Spectroscopic Based Ammonia Measurement System

Abdullah M. ARMAN
Palestine Polytechnic University, Hebron, Palestine,

Khalid A. DAGHAMEEN
Palestine Polytechnic University, Palestine,

Eyas. BALBISI
Palestine Polytechnic University, Hebron, Palestine,

Mohammad. HAJJAJ
Palestine Polytechnic University, Hebron, Palestine

DOI: https://doi.org/10.56293/IJASR.2022.5564

IJASR 2023
VOLUME 6
ISSUE 5 SEPTEMBER – OCTOBER **ISSN: 2581-7876**

Abstract: This article describes the design and implementation of a microcontroller-based system for determining ammonia concentrations in blood. By adding a blood sample to a test strip, the proposed system induces a series of reactions known as Berthelot's response, resulting in an accurate change in strip color. A current is then generated when the photodiode detects the 635 nm wavelength reflected off the strip. An op-amp is used to convert the current to voltage. Because of their ease of use and software flexibility, microcontrollers are recognized as important components in modern electronics. The concentration of (NH3) is determined by a microcontroller depending on the voltage value. The test results are shown on an LCD or recorded in data files. Any normal or abnormal outcomes are appropriately recorded by the system. A PC software program is written to accept and save data. The proposed system is initially designed using the concepts of Software Analysis and Design; the process of building the proposed systems begins with determining the system's requirements, working on the analysis, using the best design techniques according to the software Engineering process, and finally modeling it on an electronic board before being realized and implemented. It is used in biomedical measurements. It is also handy for monitoring and researching final circuits.

Keywords: Spectroscopic, Blood Ammonia, Beer-Lambert law, Systems Engineering Application

Introduction

The difficult process of digesting food into nutrients that the body can use for energy, development, and cell repair is known as digestion. Along with producing trash to be expelled, digestion also produces garbage. The digestive tract, also known as the alimentary canal or gastrointestinal (GI) tract, is made up of a long, continuous tube that runs from the mouth to the anus and is a part of the digestive system together with its supporting organs. The digestive system is made up of the mouth, pharynx, esophagus, stomach, small intestine, and large intestine, as depicted in figure 1.

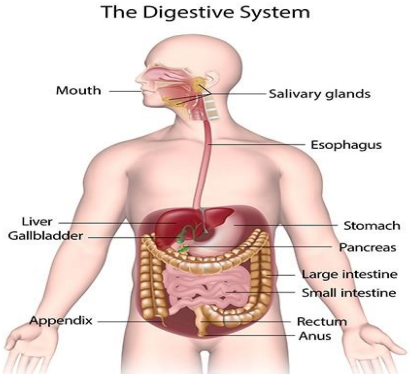

Figure 1: Digesting system [4]

Ammonia is a key component of intra-organ nitrogen (N) transport, and modeling the variables that affect blood-NH3 concentration is challenging due to the requirement to take a variety of reactions occurring in various organs into account. Despite the fact that the urea cycle entirely captures the huge volumes of NH3 created during normal liver amino-acid metabolism, this NH3 does not enter the bloodstream. The principal site of blood-NH3 generation is the gastrointestinal tract, as shown by portal vein-NH3 concentrations that are roughly three times that of systemic blood, even if some systemic NH3 comes through renal and muscle metabolism. The hydrolysis of urea by bacterial urease, bacterial protein deamination, and intestinal mucosal glutamine metabolism are the three processes that release NH3 in the gut. [1]

