Usage of Volatile Organic Compounds for Detection of Diabetes Mellitus in Exhaled Breath

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***Abstract*— In recent years, lifestyle related illness has become more pronounced and demand for technology that enables easy and quick checking of diseases is increasing. Breath analysis is a very promising field of research work having great potential for diagnosis of diseases in non-invasive way for analyzing the volatile organic compounds (VOC's) and its concentrations in exhaled human breath and also has potential for the early detection and progress monitoring of several diseases. As far as detection of Diabetes Mellitus is concerned, glucose level is calculated by invasive methods which is quite painful, time consuming and tormenting to some people, hence there has been a constant demand for the development of non-invasive, sensitive sensor system that offers fast and real-time electronic readout of blood glucose level. Acetone is not only an effective biomarker of Diabetes Mellitus but also proved to be a rapid, patient compliant viable alternative to the conventional methods of blood glucose determination. Responding to this we have prototyped a design of handy and non-invasive instrument which investigates the potential of breath signal analysis as a way for blood glucose monitoring with the help of an acetone gas sensor through which results are actualized.**

***Key words*— Diabetes Mellitus, Breath Analysis, Volatile organic compounds, Blood Glucose Level, Non-Invasive.**

I. INTRODUCTION

Approximately 346 million people worldwide are said to be Diabetic. Diabetes Mellitus is a heterogeneous group of metabolic diseases characterized by abnormally high blood glucose (BG) levels resulting from defects in insulin secretion, insulin action, or both. The number of Diabetics in the world is substantial and is increasing. According to the estimation given by the World Health Organization (WHO) there would be 693 million Diabetics (age 18–99 years) worldwide by 2045.Diabetes Mellitus has been classified into four types; Type 1 Diabetes (T1D): It occurs due to deficient production of insulin in the pancreas and requires daily administration of insulin. As this type of diabetes is majorly seen in children it is referred to as Juvenile Diabetes. [5]

Type 2 Diabetes (T2D): It occurs due to the ineffective use of the insulin which means cells fail to respond leading to insulin resistance. As it is majorly seen in aged people it is also called as Adult-Onset Diabetes. Gestational Diabetes: It occurs during pregnancy where the blood glucose level increases, which may improve or disappear after delivery. Other specific types are caused by monogenic Diabetes syndromes, diseases of the exocrine pancreas or drug induced Diabetes.

Diabetes over a long term leads to chronic complications such as kidney disease, stroke, heart disease, nervous system damage and vision loss. There isn't a proper cure for Diabetes yet; however, eating healthy food, maintaining proper weight and being active can really help. Being Diabetic, regular monitoring of the Blood Glucose (BG) level is necessary for the rest of their lives. At present one of the predominantly used invasive method for the diagnosis of Diabetes is Blood Glucose Meters (BGM's) which determines the approximate glucose content in the blood. However taking blood samples from people is intrusive, painful and inconvenient. Especially for Juvenile Diabetics which is typically type 1 Diabetes (T1D), they depend completely on insulin injection for diabetic managements, insulin dose adjustments; therefore their blood must be sampled several times a day. As a result of this after many years they may suffer from physical pain. Human breath provides a lot of information. Breath analysis, an emerging technique that is built on the advancement of modern measurement technologies, is one of the non-invasive methods being used to diagnose several diseases. VOCs are numerous which are found in both human-made and naturally occurring chemical components. They originate through regular metabolic activities as well as from a few pathogenic diseases, which flow through the bloodstream and is either exhaled through breath, urine, sweat or saliva in human body.[7] Over 1000 VOCs have been detected to emulate from human breath ranging from ppmv (parts per million by volume) to pptv (parts per trillion by volume) concentrations. Some VOC gases in exhaled breath are bio-markers of different diseases such as diabetes, asthma, lung related diseases and many more.[2] Besides all the gases, number of studies has proven that acetone is a biomarker of diabetes. Acetone gas is one in among such VOCs that are present in the sub-ppm range. Even in ancient times, physicians recognized an odor of a decaying apple in the breath of the diabetic patient. [5] After several years of research it was recognized as the smell of acetone. When body can't make insulin, cells don't receive the glucose and there is a need for fuel. To compensate, body switches to another plan that is burning fat. Burning of fat instead of sugar produces ketones, which build up in blood and urine. Ketone bodies produces by liver are as follws: Acetone (C_3H_6O), acetoacetate (AcAc, $C_4H_6O_3$) and 3-βhydroxybutyrate (3BH). Acetone is produced from the decarboxylation of acetoacetate and dehydrogenation of isopropanol. The acetone conversion process through acetoacetate is: Acetone enters the lungs, passes through exhaled breath and urine. It is proven that there is a correlation between Breath acetone and Blood Glucose (BG) level present in a human body. [1] It suggests that Diabetes in which the blood glucose level increases can be diagnosed from the breath acetone measurement. The breath acetone concentration in a healthy person varies from 0.22 to 0.80 ppm and even up-to 1.8 ppm after 2 hours of post meal, in Type 2 Diabetic person it ranges from 1.76 to 3.73 ppm and as high as 21 ppm for a Type 1 Diabetic person. Hence, a non-invasive device can be designed which gives the result instantly in a painless approach [6].

