Early Detection of Kidney Disease Using Human Breath

1. Muhammed Erziku, University of Gondar, Ethiopia, Muhammed.Erziku@uog.edu.et
2. Eyob Adugnaw, University of Gondar, Ethiopia, eyob.adugna@uog.edu.et
3. Jemil Zeynu, University of Gondar, Ethiopia, Zeynujemil080@gmail.com
4. Bethel Tamrat, University of Gondar, Ethiopia, Donna0donna0tata@gmail.com
5. Fatuma Abera, University of Gondar, Ethiopia, Saburah7999@gmail.com
6. Zerubabel Getachew, University of Gondar, Ethiopia, zerubbabelgeta@gmail.com

Abstract

Kidneys are the body's waste filtering and disposal system which is in charge of keeping the body's ionic balance. If there is an ion imbalance in the body, it may be a sign of a kidney problem. To avoid kidney problems, a proper examination and monitoring of the kidney are recommended. When kidney failure happens the only way to keep one's life is to undergo dialysis at least three days a week or to undergo kidney transplant surgery. Both of these options are prohibitively costly for the majority of Ethiopians. To address this problem a design of a homecare device that detects the status of kidney, which is noninvasive, faster, portable, at an affordable price, and accessible to most people is necessary. Many studies have been made in the field of kidney detection using several detection mechanisms and one of those mechanisms studied was using ammonia as a biomarker to test the status of the kidney. The device uses breath ammonia to analyze the performance of the kidney. With this method, samples are taken from the patient and the concentration of ammonia in the breath will be sensed by the ammonia sensor the value is then compared with the threshold amount specified and if it is greater than the threshold the device will notify the patient to get a further checkup. A developed mobile application will receive the detected value from the device via Bluetooth connection and after analyzing the status of the patient's kidney will be displayed in the app and also a voice message is used as optional for patients who can't read English. Finally, the concentration of ammonia and the status will be stored in the patient's phone storage which can be accessed anytime and shared via multiple platforms.

Keywords: Ammonia, chronic kidney disease, parts per million, gas sensor

Introduction

The kidneys are two reddish, bean-shaped organs on either side of the spine, beneath the ribs, and behind the stomach. The kidneys are located between the last thoracic and third lumbar vertebrae levels, a position where they are partially protected by the eleventh and twelfth pairs of ribs. The right kidney is positioned slightly lower than the left kidney. This is because the liver occupies considerable space on the right side superior to the kidney. [1]

The two kidneys lie in the back of the abdominal wall but not actually in the abdominal cavity. They are retroperitoneal, meaning they are just behind the peritoneum, the lining of this cavity. The urine flows from the kidneys through the ureters into the bladder, from which it is eliminated via the urethra. [2]

The kidneys are important in maintaining the body water and electrolyte balance, the acid-base balance, regulating the urine volume and composition, the blood volume, and producing vasoactive substances to regulate blood pressure and in eliminating waste products from the blood. [3]. Blood filtering is the responsibility of the kidneys. The kidney filters blood plasma. Nutrients, essential ions, and

water will be reabsorbed from and returned to the body. The remaining water and solutes constitute urine, which is then excreted from the body; by which, metabolic waste products are eliminated [4].

Kidney disease is classified into two major parts. The first is an acute kidney injury (AKI), Acute kidney damage occurs when our kidneys cease working unexpectedly and for a short period. AKI is also known as acute renal failure or acute kidney failure. This happens due to a rapid increase in serum creatinine levels in the blood. The other is chronic kidney disease (CKD). Chronic kidney disease is a chronic ailment that occurs gradually due to malfunctioning or problems related to the filtration rate of the kidney.

