamine 6G (R6G, fluorophore substance) and a buffer solution prepared from potassium iodide. Formation of a colourless substance in the chemical process results in the quenching of fluorescence property of the fluorophore (R6G). Increases in mercury level in the test sample increases the production of the colourless substance in the solution and quenching of fluorescence increases. The chemical method is appropriate for estimation of mercury in aqueous solution as low as 32 ppb.

Experimental design: Figure 1(a) shows the schematic of the smartphone based mercury level detection set-up. The set-up is the arrangement of optical components (light source, lenses, diffuser etc.), sample holder and smartphone attachment in a compact design. Optical

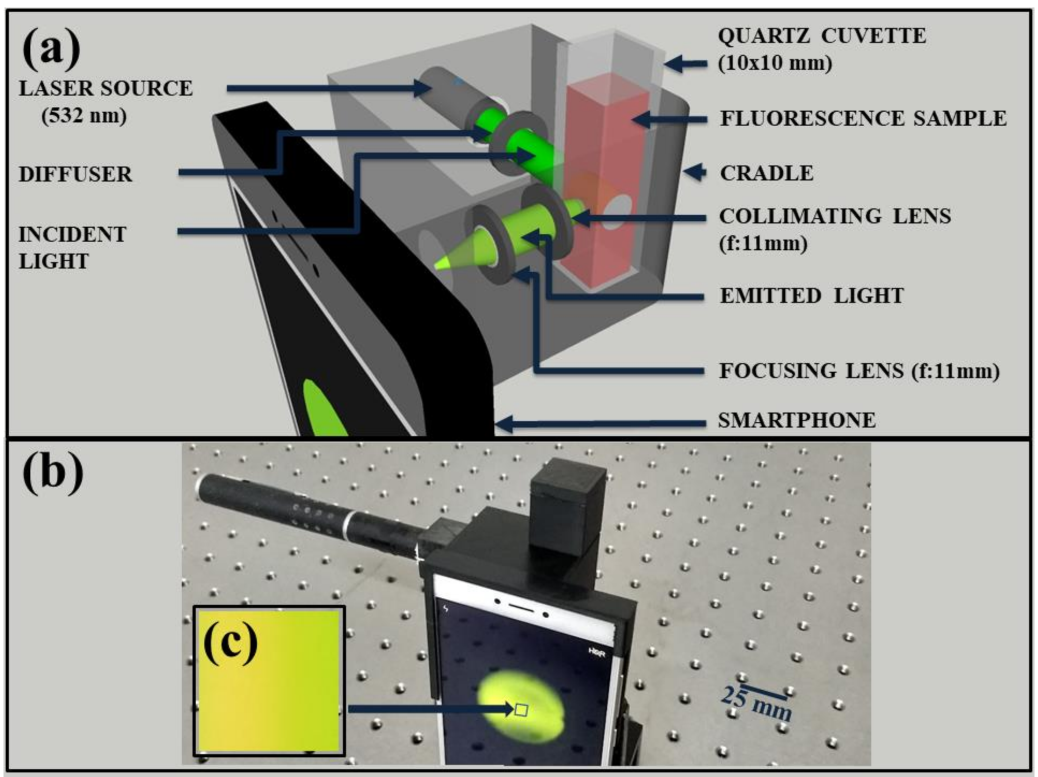


Figure 1: (a) schematic of the smartphone based mercury level detection set-up, (b) Photo-image of the designed set-up and (c) Cropped imaged (200×200 pixel) of the captured image of the test sample by the smartphone camera.

components used are 532 nm peak emission wavelength (5mW) laser source, two 11 mm focal length plano-convex lens and a diffuser. A high quality Quartz cuvette (10×10 mm) is used to hold the test sample. Collimated light signal from the laser source) is allowed to pass through the diffuser to illuminate the sample solution. Fluorescence emission from the test sample is received by the rear camera of the smartphone at right angle to the direction of the incoming signal. One plano-convex lens is placed in the optical path between the sample holder and the CMOS camera of the phone to enhance the coupling efficiency of the fluorescence emission to the imaging sensor of the phone. The compact optical set-up for the proposed work has been fabricated using a 3D printer (RAISE N2, San Diago USA). Figure (b) shows the photo image image of the proposed smartphone optical set-up. The overall dimension of the whole optical set-up is measured to be 50 mm × 40 mm × 40 mm and its net weight is 275 gm including the weight of the smartphone. For the present sensing investigation we use Motox smartphone. This phone is equipped with 13 Megapixel rear CMOS camera, with snapdragon processor, 4GB random access memory element and has android operating system. Figure (c) shows the cropped image (200×200 pixel) of the test sample captured by the rare camera of the smartphones.

Results and discussion: The characteristic study of the designed fluorescence sensor has been shown below. Absorbance study of the prepared sample shows the peak absorbance wavelength which is equivalent to the peak excitation wavelength of a fluorophore. Here the excitation wavelength of R6G is found to be 532 nm. In the graph (b) emission intensity of different sample with different Hg (II) concentration has been shown. Emission intensity gradually decreases as the concentration of Hg (II) increases in the water sample. The peak emission wavelength is found to be 555 nm for R6G. The first two graphs are obtained using the laboratory instrument. The last two figures show the estimation of mercury using the designed sensor. In the smartphone based sensor the test sample is excited by 532 nm light source and the fluorescence image (emission intensity) is captured by the camera of the smartphone. Figure (c) shows the cropped fluorescence image for different Hg (II) concentration in the test sample and (d) shows the linear relation between the Hg (II) concentration and grey-scale intensity of the fluorescence image. The linear relationship calculated from the standard calibration curve (Figure 2 (d)) is -

$$\text{Mercury Concentration} = \frac{\text{Greyscale Intensity} - (-0.1953)}{1.007}$$

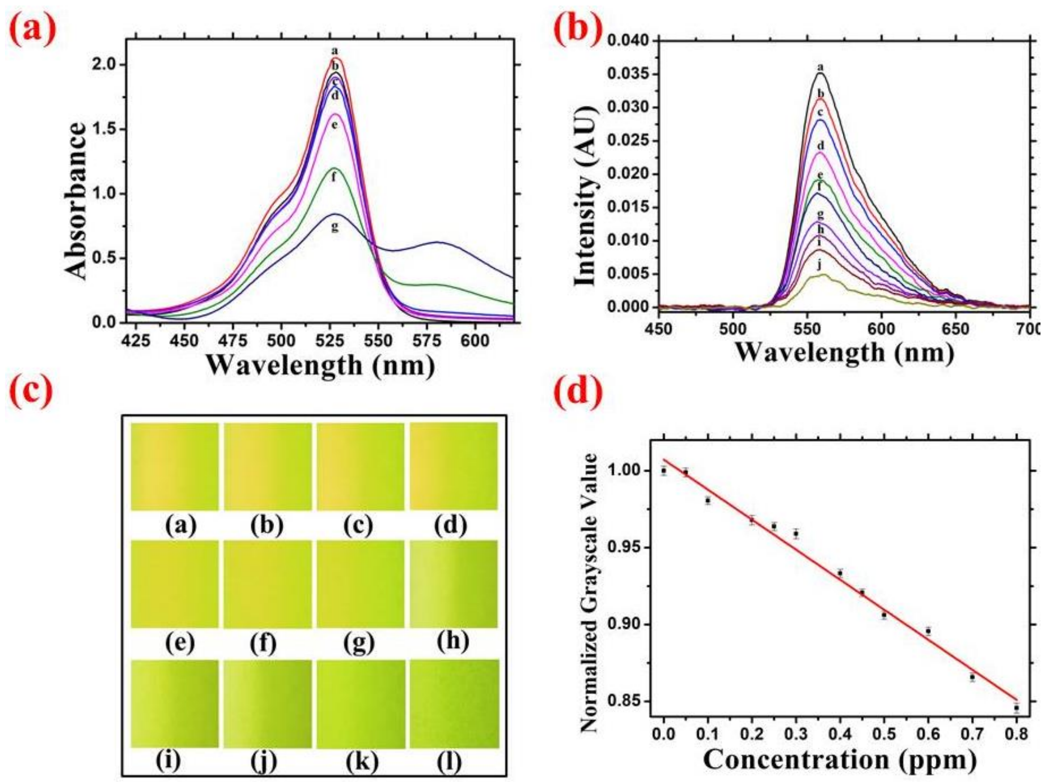


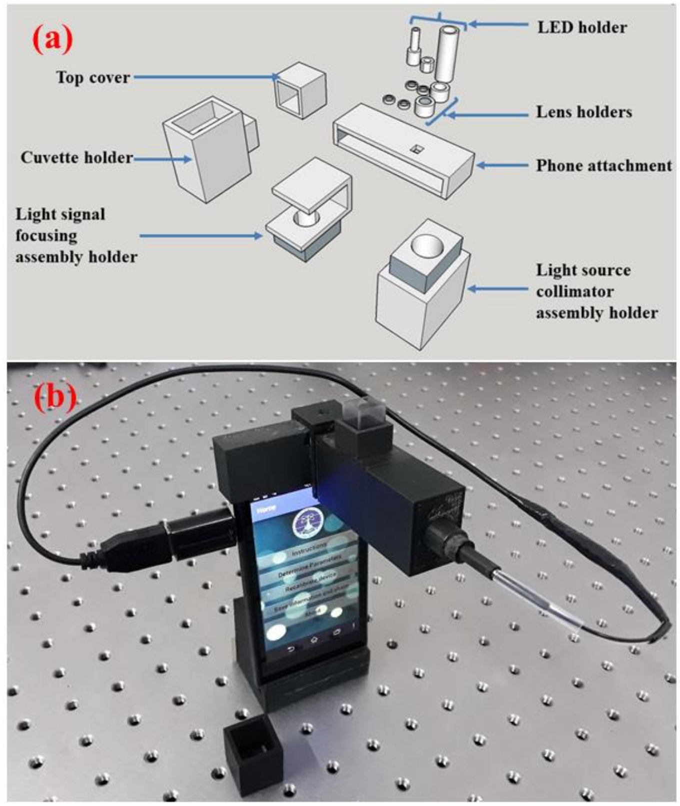
Figure 2 (a): Characteristic absorbance curve of the ternary complex at different Hg (II) level concentration in the mixture. (a) Absorption spectra 5 ml of 10-4 M Rhodamine 6G and 5 ml of buffered potassium iodide solution with 1ml gelatin. (b-f): As in (a) with the addition of 10 ml of (b) 0.05 ppm, (c) 0.10 ppm, (d) 0.15 ppm, (e) 0.30 ppm, (f) 0.50 ppm and (g) 0.80 ppm HgCl2 solution. ***Figure 2 (b):*** (a) Emission spectra of 5 ml of 10-4 M rhodamine 6G and 5 ml of potassium iodide buffer with 1ml gelatin. (b-f): As in (a) with the addition of 10 ml of (b) 0.05 ppm, (c) 0.10 ppm, (d) 0.20 ppm, (e) 0.25 ppm, (f) 0.30 ppm, (g) 0.40 ppm, (h) 0.45 ppm, (i) 0.50 ppm and (j) 0.60 ppm of Hg (II) solution. A significant change in emitted light signal with varying concentration of Hg (II) level in the solution can be observed. ***Figure 2 (c):*** Cropped fluorescent emission images of the samples recorded by our smartphone sensor [(i) – (xii) mercury concentration increases from 0.00 ppm to 0.80 ppm] and ***Figure 2 (d):*** Characteristic sensor response curve of the designed sensor.