Figure 2 illustrates the common belief that the colon is the primary location of gut-NH3 synthesis. Nevertheless, research is reviewed that suggests that the stomach (through Helicobacter pylori metabolism) and small intestine may play a more significant role. Before entering the systemic circulation in healthy patients, the liver removes the majority of this gut NH3. Using a quantitative model, the hyperammonemia seen in chronic liver illness can be explained by loss of this "first-pass metabolism" caused by portal collateral circulation, and hepatocyte dysfunction is typically not necessary. In contrast, injured hepatocytes cause hyperammonemia in acute hepatic necrosis. Despite the fact that muscle-NH3 uptake is typically minimal, it can become significant in extreme hyperammonemia. The detailed discussion of the NH3-lowering effects of intestinal antibiotics (rifaximin) and lactulose places special attention on the apparent lack of significance of the often stressed acidifying activity of lactulose in the colon. [3]

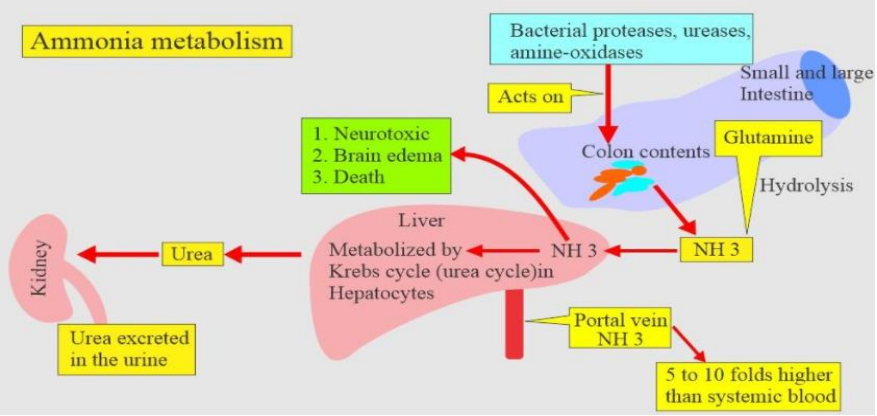

Figure 2: Ammonia production. [2]

Patients with hyperammonemia (HA) exhibit motor and cognitive disorders, whether or not they have cirrhosis, indicating that ammonia has an impact on brain function via underlying pathways. The primary mechanism of HA is ammonia-induced central nervous system toxicity. Increased blood ammonia levels and brain edema are caused by the overproduction of ammonia by gut bacteria like S. salivarius.

Argininosuccinic acid levels that are too high are one of the main genetic defects that contribute to hyperammonemia. It is a genetic metabolic disorder caused by a flaw in the body's ability to break down or act on an acid called citrulline as a result of a lack of a certain enzyme, which leads in a flaw in the urea cycle, which is crucial for eliminating ammonia (NH3) (toxic). In addition to other dangerous compounds, ammonia builds up as a result of this.

Finally, the urea is removed, and ammonia (NH3) is destroyed by a series of chemical reactions. Urea is triggered by a variety of enzymes, and when one of these enzymes is missing or damaged, a failure in the urea cycle results, leading to a spike in ammonia (NH3 harmful), an increase in some amino acids and a deficit in others, which cause symptoms of the disease. Usually, the name of the defective enzyme contains the name of the disease. [3]

Importance of this Study

In individuals with acute liver failure, inborn metabolic abnormalities, and other nonhaptic diseases, hyperammonemia (HA) is a hazardous build of ammonia in the blood that can lead in cerebral edema and brain herniation, which can induce coma or death (HA). The major goal is to create an easy, simple, economical, painless, high accuracy way to

detect blood ammonia level since measuring the amount of ammonia in the blood has had many complications related to the kind of samples, the examination apparatus, or the time needed to receive the result.

In this study, a portable invasive device will be created and implanted to measure the level of blood ammonia that is susceptible to room temperature immediately after a small sample of blood using a chemical indicator and LED of a specific wavelength using Berthelot's reagent as a self-test that helps the patient to measure his own ammonia blood levels. The suggested method, which relies on the change in color of a chemical reagent following exposure to a blood sample, will be simple, efficient, and quick for measuring blood samples from capillaries.