Kidney disease can be caused by different factors mostly due to the effect of other diseases. The diseases that act as a factor or cause of kidney disease are hypertension, diabetes, heart problem, etc. people with a history of kidney disease in the family may also have kidney disease. Tests for kidney disease can be done using a different technique. The main techniques that are used are blood test which is used to measure the amount of waste product present in the blood mainly creatinine and blood urea nitrogen, urine test which is performed using a urine sample taken from the patient this test is used to check the presence of albumin protein, imaging test which is performed using imaging equipment's like ultrasound and CT-Scan to detect shape and location defects and kidney test can also be performed by taking a kidney biopsy directly from kidney which is used to identify how much damage has been made to the kidney.

Glomerular filtration rate (GFR) is one of the major factors that is used to identify the functioning rate of the kidney. This determines how effectively the kidneys remove waste and extra fluid from the bloodstream. It's calculated by using the serum creatinine level and by considering the patient's age, body size, and gender. But now a day several studies show that taking a sample of ammonia gas from the breath can also be used as a biomarker to identify the status of the kidney.

The treatment of kidneys includes two different methods. The first one is dialysis, which is performed 2-5 times a week based on the economy of the patient and this procedure is used to clean the waste materials aggregated in the blood of the patient. The other is the kidney transplant, which is performed when there is a matching donor who is willing to give the kidney.

CKD is becoming more widespread over the world, with estimates ranging from 8% to 16%, and it is now recognized as a global public health issue [5]. Only a few studies have looked into the prevalence of CKD among diabetic patients in Ethiopia. A study performed on individuals with diabetes in Butajira Hospital had a CKD prevalence of 18.2 percent to 23.8 percent [6] and a similar hospital-based study performed in 2016 at Gondar University Hospital showed the overall prevalence of CKD as 21.8% [7].

Method

Detection mechanism

This method is concerned with breath analysis. The breath analyzer circuit uses ammonia gas sensors to accomplish the analysis since the level of ammonia in the breath of CKD patients is high due to the kidneys' improper functioning. A small container is used to collect breath samples from healthy people and CKD patients. The samples are then delivered to an MQ-135 ammonia gas sensor, which detects ammonia in the breath sample and

delivers the overall ammonia gas concentration to the controller. It will be received by the controller through an analog or digital interface, and the value will be processed. The result is then compared to the threshold value, and the result is shown on the LCD board. The ammonia gas threshold limit of the controller is defined by stating a normal person's ammonia level as less than 0.82 ppm and a CKD patient's ammonia level as greater than 0.82 PPM [22]. After detection, the value of ammonia is sent to an android phone using a Bluetooth module and the value sent to the android device will be stored.