Characteristic parameter of the designed sensor calculated from the calibration curve has been listed in tabular form-

Table 1: Characteristic parameters of the designed sensor:

Sl no	Sensor Parameters	Value
1	Standard deviation of blank sample (σ)	0.0021
2	Sensitivity (S)	0.1953 grey-scale intensity per ppm
2	Limit of Detection (LoD)	0.032 ppm
4	R Squared (R^2)	0.98625

Other work has been within the project period: the research work on colorimetric determination of dissolved substances in water in smartphone based platform has been established. The designed colorimetric sensor performance is up-to the standard of a conventional laboratory instrument. Within this period the same set-up has been redesigned keeping the optical design as same and printed using 3 D printing technology. The reliability, repeatability and robustness are increase in the redesigned sensor. Figure (a) shows the 3-D drawing of various components of the smartphone based colorimetric set-up. Figure (b) shows the photo-image 3-D printed set-up.



Colorimetric sensor is based on absorbance of light by the test sample. Here LED of wavelength equal to the peak absorbance wavelength is used as a light source. LED is powered by the smartphone itself using a USB- OTG cable. ALS of the smartphone is used to measure the transmitted light intensity as the incident light is allowed to pass through the test sample. Absorbance can be calculated using Beer Lambert law as follows-

$$A = -\log\left(\frac{I}{I_0}\right) \qquad (1)$$

where, A is the absorbance, I is transmitted light intensity and I_0 is the incident light intensity. The colorimetric sensor has been utilised to estimate fluoride, phosphate and iron in water accurately.

Plan of the next phase: In next phase of the project, the plan is to develop the complete water quality monitoring set-up including the android application. The characteristic parameters and performance of the designed sensor in comparison with standard laboratory instrument will be evaluated in future work. Field samples data collection and in-filed testing will be done in due course of the time. Entrepreneurship possibility to commercially establish the set-up will be exploited at the end of the project period.

Expected Output: The expect output of this project work is a complete user-friendly, field portable and low cost smartphone based water quality monitoring set-up, with reference to the remote and resource poor regions. Smartphone will be used for power sourcing data collecting, data analyzing, and data sharing with the help of complete hardware and software development which will be compatible with most of the smartphones. The work on mercury detection supported by the BIRAC-SRISTI funding has been presented on the SPIE photonics conference 2018.

Reference of the conference Article:

[2] Das, T., Hatiboruah, D., Chamuah, N., Hussain, I., Bora, U., and Nath, P., "Accurate estimation of mercury level concentration in water using smartphone," In Optical Sensing and Detection V, International Society for Optics and Photonics Vol. 10680, p. 106801P (2018, May).

Expected date of completion: June 2019

Overall conclusion: So far the project work is progressing according to the milestones set in the agreement. In this period, PA has done extensive literature review related to the project work and the necessary laboratory setup is established. 3-D printing of the water quality monitoring set-up has been done. In future, sensing performance of the set-up will be evaluated with the help of custom developed android application.

Reference of some work related to the water quality estimation, which are published prior to the project period from our lab is given below-

[1] Hussain, I., Das, M., Ahamad, K. U., and Nath, P., "Water salinity detection using a smartphone," Sensors and Actuators B: Chemical 239, 1042-1050 (2017).

[2] Hussain, I., Ahamad, K., and Nath, P., "Water turbidity sensing using a smartphone," RSC Advances 6(27) 22374-22382 (2016).

[3] Hussain, I., Ahamad, K. U., and Nath, P., "Low-cost, robust, and field portable smartphone platform photometric sensor for fluoride level detection in drinking water," Analytical chemistry 89(1) 767-775 (2016).

[4] Hussain, I., Bora, A. J., Sarma, D., Ahamad, K. U., and Nath, P., "Design of a Smartphone Platform Compact Optical System Operational Both in Visible and Near Infrared Spectral Regime," IEEE Sensors Journal 18(12) 4933-4939 (2018).

Progress Report (2nd Phase)

Project Title: "**Smartphone Based Instrumentation for Water Quality Monitoring with Reference to Resource poor Regions**"

Supervisor: Dr. Pabitra Nath. Associate Professor, Department of Physics, Tezpur University.

Awardee name: Ifatk Hussain, PhD scholar, Department of Physics Tezpur University.

Project Assistant: Diganta Hatiboruah, Department of Physics, Tezpur University.

Institute: Tezpur University, Napaam, Sonitpur, Assam, India -784028

Date of Start: 1 June 2017

Duration of the Progress: August 2018 to August 2019

Summary

The prime objective of the ongoing project is to develop a smartphone-based analytical tool to monitor water quality in resource-poor conditions. The key objectives of the project work while developing the proposed tool is to obtain a compact, handheld and user-friendly sensing system on smartphone platform. The smartphone analytical tool utilises the principles of light scattering, absorption, colorimetric and fluorescence intensity measurement form the test sample while estimating different parameters in water. Using the different sensing schemes, our research group at Tezpur University, have demonstrated the working of smartphone analytical tools successfully. Using which water salinity, turbidity, dissolved iron concentration; fluoride concentrations, phosphate, mercury ion concentration in water have been reliably estimated. To develop the designed sensing systems, we used the rare camera and the ambient light sensor of the phone as a detector. To guide the light signal through the test sample and eventually to be detected by the embedded sensors, a simple optical setup containing guiding optical components has been attached to the smartphone. The optical setup has been fabricated using 3D printing

technology and the optical components including pinhole, diffuser, lens, light source and grating etc. have been incorporated within it. A sample holder containing the test sample has been incorporated in the optical setup. For auto analysis of the detected signal, a custom designed application has been developed on android OS. The sensor characteristics of the designed sensors have been evaluated through comparing the experimental results with laboratory tools. We noticed the proposed sensing systems yields experimental data at par with those of the commercial counterparts.

I. Introduction

During the second quarter of the ongoing project work, we have explored the growth monitoring of biological samples in laboratory environment. Herein, the growth kinetic of different bacteria in laboratory environment has been monitored using the designing smartphone sensing system. The presence of such biological specimens in water could cause various harmful diseases. These microbial organisms are actually responsible for many severe diseases in human such as typhoid, cholera, dysentery etc. The primary source of such biological contamination in water is due to the fusion of human or animal waste to them. This happens due to the sewage overflow or improper sewage systems in rural areas. There are various measuring approaches that indicate the biological contamination in water. For example, the total *coliform* or *Escherichia coli* (*E. coli*) are frequently used to measure the water quality during rainy seasons.

As a part of the project work, we have tried to develop a smartphone platform to study the growth kinetics of bacterial specimens in standard laboratory conditions. Within the first phase of the investigation, the detail growth characteristics of *E. coli* have been studied using our proposed smartphone analytical tool. The considered bacterium is cultured in Luria-broth media and incubated in 37^{O}C along with the proper aeration. The population growth of the bacterium in the media has been monitored by our proposed smartphone sensing tool for a period of 24 hours. The minimum time interval of two consecutive measurements has been set as 30 minutes. After completion of the investigation a growth curve has been evaluated from the responses collected by our smartphone tool. The performance of the proposed tool has been evaluated through comparing with laboratory grad spectrophotometer. In microbial laboratory, usually the growth kinetics of bacterial specimen has been investigated by taking the optical density (OD) of the bacterial sample for a certain period using a spectrophotometer at a wave length 600 nm

(OD600). The spectrophotometer data and the results obtained from the smartphone sensor have compared to establish the reliability of the proposed tool.

II. Working principle:

The proposed smartphone analytical tool is based on the nephelometric principle, where the turbidity of a test sample has been measured by placing the detector at the angle normal to the incident light. It is known that, suspended particles in a solution can scatter light in all possible direction depending on the shape and structural complexity of it. In our investigation, microorganism is considered as soft suspended particles in the liquid medium and the light scattered by the organism is use to investigate their growth characteristics. The scattering of light by microorganisms can be understood from the theoretical background proposed by Rayleigh and Gans. In the proposed smartphone tool, the ALS of the smartphone has been utilized as a signal-detector. In the designed setup, a collimated beam of white light is allowed to illuminate the bacteria sample while placing it in front of the ALS. The angle between the incoming light and the position of the ALS is maintained at 90^{O}. The light source that has been used in the present work is a white LED which is powered from the smartphone battery using a USB-OTG cable. For light signal scattered at 90^{o} to the incoming beam, the scattered intensity is solely dependent on the concentration of the microorganism present in the medium. The scattered signal intensity increases with the concentration of bacteria in the sample, which can be used to estimate the growth of the microorganism in the medium for a specific time.

III. Development of the smartphone analytical tool

Figure 1 (a) schematic of the proposed smartphone tool and 1 (b) shows the photo-image of the designed setup. A white LED () has been powered from the battery of the smartphone is used an optical source in the present work. A plano-convex lens () collimates the light beam to the sample. The scattered light signal intensity at right angle to the incoming light is received by the ALS of the smartphone. The entire setup has been developed on a 3D printer and a compact optical setup can be coupled easily to the ALS of the smartphone as a plug and play tool. The dimension of the developed setup is measured to be 40 mm in length, 40 mm in breadth and 30 mm in height. The total weight of the analytical tool including the smartphone is measured to be

210 gram. In the present work Samsung Galaxy C9 pro has been used. The technical specification of the phone can be found elsewhere.

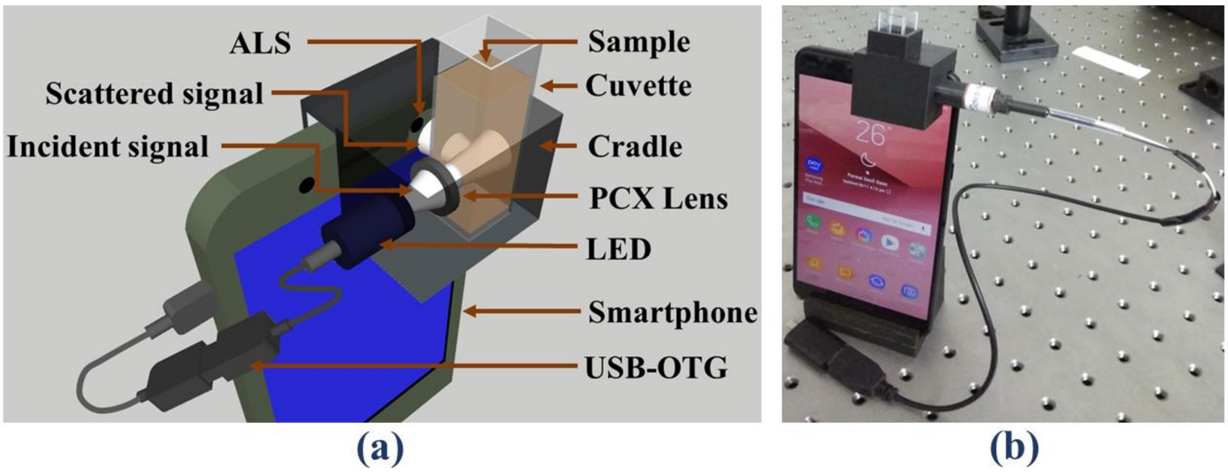


Figure 1: (a) Schematic and (b) Photo-image of the developed smartphone analytical tool.

