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Portable And Inexpensive Hemoglobin Testing Device Based On The Beer Lambert's Law

Proposed methodology and a comparative study on the basis on portability and cost

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Abstract: ***Hemoglobin (Hb) is the protein molecule present in red blood cells of the human blood which is responsible for carrying oxygen. The Hb levels need to be tracked periodically as the decreased levels can lead to diseases like anemia. Existing technologies for testing Hb levels of a given human blood sample include bulky laboratory instruments which are difficult to be carried in remote areas or high cost per test imported point-of-care devices. As a result, anemia is one of the most common disease in women and neonatal. This paper discusses a methodology to device an instrument which is both portable and inexpensive along with a comparative study with the existing devices. The proposed methodology is primarily based on the Beer Lambert's Law.***

Keywords: ***hemoglobin, anemia, hemoglobin testing, portable device, inexpensive, comparison***

I. INTRODUCTION

Hemoglobin is the protein molecule in red blood cells that carries oxygen from the lungs to the body's tissues and returns carbon dioxide from the tissues back to the lungs. It is usually measured as a part of the routine complete blood count (CBC) test or as a biochemistry test from a blood sample. Both, high and low hemoglobin levels are injurious to health. Hence, it is very important to keep a track of Hb levels. Existing instruments for testing hemoglobin levels of a given human blood include bulky laboratory instruments which are difficult to be carried in remote areas or high cost/test imported portable devices. This makes it difficult for the rural areas to be able to track their Hb levels. Due to lack of facilities and improper nutrition, rural areas do not get sufficient iron diet and iron has a direct connection with hemoglobin. Hence, a major disease these days, especially in women and neonatal is anemia, out of which the one caused by the deficiency of hemoglobin is the most common. Thus, arises the need to track the Hb levels periodically and in case of reduced levels, immediate action must be taken. Therefore, considering India's population and the large number of tests to be conducted, particularly in the remote and rural areas, we need a device which is portable, cost efficient and easy to use. The existing devices do not fulfill the above mentioned criteria. This paper thus, gives a solution by discussing a methodology to device a hemoglobin testing instrument which is portable, inexpensive and easy to use.

II. EXISTING INSTRUMENTS

The various available instruments are the bulky laboratory devices manufactured by companies like Carewell Biotech, Nihon Kohden, Sysmex, Beckman Coluter et al, or the portable imported devices like Hemocue. The former companies provide the hematology analyzers of the laboratory level i.e. they are bulky, multi-functional and expensive while Hemocue provides a point-of-care device but comes with a high cost per test. This makes it difficult for medical camps in rural areas and schools to employ a device at the station for the test. Thus, Hb testing is given importance at blood donation camps only.

III. PROPOSED METHODOLOGY

The device would primarily be based on the Beer Lambert's law to detect the hemoglobin level of the given sample. The device makes use of a light of wavelength 540nm which is passed through the prepared sample (blood sample with reagent). The intensity of the light is then detected after passing though the sample and the difference is used to calculate the hemoglobin level.

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The Beer Lambert's law states that the concentration of an analyte is directly proportional to the amount of light absorbed by it.

$$c \propto A$$

$A = \log(I_0/I)$
where,

A = absorbance of the sample
c = concentration of the sample
I_0 = incident light intensity
I = light intensity after absorption
For testing of hemoglobin, the law requires the use of a light source of 540nm to hold true.
The instrument broadly requires a light source, a sample holder, a light detector, micro controller board, and a display. Thus its three major components are -optical assembly, micro controller board and the sampling equipments.

A. Optical Assembly

The optical assembly is prepared by combining a light source, sample holder and a light detector. The light source and the detector are the kept on either ends with the holder in the between. For the light source a LED – light emitting diode, of wavelength 540nm is used and for light detector, a LDR-light dependent resistor (CdS material) module which gives peak sensitivity at around 520nm are used. The reason for selection of 540nm for the LED is that it supports the Beer Lambert's law specifically around this wavelength. The LDR module used, is based on the LM393 and gives an analog output which can be directly used for further calculations .A cuvette holder is used wherein the cuvette containing the sample can be placed. The cuvette holder has two circular cavities on opposite ends – one for the inlet of light and the other for the outlet. The outlet cavity has the LDR placed next to it, to detect the light intensity received at this end. All three components are held at a specific position, decided through multiple tests and output optimization. These components are fixed in an assembly holder. This assembly will act as the heart of the instrument, giving the analogue output required for the mathematical calculations. The assembly formed is less than 10cm in length with a light path length of 10mm, which makes it very compact.