System Design and Construction

As illustrated in Figure 4, the system is made up of a light source, a photo detector, and a microcontroller. Arduino is a free and open-source platform for creating electronic projects. Arduino is made up of a physical programmable circuit board (also known as a microcontroller) and a piece of software, or IDE (Integrated Development Environment), that runs on a computer and is used to create and upload computer code to the physical board. It will be Arduino hardware compatible. The Arduino MEGA 2560 was chosen because it has sufficient memory and digital/analog I/O connections, and it is also reasonably priced. Figure 3 depicts the Arduino MEGA 2560 controller and its pins.

Figure 3 Arduino MEGA 2560.

There are two primary components to the system. the software component, which is depicted in figure 5, and the physical components, which are depicted in figure 4. The physical components are a portable intrusive device that is implanted to assess the level of blood ammonia using a chemical indicator and an LED of a certain wavelength with Berthelot's reagent as a sort of self-test that aids the patient in determining his own blood ammonia levels. For quantifying blood samples from capillaries based on the Change in color of a chemical reagent after exposure to a blood sample, the Beer-Lambert law-based approach is suggested.

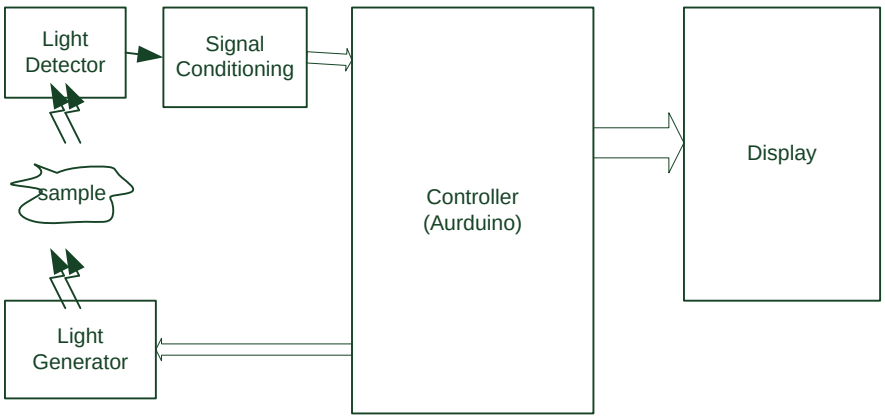

Figure 4: Block diagram

The Beer-Lambert Law, often known as Beer's Law, is the linear relationship between absorbance and concentration of an absorbing species and describes how light is attenuated via a substance in proportion to that substance's qualities.

Typically, the general Beer-Lambert law is expressed as [A = a (λ) * b * c] Where A is the measured absorbance, a (λ) is a wavelength-dependent absorptivity coefficient, b is the path length, and c is the analytic concentration [7][8]. The software that explains how the system functions is the other component of the system. The sample is first illuminated by the device. The urine sample is transparent to that light. A light detector will capture this light. Following some filtering, signal conditioning, and conversion to digital format, a computable value that can be utilized for the Beer-Lambart Law calculation is produced. The activity diagram that follows in figure 5 illustrates the flow of the required series of actions. [8..9]