IV. Development of android application:

To convert the designed smartphone sensor into a standalone tool a custom designed application has been developed using the cloud based resource - MIT appinvetor-2'. Figure 2 shows screenshot image of the developed android application which has been for analysis of bacterial growth in the media. Figure 2 shows the screenshot images of the important steps involve to run the application. The app has been named as 'BioApp'. On clicking, the 'BioApp' the main screen of the application pops up. In the main screen three buttons are available namely 'Instruction', 'Test' and 'About'. By clicking the 'Instructions' and 'About' button, a user will be able to read the guidelines and the information related to the app development respectively. On clicking the 'Test' button, another screen will pop up where the responses of designed smartphone are recorded. The new tab is termed as "Growth Monitor" (Figure 1(c)). In this immediate tab there are three buttons are available for the user namely 'Starts', 'Stop/Restart' and 'Growth Curve'. The 'Start' button enables the ALS of the smartphone to record the light signal coming scattered from the test sample. The 'Growth Monitor' tab also contains a clock, which will help the user to record the signal after a specific period of time. The application has been design to record 10 consecutive measurements for the scattered signal and to display the mean value against the appropriate time points in the table shown in the figure 2 (c). This process has been repeated at an interval of 30 minutes for 24 hours to record the sensor response from the bacterial sample. On completion of the investigation, one can obtain the desired growth curve by clicking the 'Growth Curve' button in the extreme end of the immediate tab. The 'Stop/Restart' button in the 'Growth Monitor' is there to stop and restart the process.

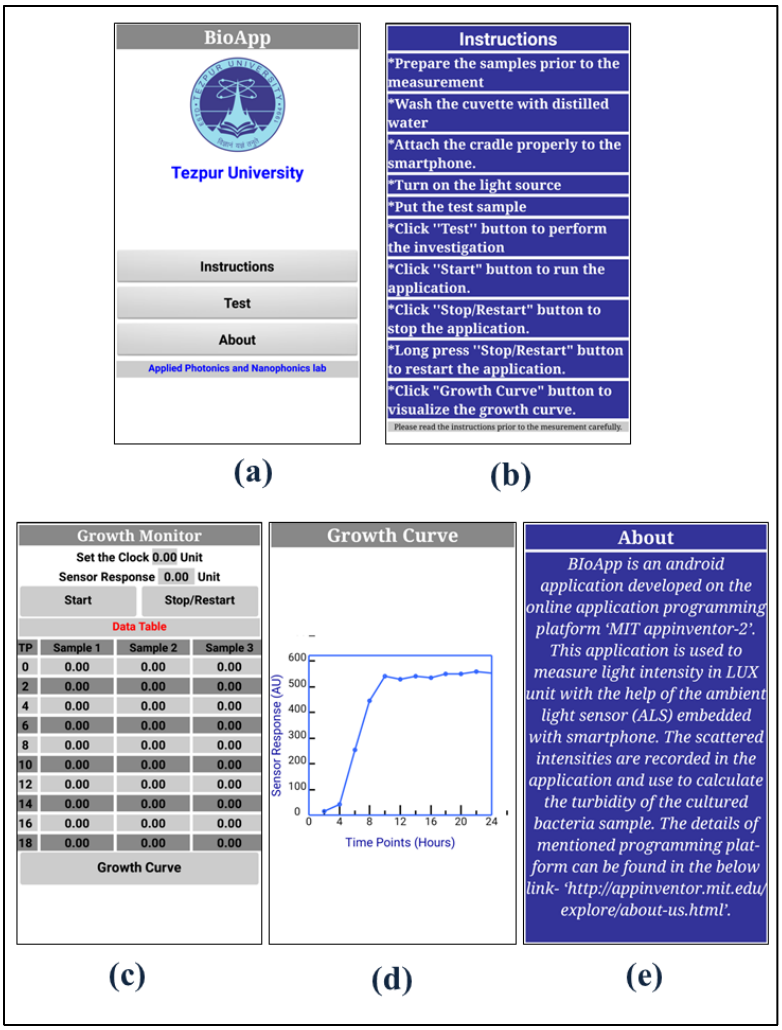


Figure 2: Screenshot of the developed android application.

V. Investigation with the proposed smartphone analytical too

The designed tool has been initially calibrated using a standard turbid sample (Formazin). Different turbidity levels of formazin standard samples have been prepared in the laboratory and the scattered signal has been recorded by the designed smartphone tool. The range of turbidity where the proposed smartphone sensor shows a linear variation of scattered signal (linear range) has been obtained. For the proposed setup, the turbidity range up to where the designed sensor shows linear response has found to be 0 NTU to 400 NTU. Figure 3 shows the response characteristics of the sensor while measuring the turbidity level of formazin sample in the range 0 – 400 NTU. For the considered standard turbid media, the turbidity of the medium can be estimated using the following relation -

$$\text{Turbidity (NTU)} = 2.824 \times \text{scattered signal intensity (LUX)} - 1.062 \quad (1)$$

The coefficient of regression (R^2) of the calibrated curve is estimated to be 0.99831

Equation (1) has been used to estimate the turbidity/concentration of the bacterial sample in the medium. The designed application utilizes the calibration equation to know the concentration of unknown sample.

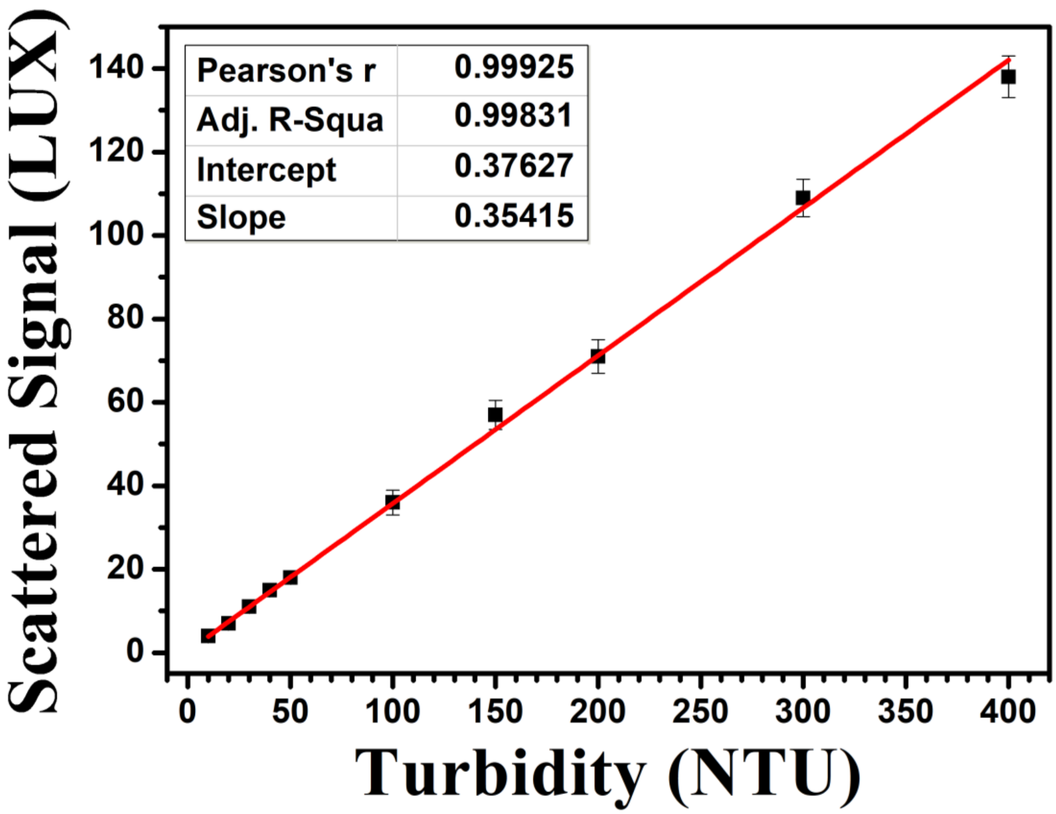


Figure 3: Regression analysis of standard formazin samples.

In the next step we monitor the growth of *E. coli* in laboratory environment using the designed sensing system. Figure 3 shows the characteristic growth curve of the considered bacterium recorded by the designed smartphone tool over a period of 24 hours in the laboratory environment. Simultaneously the ODs of the same media have also been recorded by the bench-top spectrophotometer. Clearly, we notice a similar trend in growth in the sample while estimating the growth kinetics by the proposed smartphone sensor and the spectrophotometer. All the three important phases of growth namely the '*lag phase*', '*log phase*' and '*stationary phase*' can be seen in the figure 4.

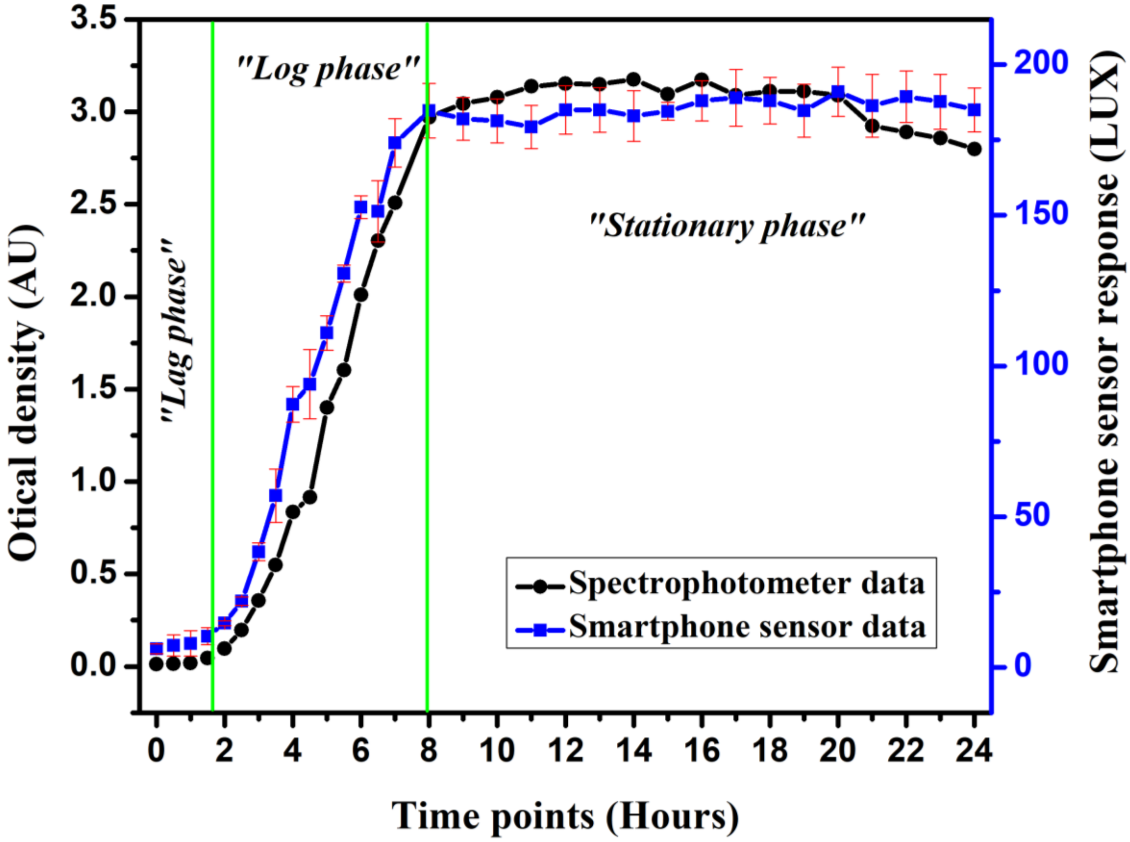


Figure 4: Comparison of the growth curve recorded by the standard spectrophotometer and by the designed smartphone sensor