- As proposed by Danielle Bruen Et al. the current invasive method is based on the enzymatic catalysis principle where a thin needle is used to prick the finger of the patient to minimize the discomfort and further, this principle was adapted to develop the first generation of Glucose Biosensors [1].
- As proposed by Janet Marsden Et al. urine strip testing can be used to check for blood in the urine also detect ketones in the urine. The presence of ketones in the urine therefore indicates that patients' blood glucose level is likely to be very high and that they may have ketoacidosis, which is a potential life-threatening complication of Diabetes and needs urgent treatment.
- As proposed by Tamar Lin Et al. GlucoTrack can measure blood sugar levels through a combination of ultrasonic, electromagnetic and thermal waves. To provide readout, the sensor is clipped on the ear. The device is designed for adults with type 2 diabetes and is approved in Europe, where the company has started to commercialize the glucose monitor.[4]
- As proposed by T Kakkar Et al. glucosense is a laser technology to monitor glucose levels. The device is made of a nano-engineered glass that fluoresces when stimulated by a low power laser [4].
- As proposed by Renaat Coopman Et al. Keratin, the protein that makes up our fingernails and hair, can bond with glucose. This glycation has a linear relationship to blood glucose levels over time. For the purposes of developing a standardized model, fingernails are also preferable because there is less growth rate variation than for hair. The use of fingernail clippings in this method has the potential to improve testing for initial diagnosis of Diabetes, especially in developing nations. Fingernail clippings can be collected without pain and without requiring special training.

In section I we have discussed about the introduction and literature survey pertaining to our project. In the sections

II,III,IV,V, we would be covering details of implementation and results obtained and what we infer from it.

II. METHEDOLOGY

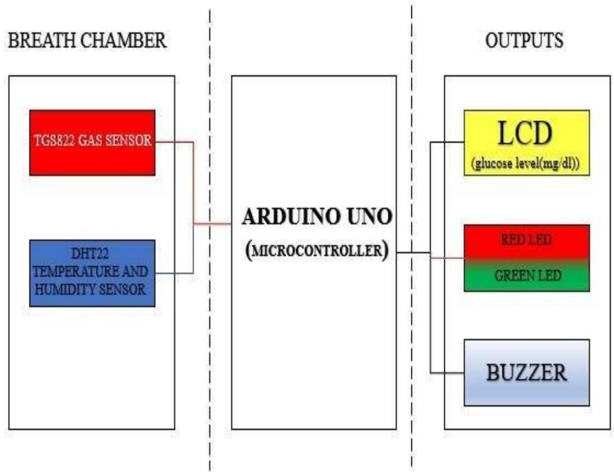

Fig. 1 Schematic Block Diagram

By considering the requirement specification like unit size, sensors, connectivity, controller, power the expected prototype is to be achieved as shown in Figure.1. With the help of mouthpiece, we blow breath into the breath chamber. The entire sensor data which is given to the Arduino controller board through I2C communication protocol is implemented to communicate with digital sensors to read data and is converted into standard value and the respective output of the blood glucose level is obtained on the LCD. A message can be displayed on the LCD as an indication that the device is all set to start blowing when the microcontroller is turned ON with the help of a switch along with indication of LED such that blinking of red LED indicates that the subject is Diabetic where as blinking of green LED indicates that the person is free of diabetes and healthy. There is a buzzer provided to buzz as an indication to determine subject's health condition. To ventilate the breath-chamber the exhaust fan is used with the aid of the switch. The continuous power is given through non-rechargeable battery.