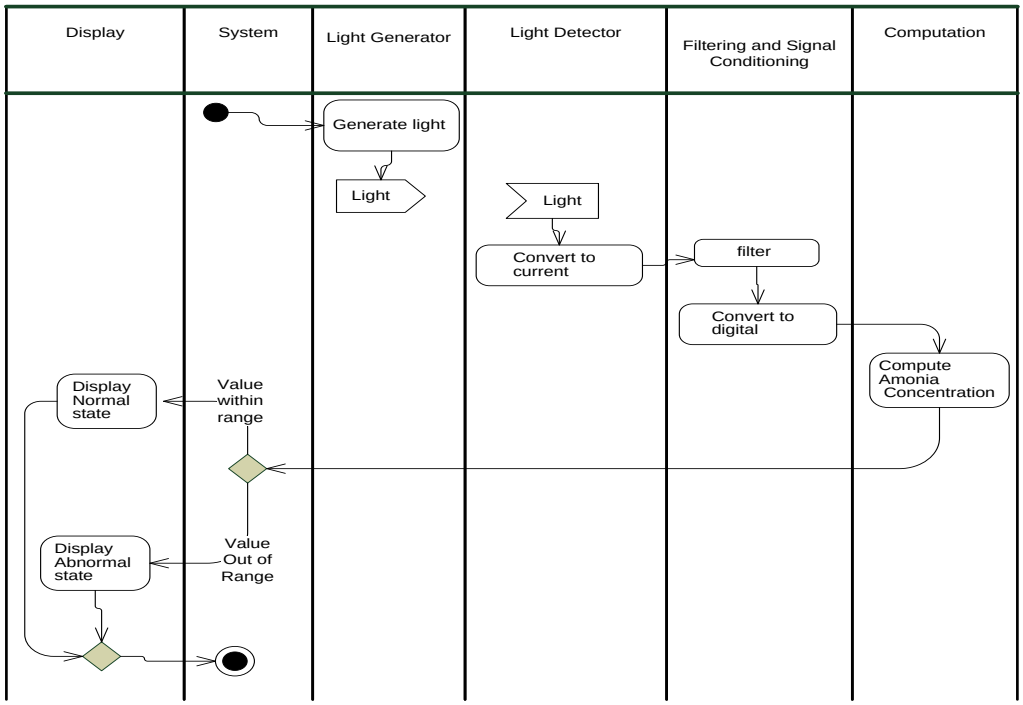

Figure 5 Activity diagram of the system

Equation extraction

The experiments were performed at ten (a 10) different concentrations [0-100] µmol/L with a 10 µmol/L increment after the hardware and software of the system were created and put into operation. Each Strip must be exposed to a specific solution concentration for the color to change. After the reaction is complete, the strips are shown in Figure 6.

Figure 6 Strips after exposure

An equation links between the intensity of the color on the strip as a result of the reaction with the concentration was extracted using Excel software, the equation extracted to obtain the curve was

(y = -0.3456x + 4.4358), noticing that the voltage obtained on 0 µmol/L and voltage where decreasing gradually as it shown in the curve in Figure 7 reaching the lowest point at 100 µmol/L.