In the next step, the uncertainty of the proposed sensor responses has been evaluated while analysing the growth kinetics of *E. coli* bacterium in the laboratory environment. Table 1, shows the characteristic percentage relative standard deviation (%RSD) value estimated for a period of 18 hours. To estimate the %RSD value, 10 consecutive measurements have been recorded for the same test sample. The maximum %RSD value for *E. coli* was found to be 10%. The relatively low %RSD value suggests a good degree of accuracy and reliability of the designed sensor.

Table 1:

Percentage relative standard deviation (%RSD) in estimation of *E. coli*

Time Points	Mean	SD	% RSD
0	6.24	0.63	10.14
2	14.67	0.82	5.57
4	87.33	5.89	6.74
6	152.67	3.74	2.45
8	184.67	12.03	6.51
10	181.33	7.26	4.00
12	185.00	8.04	4.35
14	183.00	1.41	0.77
16	188.00	6.68	3.55
18	188.00	3.74	1.99

VI. Summary:

In summary, in the second phase of the project we demonstrate the working of a simple smartphone analytical tool to monitor the growth kinetics of bacteria under standard laboratory environment. A compact plastic optical set up has been developed in a 3D printer the necessary optical components including the sample holder and can be coupled easily to ALS of the smartphone. The growth kinetics of *E. coli* has been monitored successfully by the designed smartphone sensor. The proposed analytical tool offers several important advantages including compactness, portability and user-friendly. We envision, the design sensing tool could emerge as an alternating sensing platform along with OD measurements for monitoring of growth of bacteria under standard laboratory conditions.

Remarks: Based on the work done so far a paper was published:

"Hatiboruah, D., Devi, D. Y., Namsa, N. D., & Nath, P. (2020). Turbidimetric analysis of growth kinetics of bacteria in the laboratory environment using smartphone. Journal of Biophotonics, 13(4), e201960159."

Progress Report (3rd Phase)

Project Title: "**Smartphone Based Instrumentation for Water Quality Monitoring with Reference to Resource poor Regions**"

Supervisor: Prof. Pabitra Nath, Department of Physics, Tezpur University.

Awardee name: Iftak Hussain, PhD scholar, Department of Physics, Tezpur University.

Project Assistant: Biprav Chetry, Department of Physics, Tezpur University.

Institute: Tezpur University, Napaam, Sonitpur, Assam, India -784028

Date of Start: 1 June 2017

Duration of the Progress: 17 June 2020 to 4 March 2021

Project introduction

The core objective of this ongoing project is to develop an interactive and analytical tool based on a smartphone which will be a compact, user-friendly sensing system used to monitor water quality parameters in resource-poor conditions. The sensing setup utilizes the principles of light scattering, absorption, colorimetric and fluorescence intensity measurement from the test sample while estimating different parameters in water. For the development of the sensing setup, the ambient light sensor and the back camera of the smartphone are used. An optical setup housing all the optical components like lenses, diffuser, LED, etc. and the smartphone was developed using 3D printing technology. The sample was tested using the smartphone for the different parameters in the compact optical setup itself and the analysis of the sample was done using a custom-designed application on android OS. Using the different sensing schemes, our research group at Tezpur University have demonstrated the working of smartphone-based analytical tools successfully. Different parameters like water salinity, turbidity, dissolved iron concentration; fluoride concentrations, phosphate, mercury ion concentration in water and growth kinetics of bacteria in a laboratory setting have been reliably estimated. The designed sensing system's efficiency was evaluated by comparing the experimental data with the laboratory sensing tools. It is found that the designed sensing setup yields favourable results which are at par with the traditional laboratory tools.

Summary of the work that has been done in the third phase

Dual mode smartphone based sensing for accurate estimation of sulphate and chloride in water:

In the third phase of the project, we have demonstrated a sensing system that can measure and give an accurate estimation of sulphate and chloride level in the water. The designed sensor is based on the detection of the transmitted modulated signal (for spectrophotometric based study) and scattered signal intensities (for turbidimetric based study) from a sample. To detect and receive the signal, the Ambient light sensor (ALS) of the smartphone has been used for both modes of sensing. The assessment of the water samples for the sulphate and chloride levels was done by a smartphone based compact optical setup and a customized android application was developed for the data collection and analysis in the smartphone itself. The proposed sensing system could emerge as an alternative platform that can be utilized for monitoring other parameters of water and other media as well.

Introduction:

According to WHO's 2017 report, approximately 30% of the total world's population have access to safe drinking water. Various nutrients and dissolved ions are present in water which are hazardous to human health. A large amount of sulphate and chloride degrades the quality of water. These two minerals should be present in the water bodies in a very limited quantity for the water to be safe for utilization. So, a proper analysis of the water bodies for the sulphate and chloride content is very essential to monitor the quality of water. In this work, we have demonstrated a dual-mode smartphone-based photometric and nephelometric sensing system using a single optical setup. This work is the first- ever demonstration of a multi-modal sensing system that uses the ALS of the phone as a photo-detector. A 3D fabricated optical setup housing all the optical components and the smartphone was used for the sensing purpose for both the spectrophotometric and turbidimetric studies. The designed setup's performance in estimating the sulphate and chloride level in water is comparable to the commercial laboratory grade spectrophotometer and nephelometer. Furthermore, an android application was also designed to analyse the sensor's data in the smartphone itself making the whole setup a user-friendly one.

Experimental design:

Figure 1 (a) and (b) shows the schematic representation of the proposed sensing setup while using it for spectrophotometric and turbidimetric sensing studies respectively. Figure 1 (c) and (d) show the corresponding photo-image for 1 (a) and (b) as developed for the present work. The optically shielded plastic optical setup was fabricated using a 3D printer. The designed optical setup can be coupled to the ALS of the smartphone to receive the transmitted modulated light and the 90° scattered light signal from the sample placed in a quartz cuvette. The optical setup consists of two plano-convex lenses, each having a focal length of 12 mm and a diameter of 6 mm to collimate and couple the transmitted signals to the ALS of the phone. The sample is placed in a quartz cuvette of dimensions 10 mm x 10 mm in the optical path of the setup. For the photometric mode, the optical path length is measured to be 15 mm and for the turbidimetric mode it comes out to be 10 mm. To control the incident light signal a pinhole of diameter 50 µm is placed in front of the optical source. Two LEDs of different peak emission wavelengths – 420 nm and 571 nm and a white LED have been used for the analysis of the target parameters in water. Powering of the LEDs is done by the smartphone itself using a USB-OTG cable.

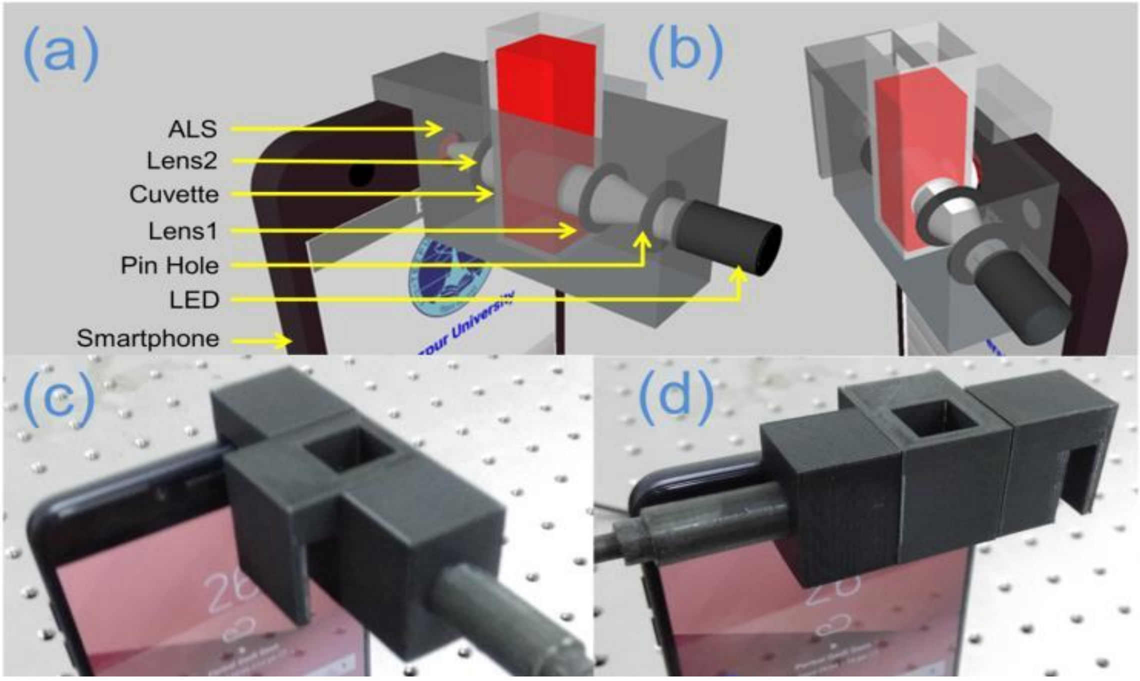


Figure 1: Schematic of the designed dual mode smartphone platform (a) spectrophotometric mode and (b) turbidimetric mode (c) and (d) Photo-image of the fabricated dual mode smartphone platform.

Dimensionally the whole optical setup is 70 mm in length, 40 mm in breadth and 40 mm in height. The smartphone that was used in the sensing studies was the Samsung Galaxy C9 Pro. The overall weight of the sensing setup including the smartphone comes out to be around 250 gm.