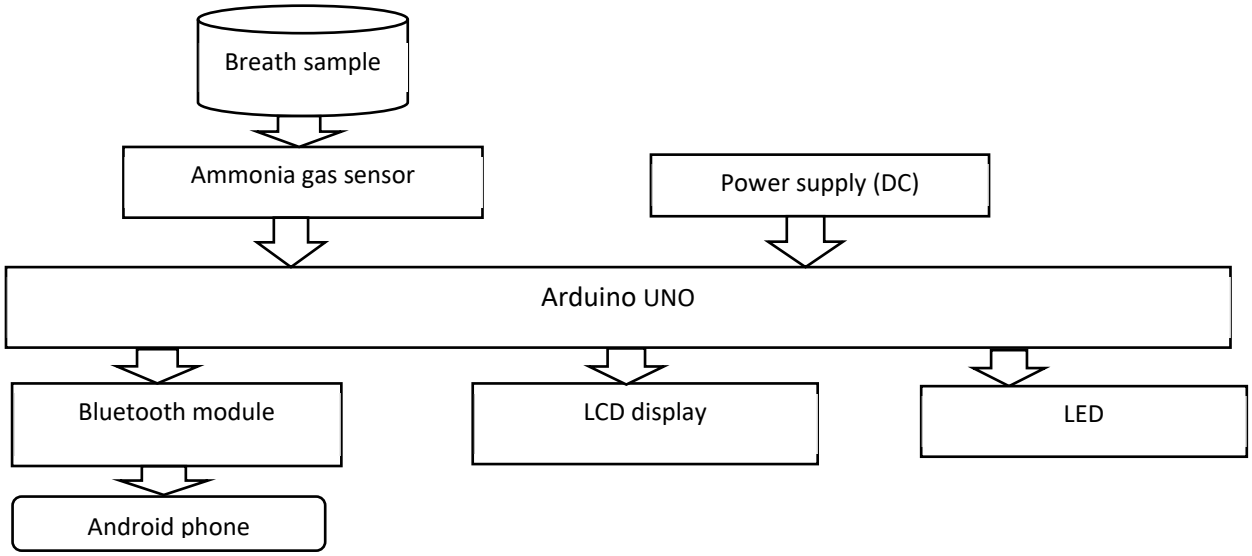

Figure 1: Block diagram of the system

System architecture

The system developed consists of five different subsystems which are integrated to get the desired function. These are: -

1. **Sensing mechanism**

The sensing mechanism employed in this system is an MQ gas sensor that can sense the amount of ammonia from the breath sample and this detected sample will be delivered to the microprocessor for further analysis.

2. **Processor**

In this system, a microprocessor was used to receive the output from the sensor and convert the value received from the gas sensor to the right format. An Arduino microprocessor is used in this system. The Arduino microprocessor is used to calculate the PPM of ammonia detected and send this value to the output system.

3. **Bluetooth connection**

A Bluetooth connection system is needed to connect the device with an android device. The Arduino will send the calculated PPM value via Bluetooth module to the app and this will be displayed in the GUI.

4. **Display**

The system consists of an LCD and a mobile application to display the concentration of ammonia.

5. **Phone**

The mobile phone is used to install and run the application which is needed to display the concentration of ammonia and also the application will be using the phone's storage

memory to store the daily concentration of ammonia which will be used in the future if needed.

Workflow of the system

As depicted in fig.2a the designed device calculates the concentration of ammonia in terms of PPM. The calculated value will be compared with a threshold concentration set based on the concentration of ammonia normal person's breath. After comparison, the device will determine if the detected amount is normal or not and will notify the user. The users can also read about kidney disease symptoms and prevention methods, this will inform several people about the kidney and its symptoms and also the application will provide the users with a set of things to avoid to protect their kidneys.

Result

To test if the prototype is working properly or not, a test was performed in the ambient air as in fig. 2b where the

.

average standard concentration of ammonia in the air is 0.01-0.03 ppm which may increase in an enclosed area. This standard value for the concentration of ammonia is used to check the prototype. The average measured concentration using the prototype ranges from 0.1-0.5 ppm in free air where the temperature and humidity are in the device specified range.

The prototype was tested using the breath of a normal person as in fig. 2c which always should be less than the threshold limit of 0.82 ppm. The device should detect the ammonia in the sample. The detected value from the sample is 0.29 ppm. This sample was taken from one of the group members voluntarily. As it is shown in the fig.2e, we use some kinds of substances that have a high amount of ammonia concentration that exceeds the threshold level