II. HARDWARE IMPLEMENTATION

Components are integrated as quoted in Section II. Selected sensors need to be coded to convert the electrical parameters pertaining to it into relevant values which could be handed from a biological perspective. The code must be accurate and precise as possible in order to eliminate exponential error from arising due to further conversions. A microcontroller becomes necessary for functionality to be controlled in a unit. Hence, keeping in mind the easy availability and adaptability, low power we have chosen Arduino UNO. Major backbone of the device resides in the TGS822 acetone sensor due to the major advantage being a large detection range which in turn helps us to detect accurate levels of acetone. [3] Sensor works by utilizing analog inputs of the microcontroller. Temperature and humidity are the major factors which affects the human breath when detected through the acetone sensor, to minimize these effects DHT22 sensor is used as a compensator due to its high precision rate. This sensor uses digital signal on the data pin. Continuous power is to be supplied to the unit in order to keep the sensor heaters running. This is to avoid long warm up times in order to get the sensor stabilized. Hence the battery must be chosen in such a way that it is robust, lightweight and durable. An LCD display becomes an important component to add visual output to the project. The display is featured by a 16 character 2 line slots to provide a clear and high contrast white text upon a backlight. The LCD screen we use is with regard to I2C communication interface. A light emitting diode is a semi conductor device that emits visible light when an electrical current passes through it. An LED with a voltage source connected to the positive side (longer lead) or the anode and the negative side or the cathode initiates the flow of current resulting the LED to glow. Mouth piece is durable tubing which could be detachable through which the subject initially blows into the breath chamber. Subsequently the output is visible on the LCD. After undergoing the series of former mentioned descriptive. Entire unit is encapsulated within an isolative casing. This is shown in Figure.2.

III.DESIGN FLOW

Working preview of the device is according to the flowchart as shown in Figure.3.

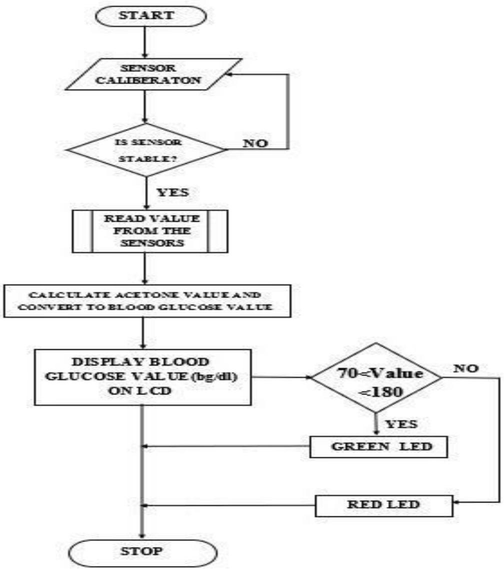

Fig. 3 Flowchart

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Fig. 2 Blood glucose value displayed on LCD

IV. RESULTS AND DISCUSSION

The device that has been designed is a non invasive model. It is equally qualitative and quantitative. The device detects the amount of acetone content in the subject breath and thereby proportionally displays the blood glucose level which indicates whether the subject is diabetic or not and emulates to the invasive method reading. The subject samples have been collected from our device and have been validated with the invasive method readings .On careful analysis of the obtained results, a conclusion can be drawn on the accuracy of the Figaro sensor. The probability of the presence of the breath acetone depends on many factors. The factors to be considered here is whether the user is tested pre-lunch or post lunch. Via the regression analysis, the visualized results of the conventional and that of our designed device for pre and post lunch conditions in the form of Blood Glucose Levels can be summarized as shown in Figure 4.1 and Figure 4.2.

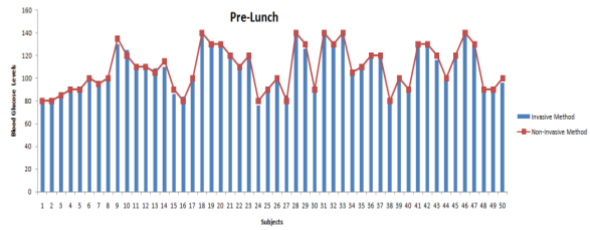

Fig 4.1 Visualized results under pre-lunch state

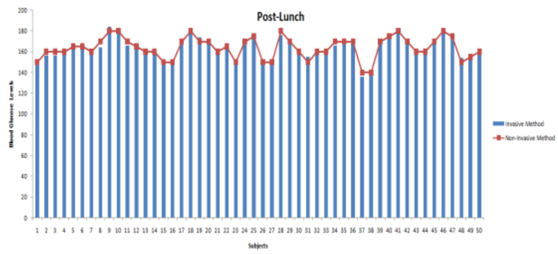

Fig 4.2 Visualized results under post-lunch state

V. CONCLUSION

Breath acetone has been well validated as diabetes biomarker that can provide a non-invasive means of monitoring and screening diabetes. Since then, researchers have been looking for novel ways to allow its detection at very feasible and favorable condition. The utilization of biosensor for breath acetone detection features many advantages overthe conventional means of its detection. The portable non- invasive glucose measuring device designed on the basis of correlation between the exhaled human breath acetone content and blood glucose level was very effective, user friendly and had a good accuracy when compared with that of invasive device. Due to the global pandemic situation though the number of subjects was constrained result was precise. As part of the future scope system can be made improvised in case of the accuracy by placing two TGS822 sensors or even by replacing with more accurate acetone detecting sensor. By reducing the cost of the apparatus and android mobile applications and web development can be integrated with the device. Further fine tuning of scaling function can be also made.

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