Results and Discussions:

Initially, the performances of the two modes of sensing were evaluated for known standard samples. Figure 2 (a) and (b) represent the characteristic sensor responses while monitoring the ODs of known concentrations of sulphate and chloride ions in water samples respectively. The figure also includes the spectrophotometer data for the same samples as recorded by the standard spectrometer. A good correlation between the smartphone based sensing system and the spectrometer data has been noticed which suggests the reliability of the designed platform. From the characteristic curves, the calibration equations for estimation of sulphate and chloride ions concentration by the designed sensor can be derived as follows:

For Sulphate:

Concentration = $\frac{OD+0.008}{0.011}$

For Chloride:

Concentration = $\frac{OD-0.05}{0.013}$

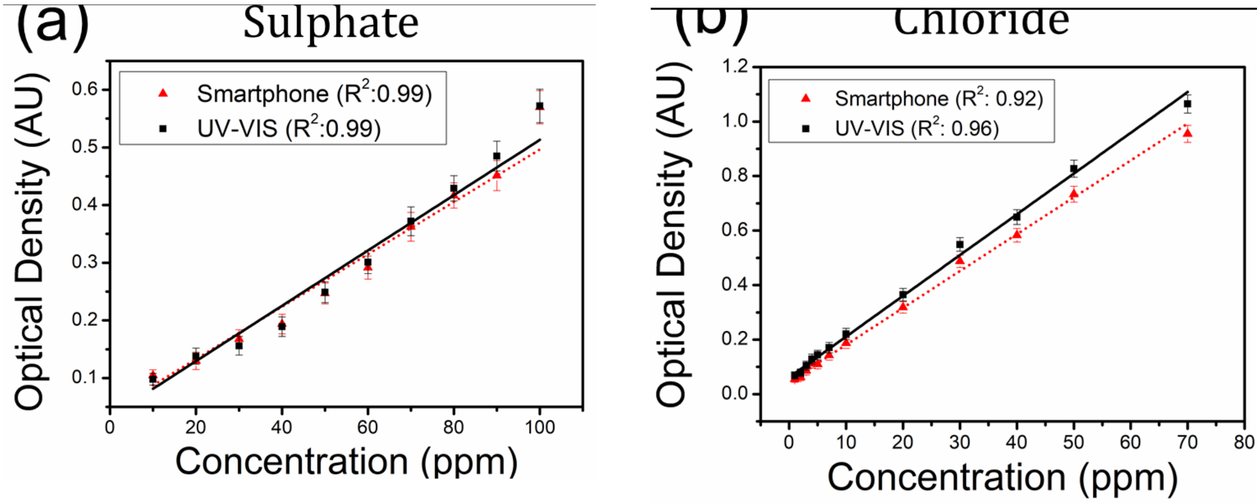


Figure 2: Calibration equations and comparison with standard tool for standard (a) sulphate and (b) chloride samples while measuring OD using the designed platform and a standard UV-VIS spectrophotometer

Next, the turbidimetric mode of study was performed by the designed setup using a standard turbid media. Scattered light signal intensities from formazin samples have been recorded by the ALS of the phone and by using the developed android application it was converted into turbidity level of the medium. Figure 3 showcases the calibration curve for the different light intensities scattered from the standard formazin samples.

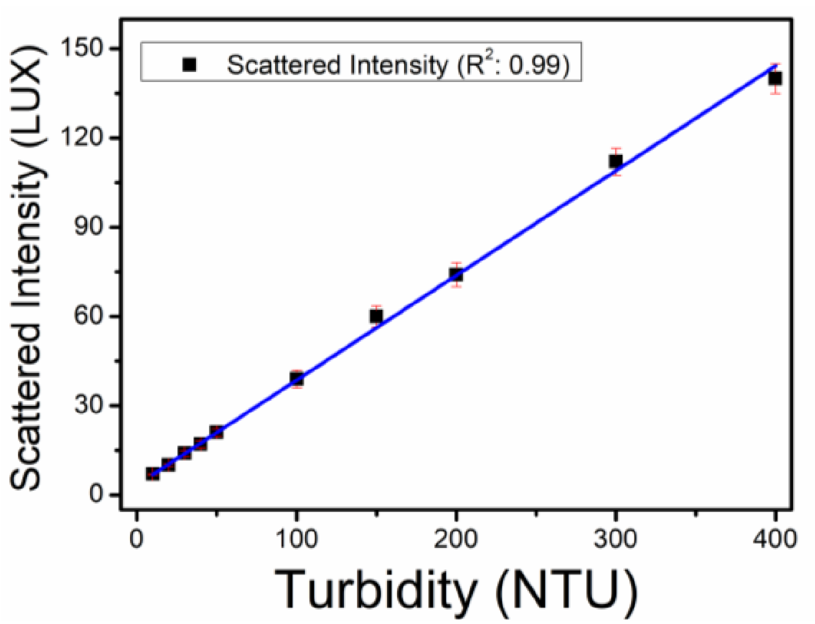


Figure 3: Calibration curve obtained for the standard formazin samples using the designed smartphone platform.

The calibration equation to determine the turbidity of an unknown sample obtained from the calibration curve is given as:

$$\text{Turbidity } (\tau) = \frac{Scattered\ intensity - 0.38}{0.35}$$

In the next step, the characteristic curves for sulphate and chloride ions concentrations in the turbidimetric mode of sensing have been evaluated. Figure 4 (a) and (b) shows the calibration curves for sulphate and chloride samples while measuring its turbidity level along with the turbidimetric data of the same samples recorded by a standard nephelometer.

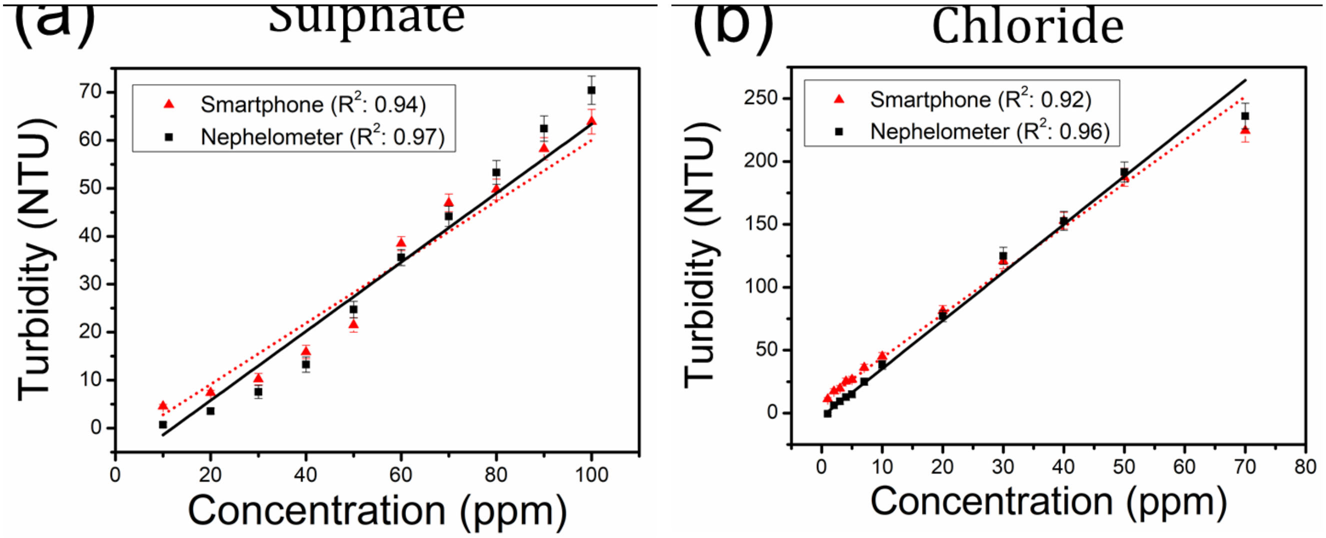


Figure 4: Calibration equations and comparison with standard tool for standard (a) sulphate and (b) chloride samples while measuring turbidity using the designed platform and a standard nephelometer.

The important figures of merits of the sensing system are presented in the following table:

Sl. No.	Figures of Merits	Sulphate		Chloride	
		Spectrophotometric	Turbidimetric	Spectrophotometric	Turbidimetric
1	Sensitivity	0.011 AU/ppm	0.68 NTU/ppm	0.013 AU/ppm	3.45 NTU/ppm
2	LoD	0.45 ppm	0.5 ppm	0.43 ppm	0.4 ppm
3	%RSD	8.99%	7.25%	8.94%	9.72%
4	%Bias	8.89%	8.69%	9.40%	9.28%

The high sensitivity, low LoD limits and acceptably low *%RSD* and *%Bias* indicate that the designed platform is reliable for monitoring sulphate and chloride ions with a high degree of precision.

In the final step of the present investigation, the field applicability has been realized through monitoring the sulphate and chloride ions concentration of field-collected water samples. Figure 5 (a) and (b) show the characteristic responses of the designed sensor for sulphate and chloride ions concentration in the considered water samples along with the corresponding spectrophotometer data of the same samples recorded by the standard UV-VIS spectrophotometer tool. A good degree of accuracy is noticed while comparing the experimental data with the standard tool.

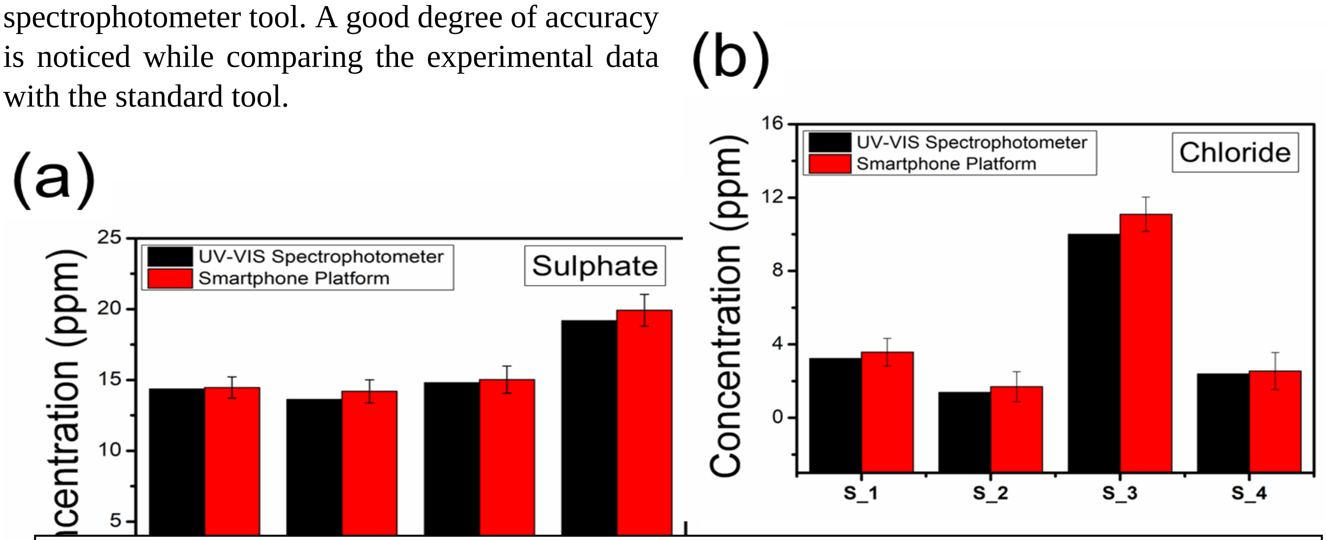


Figure 5: Histogram representation of (a) sulphate ion and (b) chloride ion concentration in field collected water samples estimated using UV-VIS spectrophotometer and smartphone based spectrophotometer.