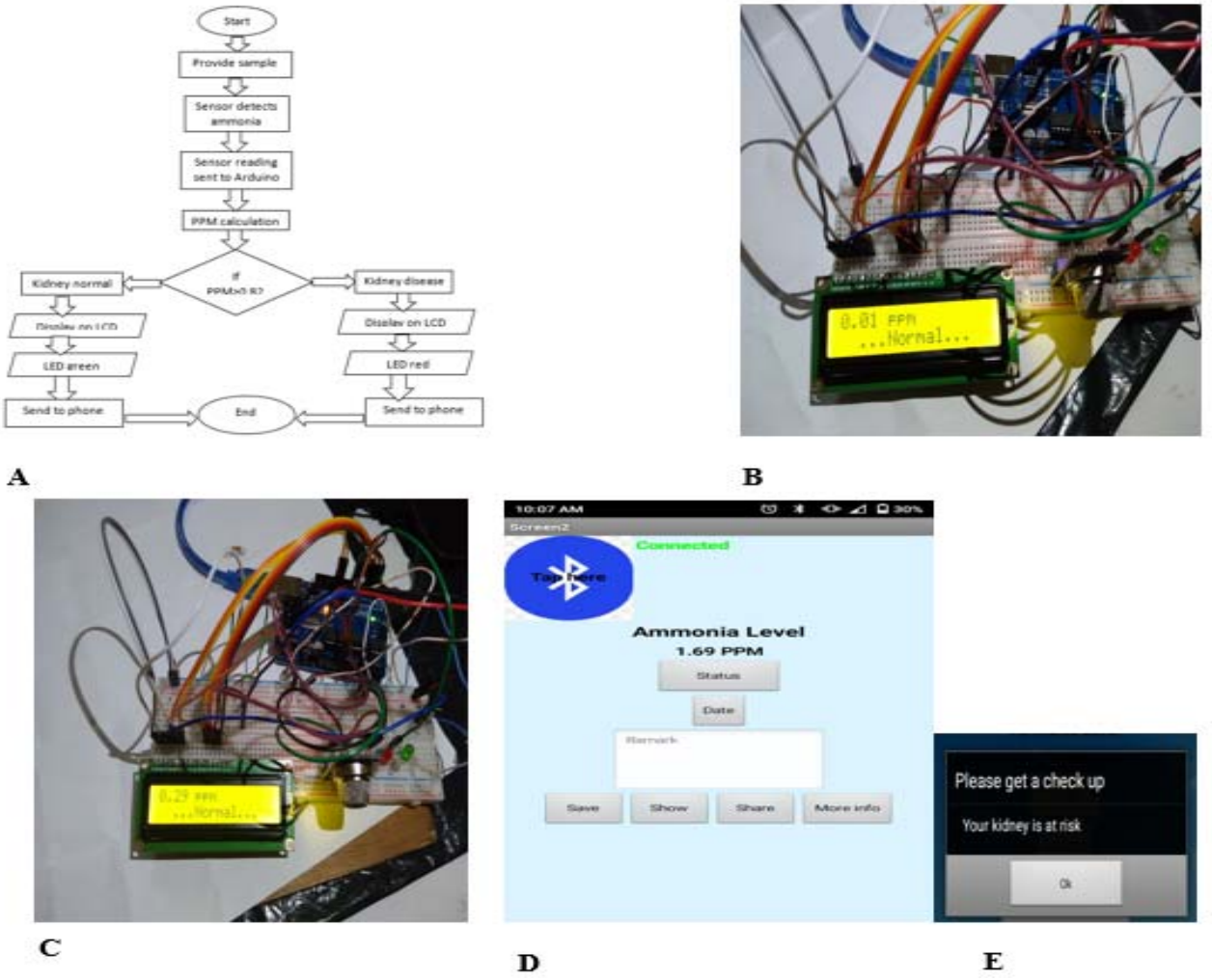

Figure 2: (A) Flowchart of the device (B)Atmospheric ammonia concentration result (C) Result of a normal person breath sample (D) Mobile application result with an ammonia concentration of 1.73 PPM and (E) Status Notification message for detected value

Discussion

The rise in the number of CKD patients in our country is because people have a poor habit of going to the doctor regularly, and they only go to the hospital when they have a serious illness. This is due to a variety of factors, including unfair and expensive tests, equipment's needed for regular tests are expensive and due to this, some healthcare sectors don't have the equipment, long wait times for service, and people's inability to afford the services provided by hospitals, so regular checkups are seen as a sign of wealth. Assessing these problems, the design team came up with an idea to provide a device that could eliminate these major difficulties that prevent people from having regular checkups.

Compared to the devices that are in use these days the designed device is affordable to any healthcare sector and also it can be afforded to several individuals the device can be used as a homecare device and people can use it to get a daily checkup and save their daily information in the

storage provided by mobile application and can share the saved information with a health professional when needed. And also, the designed device is light weighted and portable and this makes it more suitable for home care.

The devices available in the market are healthcare organization-oriented because they can't be used without the presence of certain health professionals but these devices can be used without the presence of health professionals so individuals can buy the device and use it at home.