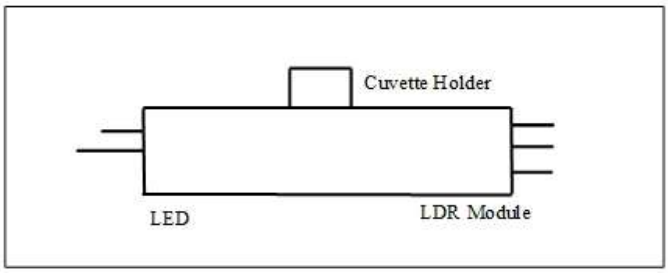

Fig. 1. *Block diagram of the optical assembly consisting of a light source – LED, a cuvette holder and a light detector- LDR*

B. Micro controller board

The optical assembly, discussed above is interfaced with Arduino uno, which is a micro controller board based on the ATmega328P . The reason for selection is its capability to perform requirement of the tasks, light weight, compactness, inexpensive and scope for future expansions. It uses a 12V, 700mA adapter for power supply, and gives power supply to the LED and the LDR. This board plays a major role in cost cutting.

C. Sampling equipments

The blood sample requirement is of 7-10µL, thus, we need a micro pippete and a micro cuvette. The micro cuvette must be made up of an optically clear material which does not interrupt the readings. The pipetted sample will be dropped in a micro cuvette, which will contain a reagent to be mixed with. The cuvette will directly be placed in the cuvette holder. These

cuvettes are inexpensive, easy to use and disposable. They can even be corked for easy and safe disposal. The instrument does not use the conventional microchips as a measure to cost cutting.

IV. WORKING

Both light source and detector take power supply from the Arduino Uno, which takes power supply for self from a 12V, 700mA adapter. The light source transmits a light intensity of wavelength 540nm through the sample, while passing through one open cavity of the cuvette holder. This light gets absorbed in some portion and the rest is received by the light detector kept on the cuvette holder cavity on the other side. The module present on the detector, transmits the intensity of light received in the form of an analogue signal to the Arduino Uno. The analog signal thus received by Arduino Uno, has its value ranging from 0-1023 (0-5V) which is inversely proportional to the intensity of the light detected. This analog value is then used in the Beer Lambert's Law, to detect the level of Hb of the given sample. A LCD can be connected further to the Arduino Uno, for display of the output.

V. COMPARATIVE STUDY

The proposed idea was compared on the basis of four parameters – portability, manufacturing, cost per sample and cost of the device. The various hematology instruments used for comparison were of companies Carewell Biotech, Bechman Coulter, Nihon Cohden, et al in the category of laboratory devices and Hemocue in the portable devices.

TABLE I. COMPARATIVE TABLE

Parameters	**References**		
	Hemocue or similar portable device	***Carewell Biotech/Nihon Cohden/Beckan Coulter Hematology Analyser***	***Proposed Idea***
Portability	Yes	No	Yes
Manufacturing	Imported	Imported	Domestic
Cost per sample (approx, in INR)	50	20-30	3-5
Cost of device (approx, in INR)	50,000	2.5-4.5 L	3000-5000

Fig. 2. *A comparative table between portable devices, laboratory standard devices and the proposed idea on the basis on parameters- portability, manufacturing, cost per sample and cost of the device*

On comparison, we see that the proposed idea stands ahead in all four parameters. When directly comparing it with Hemocue devices, the cost per test for Hemocue is approximately INR 50 while that of the proposed idea lies between INR 3-5, which is almost 10 times lesser than the former. Also, the cost of the device itself is 10 times lesser than Hemocue and far lesser than the laboratory hematology instruments.

RESULT

Hemoglobin test as discussed, being an important blood test which must be tracked periodically has limited and expensive existing instruments. This paper discusses a methodology to device the instrument for the same, based on the Beer Lambert's law. The component required by the instrument are very less and easily accessible. It employs an easy technology. In a comparative study on the basis of various parameters with other instruments for the same application, the proposed methodology stands ahead. Hence, giving an inexpensive and portable device that can be used in medical camps in rural areas, schools et al. And can help lower the number of anemic patients with timely detection and appropriate medication.

CONCLUSION

The proposed idea of the hemoglobin testing device based on the Beer Lambert's Law is to have a device with which is compact, user friendly, portable and cost efficient. When compared with other available options of Hb testing, it stands ahead of all. It justifies the major objective of portability and cost efficiency.

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