The designed system is capable of monitoring other parameters of water such as pH level, turbidity, salinity, dissolved minerals, and toxic chemicals. The integration of two sensing principles on a single platform makes the proposed sensor robust in terms of estimation of a specific parameter in water and other liquid media. The present work demonstrates the proof-of-concept of the sensing platform for reliable monitoring of water quality parameters which is relatively easy to operate and inexpensive as compared to its commercial counterparts.

Remarks: Based on the work done so far a paper was published:

"Hatiboruah, D., Talukdar, B., Ahamad, K. U., & Nath, P. (2021). Dual mode smartphone based sensing for accurate estimation of sulphate and chloride in water. IEEE Sensors Journal, 21(17), 19314-19321."

Plan for the final phase

In the final phase of the project, the commercialization and the production of the proposed optical setup for the accurate estimation of fluoride level in water will be done. For the possible commercialization of the proposed smartphone based optical setup, a startup named OLatus based out of Guwahati, Assam has approached us for the sensing setup. An email regarding the communication done from OLatus regarding this matter is attached herewith for your reference.

Progress Report (4th Phase)

Project Title: "**Smartphone Based Instrumentation for Water Quality Monitoring with Reference to Resource poor Regions**"

Supervisor: Prof. Pabitra Nath, Department of Physics, Tezpur University.

Awardee name: Iftak Hussain

Project Assistant: Biprav Chetry, Department of Physics, Tezpur University.

Institute: Tezpur University, Napaam, Sonitpur, Assam, India -784028

Date of Start: 1 June 2017

Duration of the Progress: 5 March 2021 to 31 March 2022

Project introduction

The core objective of this ongoing project is to develop an interactive and analytical tool based on a smartphone which will be a compact, user-friendly sensing system used to monitor water quality parameters in resource-poor conditions. The sensing setup utilizes the principles of light scattering, absorption, colorimetric and fluorescence intensity measurement from the test sample while estimating different parameters in water. For the development of the sensing setup, the ambient light sensor and the back camera of the smartphone are used. An optical setup housing all the optical components like lenses, diffuser, LED, etc. and the smartphone was developed using 3D printing technology. The sample was tested using the smartphone for the different parameters in the compact optical setup itself and the analysis of the sample was done using a custom-designed application on android OS. Using the different sensing schemes, our research group at Tezpur University have demonstrated the working of smartphone-based analytical tools successfully. Different parameters like water salinity, turbidity, dissolved iron concentration; fluoride concentrations, phosphate, mercury ion concentration, zinc ion concentration in water and growth kinetics of bacteria in a laboratory setting have been reliably estimated. The designed sensing system's efficiency was evaluated by comparing the experimental data with the laboratory sensing tools. It is found that the designed sensing setup yields favourable results which are at par with the traditional laboratory tools.

Summary of the work that has been done in the Fourth phase

A smartphone-based photometric and fluorescence sensing for accurate estimation of zinc ion in water

In the final phase of the project, we have developed and demonstrated a smartphone-based sensing platform capable of accurate concentration estimation of zinc ions present in water. The developed setup has been designed for simultaneous sensing in photometric and fluorescence mode on a single platform. In this designed setup, two inbuilt sensors of the phone, namely, the ambient light sensor (ALS) and the rear camera of the smartphone have been used for the sensing purpose. For photometric-based sensing, the ALS receives the transmitted modulated signal from the sample, while the rear camera records the fluorescence signal emitted from the sample at a right angle to the direction of the excitation signal. The assessment of the water samples for the zinc ion levels was done by a smartphone-based compact optical setup and a customized android application was developed for the data collection and analysis in the smartphone itself.

Introduction:

According to WHO's 2017 report, approximately 30% of the total world's population have access to safe drinking water. Various nutrients and dissolved ions are present in water which are hazardous to human health. Zinc is considered to be one of the key parameters to be estimated when assessing water quality. A large quantity of zinc present in the water bodies degrades the quality of water. So, a proper analysis of the water bodies for the zinc ion content is very essential to monitor the quality of water. In this work, we have demonstrated a dual-mode smartphone-based photometric and fluorescence sensing system using a single optical setup. A 3D fabricated optical setup housing all the optical components and the smartphone was used for the sensing purpose for both the modes. The designed sensing platform's performance in estimating the zinc ion concentration in water is comparable to the commercially available laboratory-grade analytical tools. Also, the assessment and analysis of the sensor's data were done using a custom-designed android application in the smartphone itself making the whole setup a point of care and a user-friendly one.

Experimental design:

Figure 1 (a) shows the schematic representation with the optical layout of the proposed analytical tool that has been designed to capture both the transmitted light and the fluorescent signals from a sample solution and (b) shows the photo-image of the complete developed setup. The optically shielded plastic optical setup was fabricated using a 3D printer. A LED powered by the phone's battery using a USB-OTG with a peak emission wavelength of 525 nm has been used as an optical source for the sensor. Using a pinhole and a plano-convex lens (focal length-10 mm), a fine collimated beam of light is obtained. The transmitted light is further guided and focused on to the ALS of the phone using optical fiber and a system of pcx lenses. For the detection of the fluorescence signal, a long-pass optical filter with a cutoff wavelength of 550 nm has been placed in the optical path of the rear camera lens of the phone. A focusing lens of focal length of 10 mm is placed in the optical path to collect the fluorescence signal by the camera. The rear camera captures the dispersed images of the emitted signal produced by a transmission diffraction grating of groove density of 1200 lines/mm. The overall dimension of the designed setup is 60 mm × 35 mm× 35 mm in length, width and height, and the net weight is estimated to be 300 g, including the smartphone.

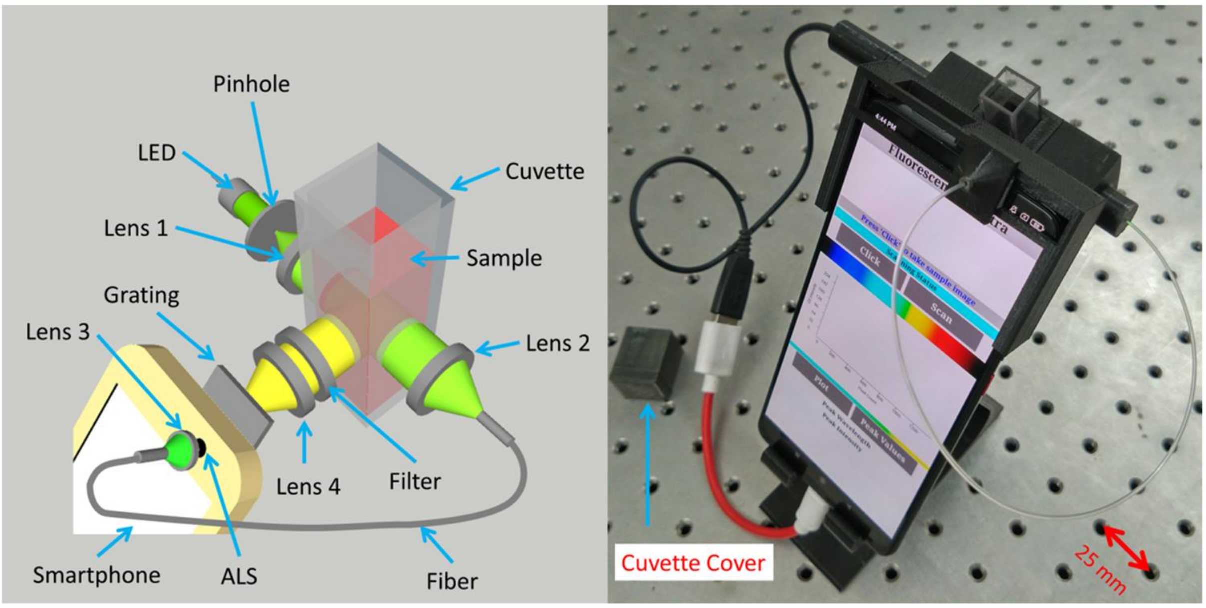


Figure 1: (a) Schematic and optical layout design of the smartphone sensing platform and (b) Photo-image of the fabricated smartphone-based analytical platform

Figure 2 shows the different screenshots of the custom-designed application 'FSOD' developed using the online application platform MIT App inventor-2. The different steps involved in the image analysis process is shown in the figures. All the data analysis and processing were done on the phone itself using the developed application.

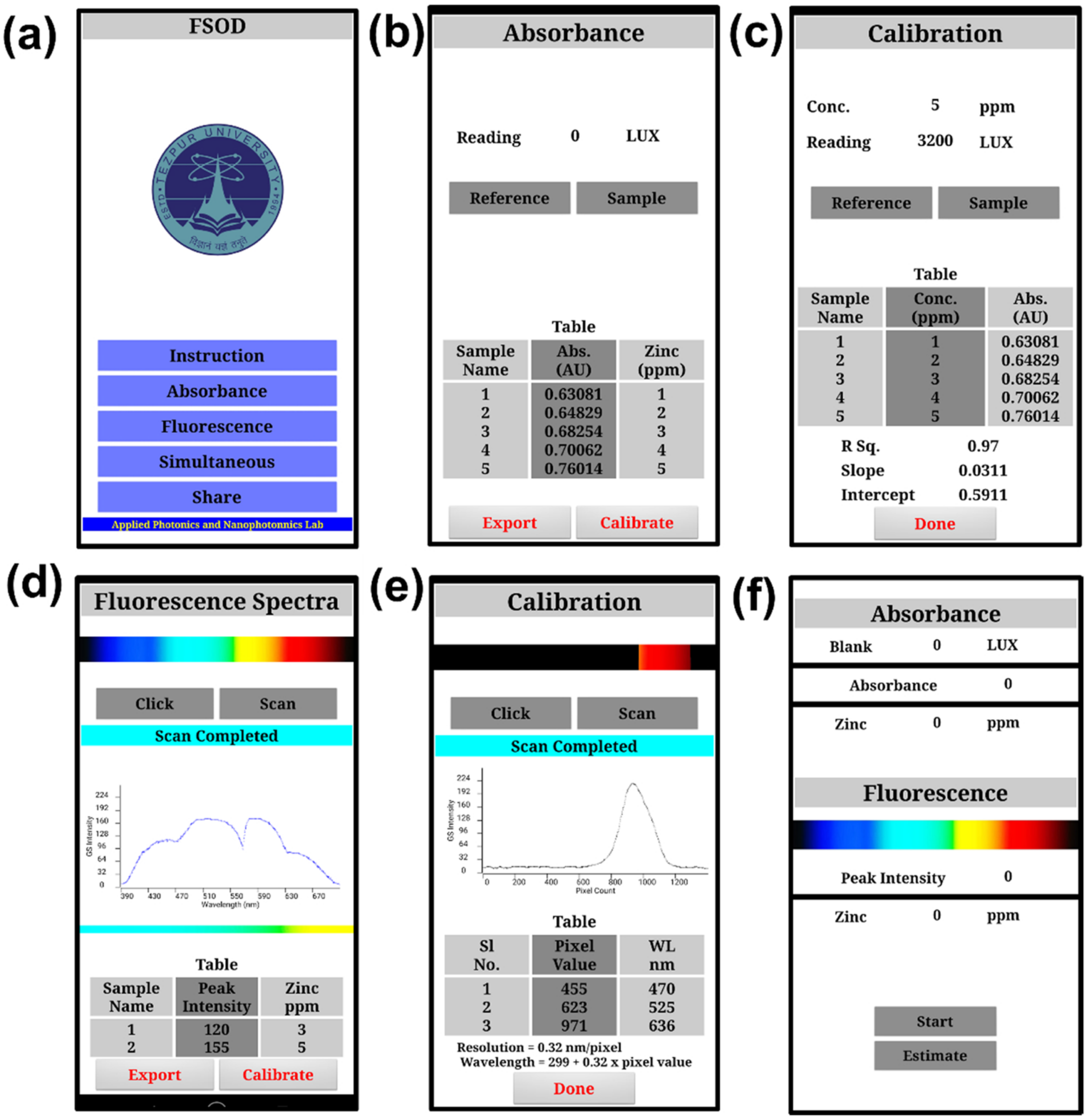


Fig.2 Screenshot images of the custom developed android application FSOD (a) Home screen of the app, (b) & (d) Pre-calibrated settings for estimation of absorbance and fluorescence spectra, (c) & (e) Calibration settings for estimation of absorbance and fluorescence spectra, (f) simultaneous spectrophotometric and fluorescence based detection of zinc ions.