Time-wise devices that are being used at this moment require a longer time, after the serum is extracted from the whole blood, the result of the creatinine test takes about 30 minutes. But with this device patients can see their results within seconds.

This design also provides additional features for smartphone users, because the application designed for android devices will allow the user to see the results on their phone and provide them with a means to save the results into phone storage. The saved file can be shared with doctors when a history of the patient's kidney condition is required.

Concussion

Chronic kidney disease poses a serious issue to global health policy in the twenty-first century. The rising prevalence of chronic diseases such as chronic kidney disease has serious health and economic consequences in developing countries. More comprehensive and cost-effective diagnostic devices for chronic kidney disease are urgently needed in developing countries like Ethiopia.

So, this project aimed to provide a device that can be afforded and used at home without the intervention of any professional allowing them to get a quick checkup within a few minutes.

The device is designed for detecting kidney abnormalities. The device takes samples from the user and analyses the ammonia level in the breath sample. The result is then compared to the threshold ammonia level of 0.82 PPM. The device shows a "normal" message for values that are less than the threshold and "Get Checkup" for values that are greater than the threshold to appraise for further diagnosis.

The periodic checking up of the kidneys is difficult because the tests are expensive and the tests require around 30 minutes to get and the long wait to get those results is frustrating. In approaching this gap this project sought to use the ammonia that is being exhaled as a means to design a home care device. This homecare device is cost-effective, portable, and durable, as a result, users can check the status of their kidneys in the comfort of their homes. In addition, the status can be stored on their smartphones and the results are notified using sound interfaces. If this device gets manufactured and introduced to markets, the culture of getting routine kidney checkups will be improved. Furthermore, lives that might be lost because of kidney failure could be saved.

Acknowledge

We would like to extend our sincere gratitude to the university of Gondar institute of technology's Biomedical Engineering department. Thank you all so much once again!

References

[1] Gerard J. Tortora, Bryan Derrickson, Priciples of Anatomy and Physiology 13th edition, United States of America.: John Wiley & Sons, Inc, 2012.

[2] Arthur J-Luciano, James Vander, et al, Human Physiology: The Mechanism of Body Function, Eighth Edition, The McGraw−Hill Companies, 2001.

[3] K. W. Chung, BRS Gross Anatomy 5th edition, United States of America: LIPPINCOTT WILLIAMS & WILKINS, 2005.

[4] "Health A-Z: Chroic Disease," NHS, 29 August 2019. [Online]. Available: https://www.nhs.uk/conditions/kidney-disease/diagnosis/#:~:text=Chronic%20kidney%20disease%20(CKD)%20can,may%20not%20be%20working%20normally.. [Accessed 1 May 2021].

[5] Hahar AJ, Molitch ME, "Management of diabetes mellitus in patients with chronic kidney disease.," Clinical Diabetes and Endocrinology, 2015.

[6] Temesgen Fiseha, Mehidi Kassim,Tilahun Yemane, "Prevalence of Chronic Kidney Disease and Associated Risk Factors among Diabetic Patients in Southern Ethiopia," *American Journal of Health Research,* vol. 2, no. 4, pp. 216-221, July 2014.

[7] Hailemaryam Alemu, workagegnehu Hailu, Ayneshet Adane, "Prevalence of Chronic Kidney Disease and Associated Factors among Patients with Diabetes in Northwest Ethiopia: A Hospital-Based Cross-Sectional Study," *Current Therapeutic Research,* vol. 92, no. 92, pp. 2-3, 2016.

[8] Sebastjan Bevc, Eva Mohorko, Mitja Kolar et.al, "Developmet of breath ammonia analysis system for disease diagnosis," *Asian Journal of Biochemical and Pharmaceutical Research,* vol. III, no. 1, pp. 50-59, 2019.

[9] A. Raj, "circuit design," 09 February 2018. [Online]. Available: https://circuitdigest.com/microcontroller-projects/arduino-mq137-ammonia-sensor. [Accessed 11 may 2021].