Results and Discussions:

In the sensing device, the phone camera captures the fluorescence signal of the test samples and converted them into RGB images from where the signal intensity can be extracted using the designed android application. Before evaluating any fluorescence spectrum, the pixel values were converted into corresponding wavelength values by analyzing the spectra of three LEDs with peak emission wavelengths of 470 nm, 525 nm, and 636 nm. Fig 3 shows the

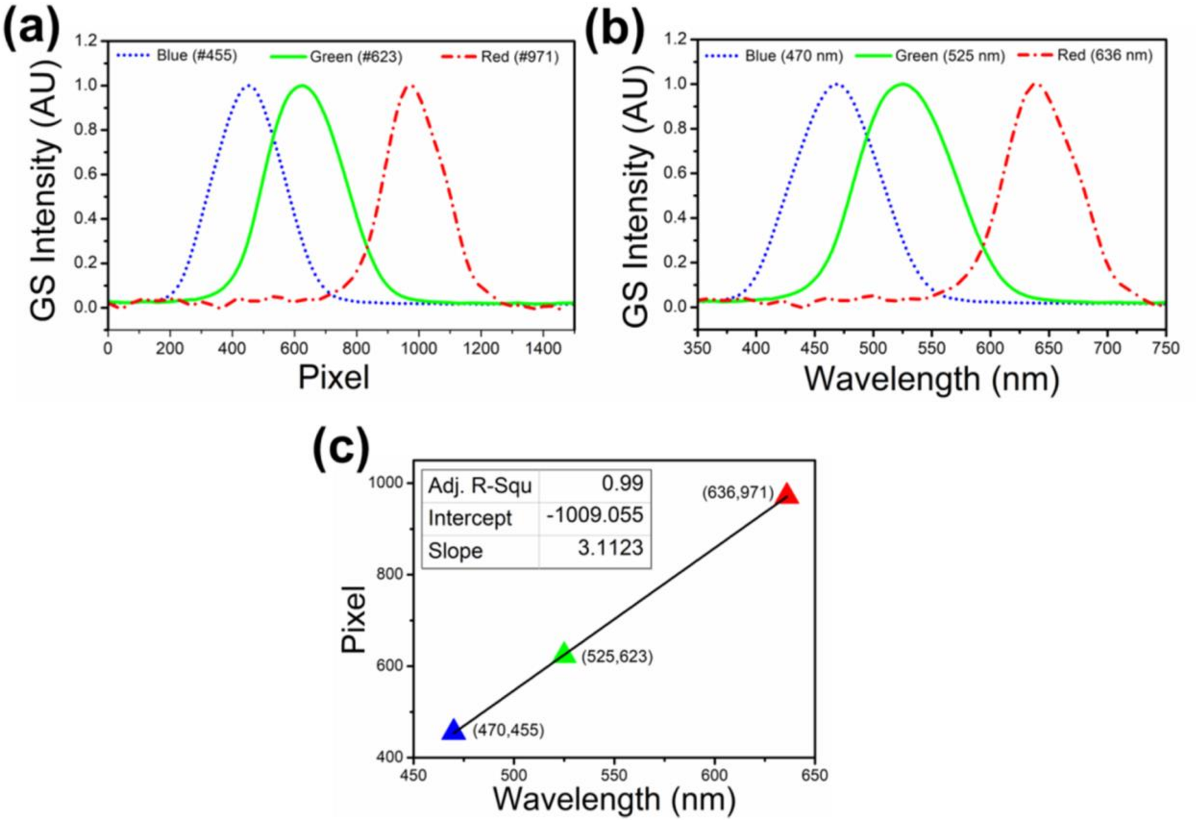


Fig.3. Pixel to wavelength conversion of the designed sensing platform. (a) uncorrected spectra, (b) corrected spectra after estimating the correction factor of the smartphone spectrometer, and (c) pixel vs. wavelength plot for three LEDs having peak emission wavelengths at 470 nm, 525 nm, and 636 nm.

corresponding spectra related to the pixel-to-wavelength conversion.

Initially, the performance of the designed sensor is tested for standard zinc samples. Six different sample solutions of concentrations ranging from 1–6 ppm were considered.

For the photometric mode of sensing, the designed sensor estimates the absorbance of a given sample utilizing the following equation

$$Absorbance = \log_{10} \frac{I_0}{I}$$

where, I_0 and I refer to incident and transmitted light signal. Here, I_0 represents the sensor response value for blank sample (DI water).

Five consecutive responses of each sample were recorded by the ALS of the phone. Fig. 4(a) represents the characteristic plots and the least square fitted curve of the sensor responses against the analyte concentrations. The R^2 value from the calibration curve comes out to be 0.98. To calculate the concentration of the zinc ions of an unknown sample, the following equation is used –

$$Concentration = 18.84 * Absorbance - 0.49$$

The estimated sensitivity, LoD, and LoQ for the spectrophotometric mode of the designed platform are found to be 0.05 AU/ppm, 0.13 ppm and 0.45 ppm respectively. A linearly good correlation is found between the designed tool's responses and UV–VIS spectrophotometer readings as shown in Fig. 4 (b).

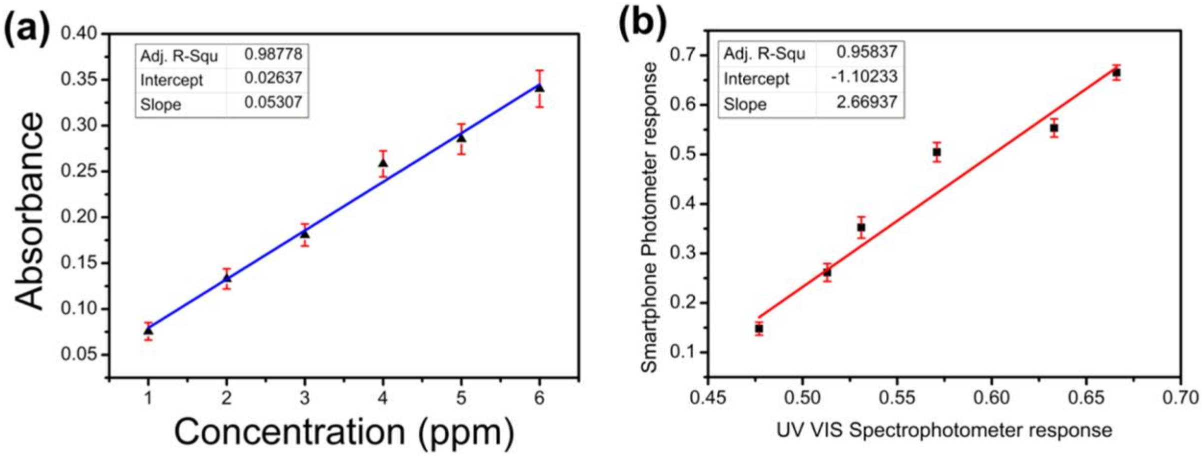


Fig.4 (a) Calibration curve of the photometric mode of the designed platform for standard Zn2+ samples mixed with RhB (0.05 mM) and AuNPs (1 mM) assay, (b) Absorbance measured in the designed tool in comparison with a standard UV–VIS spectrophotometer data.

For the Fluorescence mode of sensing, a similar technique is used for the calibration of the proposed sensing tool. The sample has been excited with an optical source of wavelength 525 nm, and the corresponding fluorescence emission signal from the sample is allowed to pass through a 550 nm long-pass optical filter to couple with the CMOS imaging sensor of the phone. A transmission diffraction grating is placed in the optical path length of the fluorescence signal. The designed sensor captures the dispersed spectra of the modulated fluorescence signal and converts that signal to a digital image. Upon capturing the image of the sample, the developed android application extracts the color channel values against the pixel numbers from the image. The application further converts the pixel numbers into the wavelength number using the correction factor. Standard zinc samples from 1 ppm to 6 ppm concentrations were used and their fluorescence emission spectra were investigated to analyze the response of the designed sensor. Fig 5(a) shows the fluorescence spectra of standard Zn^{2+} samples. The system shows the maximum sensitivity at 575 nm, and hence grayscale intensities corresponding to this specific wavelength have been considered for evaluating the calibration equation –

$$Concentration = (0.33 * GS\ Intensity) - 1.61$$

The above equation has been used to estimate the concentration of zinc ions in unknown samples. The sensitivity, LoD, and LoQ for the fluorescence mode of the designed platform are 10.5 AU/ppm, 0.1 ppm and 0.35 ppm, respectively. A good linear correlation between the designed sensor's readings and a standard spectrometer reading is found which can be seen from the linear fitted curve in Fig. 5 (b).

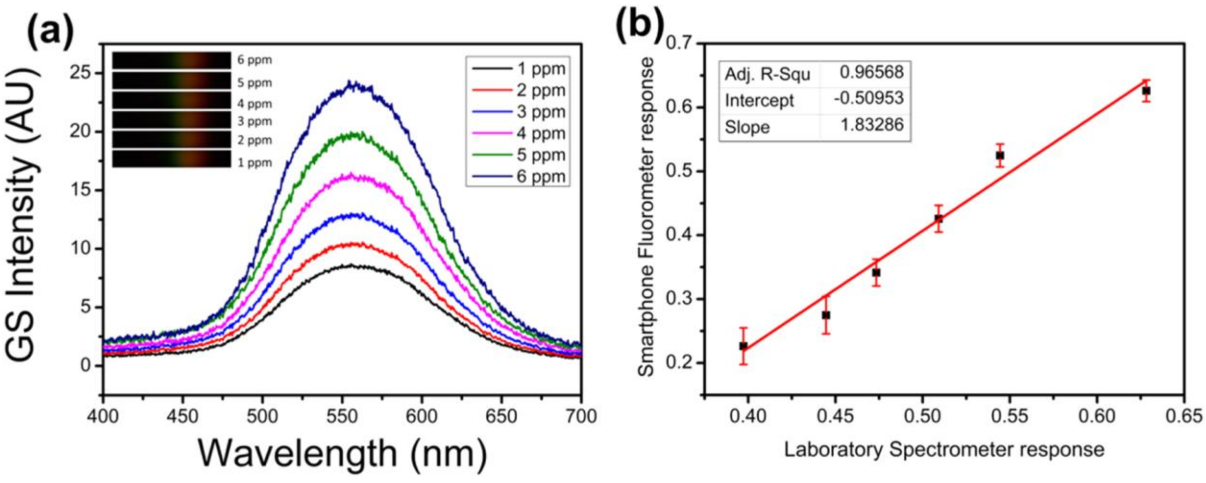


Fig. 5 (a) Fluorescence spectra of standard Zn2+ samples with RhB (0.05 mM) and AuNPs (1 mM) mixture as obtained from the designed smartphone platform and (b) Fluorescence responses of the designed tool in comparison with the standard laboratory spectrometer data.

The performance of the designed sensor was evaluated in presence of other interfering metal ions namely copper, manganese, aluminium, sodium, magnesium, mercury and arsenic. The interfering elements were taken in the concentration of 5 ppm each. Fig. 6 shows the characteristic histogram representation of the sensor responses in presence of the other metal ions elements. The figure clearly shows that the response of the sensor is unaffected due to the presence of the other elements.

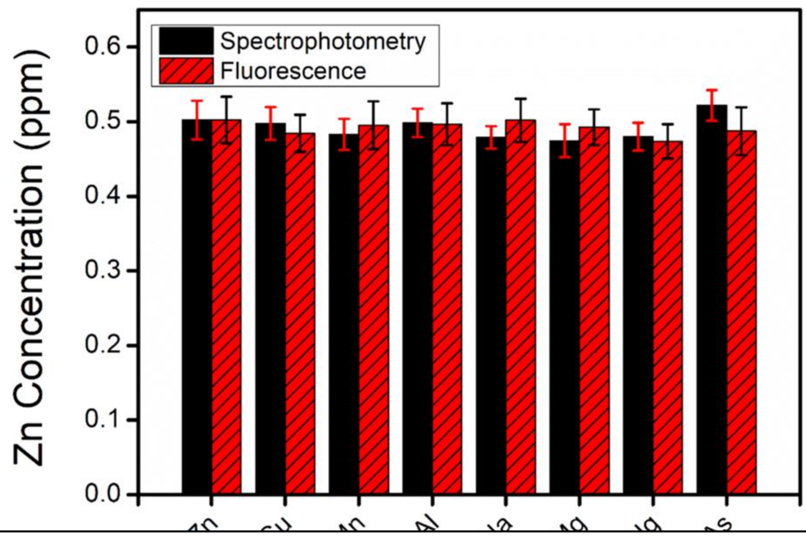


Fig. 6. Responses of the designed smartphone platform were recoreded under both the sensing modes after adding Cu2+, Mn2+, Al3+, Na+, Mg2+, Hg2+ and As3+ in the standard Zn2+ samples.

In the final step, the performance of the designed sensor for field-collected water samples was evaluated. Five different locations namely - Bharolu river water, Guwahati (SW1), Brahmaputra River water, Sonitpur (SW2), public water supply of Napaam Village, Sonitpur (SW3), pond water of Tezpur University (SW4), and tap water of Tezpur University (SW5) were identified and their water samples were collected. All the samples showed negative responses for Zn^{2+} ions when analyzed using the designed smartphone platform. The negative response indicates the low presence of Zn^{2+} in the field-collected water samples. Atomic absorption spectrometer was used to confirm the actual concentration of zinc ions in the water samples which came out to be in the range of 0.05–0.09 ppm, which was well below the detection limit of the designed sensor. So, Zn^{2+} salt was added externally to the field-collected water samples for the present investigation. Fig. 7 shows the characteristic responses of each sensing mode (photometric and fluorescence) of the designed platform. A good degree of correlation between the experimental data obtained from both the sensing modes was observed.

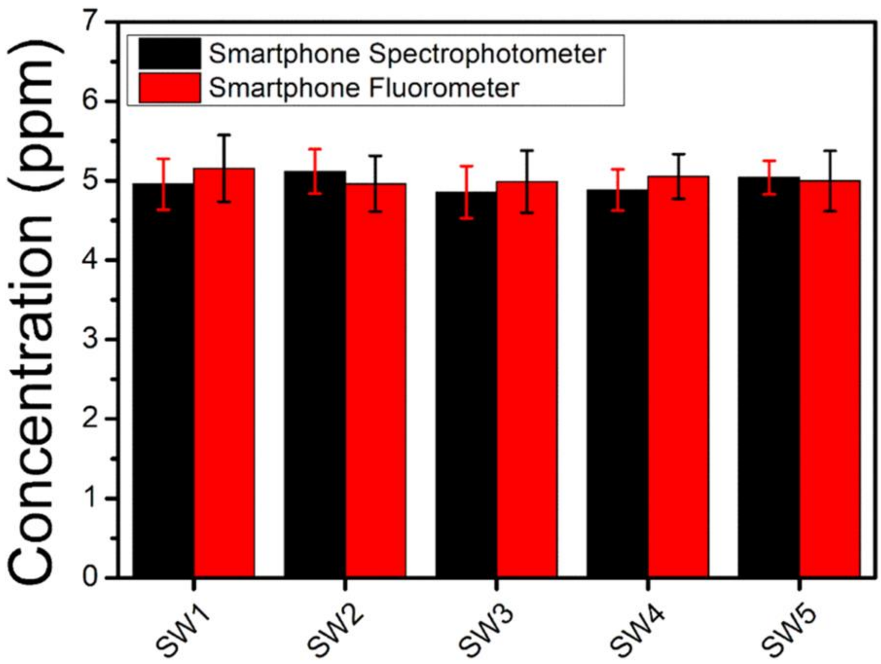


Fig. 7. Estimation of Zn2+ ions concentration in field-collected water samples using both the sensing modes (absorbance and fluorescence) of the designed smartphone tool.

So, to conclude, we can say that this work is the first-ever demonstration of simultaneous detection of photometric and fluorescence signals on a single sensing platform. Here, the two embedded sensors of the phone - the ALS and the rear camera, have been used to design the proposed platform. Also, the development of the custom-designed android application for the image analysis of the samples makes this system a truly standalone one. The applicability of the platform has been demonstrated through the detection of Zn^{2+} ions in field-collected water samples. This setup can also be utilized for the detection and analysis of other chemical and biological samples by suitable selection of the optical source and the optical filter in the present design of the sensing platform.

Remarks:

This work is published in the ‘Sensors and Actuators: A. Physical’ journal –

Hatiboruah, D., Biswas, S., Sarma, D., & Nath, P. (2022). A smartphone-based photometric and fluorescence sensing for accurate estimation of zinc ion in water. *Sensors and Actuators A: Physical*, *341*, 113586.

Statement of Expenditure

1. Name of implementing organisation: Tezpur University
2. Type of event sanctioned: Research Project sponsored by **BIRAC- SRISTI**
3. Name of the Project: **"Smartphone Based Instrumentation for Water Quality Monitoring with Reference to Resource Poor Region"**
4. Period of the project: (01-06-2017 to 15-09-2022)
5. **BIRAC SRISTI** Sanction no: BIRAC SRISTI PMU 2017/006 dated 11th March 2017
6. Total amount sanctioned: **₹ 15,00,000**
7. Head wise Statement of Expenditure

Sl No.	Sanctioned Heads	Funds Allocated	Expenditure Incurred			
			1st Phase	2nd Phase	3rd Phase	4th Phase
1	Scholarship	Rs. 3,75,000	Rs. 1,22,917	Rs. 50,000	Nil	Rs. 75,000
2	Consumables	Rs. 7,30,000	Rs. 1,38,816	Rs. 2,76,276	Nil	Rs. 34,892
	Equipment				Rs. 2,89,275	Rs. 1,54,231
	Contingency		Rs. 64,780	Rs. 39,156	Rs. 11,081	Rs. 1,80,897
3	Internal Travel	Rs. 1,00,000	Rs. 48,487	Nil	Nil	Nil
4	Outsourcing	Rs. 95,000	Nil	Nil	Nil	Nil
5	Miscellaneous Expenditure	Rs. 2,00,000	Nil	Nil	Nil	Rs. 16,300
6	Total	Rs. 15,00,000	Rs. 3,75,000	Rs. 3,65,432	Rs. 3,00,356	Rs. 4,61,320
			Total expenditure – Rs.15,02,108 (Including interest generated of Rs. 2108)			

Signature of Principal Investigator

Signature of Accounts Officer

Finance Officer
Tezpur University

Date: November 16, 2022

Date:

Utilization Certificate

1) Title of the project: **"Smartphone Based Instrumentation for Water Quality Monitoring with Reference to Resource Poor Region"**.

2) Name of the Institutions: Tezpur University, Napaam, Sonitpur, Assam-784028

3) Principal Investigator: Prof. Pabitra Nath

4) SRISTI letter No. and date sanctioning the project: **BIRAC SRISTI PMU 2017/006 dated 11th March 2017**

5) Head of account as given in the original sanction letter:

I. Scholarship

II. Consumable & Materials & Contingency

III. Internal Travel

IV. Outsourcing

V. Miscellaneous expenditure

6) Amount received during the project tenure (2017-2022): **Rs. 15,00,000.00**

7) Total amount that was available for expenditure (excluding commitments) during the project tenure: **Rs. 15,00,000.00**

8) Actual expenditure (excluding commitments) incurred during the project tenure: **Rs. 15,00,000.00**

9) Balance amount available at the end of the project tenure: **Rs. 0**

10) Amount already committed, if any: **NA**

11) Amount to be carried forward to the next financial year (if applicable). Indicate the amount already committed with supporting documents: **Rs. 0**

12) Amount unspent, if any: **Rs. 0**

Signature of Principal Investigator

Date November 16, 2022

Signature of Accounts Officer 06/12/2022

Date

Finance Officer
Tezpur University

UTILISATION CERTIFICATE

(FOR 2017-22)

Certified that out of **Rs. 15,00,000.00** of grants-in-aid sanctioned during the period **01-06-2017 to 15-09-2022** in favour of Prof. Pabitra Nath under BIRAC-SRISTI sanction letter no **BIRAC SRISTI PMU 2017/006 dated 11th March 2017**, a sum of **Rs. 15,00,000.00** has been utilized for the purpose of Equipment, Salaries, Recurring head and Overhead expenditure for which it was sanctioned and that the balance of **Rs. 0** remaining unutilized at the end of this period.

16/11/22

Signature of
Principal Investigator
With date

Signature of Registrar/
Of the Institute with date

Registrar
Tezpur University

Signature of Accounts Officer
of the Institute with date

Finance Officer
Tezpur University