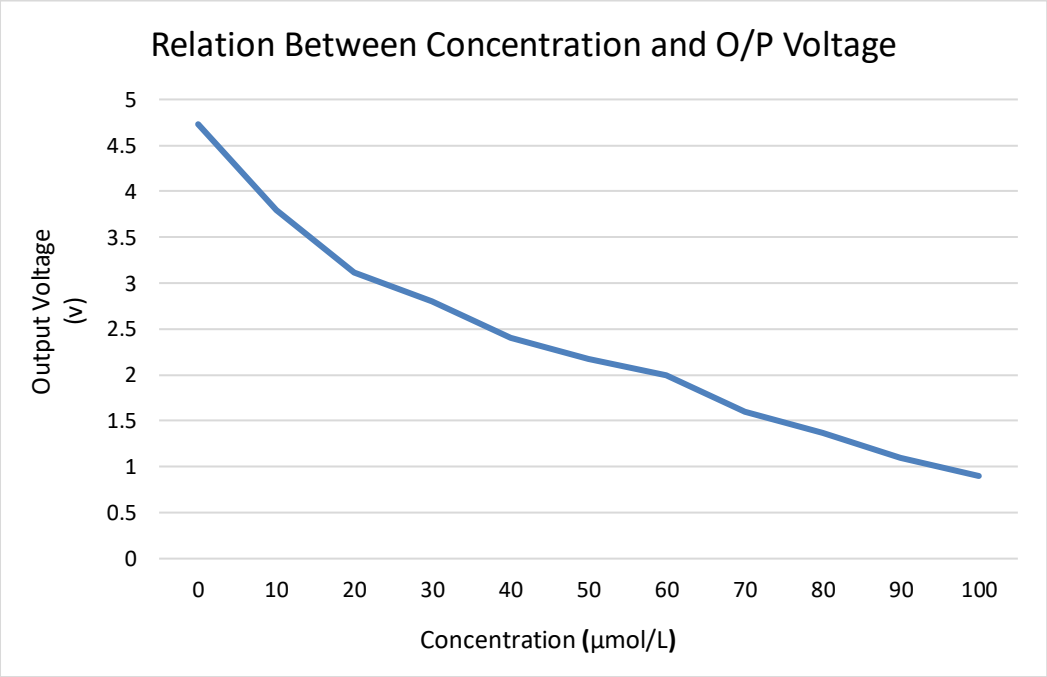

Figure 7 Relation between Concentration and O/P Voltage

System results

After the system is installed, the readings are examined on ten samples prepared in a chemistry laboratory where its concentrations were known previously and then compared result.

Table 1 Results of the system

Sample Number	Concentration (µmol/L)	Result	State
1	10	9.3	Normal
2	20	17.8	Normal
3	30	25.6	Normal
4	40	42.7	Normal
5	50	54.1	Normal
6	60	61.2	Abnormal

7	70	81.7	Abnormal
8	80	78.4	Abnormal
9	90	87.4	Abnormal
10	100	94.9	Abnormal

Conclusion

A simple and inexpensive method was developed to determine blood ammonia concentrations. Blood ammonia levels are typically in the range of 11 to 50 µM.The tests were repeated on a 10 different concentrations [0-100] µmol/L with 10 µmol/L increment. The extracted ammonia is then quantified using a colorimetric reaction. The method could reliably differentiate between normal and abnormal cases. Ammonia (NH3) concentration in the sample has been known by putting blood on a test strip which inters a series of reactions to give an accurate change in the strip color , which leads to the change of the absorbed amount of 635 nm wavelength, after that sensing the 635 nm wavelength reflected from the strip by the photodiode generating a current as a result, current will pass through an op-amp converting it to voltage, microcontroller is used to control the system components and keep the process on the right path and taking steps sequentially in addition to calculate the (NH3) concentration depending on the value of the voltage.

References

1. Niamh T. Brannelly, "THE DEVELOPMENT OF A POINT OF CARE DEVICE FOR MEASURING BLOOD AMMONIA", July 2016.
2. Young-Sang Byoun, The prevalence of liver disease types. chronic hepatitis was the most, Sep.18,2012.[online] https://www.researchgate.net/figure/The-prevalence-of-liver-disease-types-Chronic-hepatitis-was-the-most-common-type-of_fig1_232612257
3. Mohamed Fayed, Unexplained Fatal Hyperammonemia in a Patient With New Diagnosis of Acute Monoblastic Leukemia, December 02, 2021.[online] https://www.cureus.com/articles/78059-unexplained-fatal-hyperammonemia-in-a-patient-with-new-diagnosis-of-acute-monoblastic-leukemia
4. Minesh Khatri, The Digestive System Diagram, Organs, Function, and More, March 08, 2022. [online] https://www.webmd.com/digestive-disorders/digestive-system
5. Rimsha Ali, Hyperammonemia, AUG.08, 2022. [online] https://www.ncbi.nlm.nih.gov/books/NBK557504/
6. Shivaraj Nagalli, Elevated Liver Enzymes, JUN.14,2016. [online] https://my.clevelandclinic.org/health/symptoms/17679-elevated-liver-enzymes
7. Avi, Shmueli, Beer-Lambert Law, OCT.10,2020. [online] http://life.nthu.edu.tw/~labcjw/BioPhyChem/Spectroscopy/beerslaw.htm
8. J. Fernández de Cañete , C. Galindo , J. Barbancho , A. Luque , "Automatic Control Systems in Biomedical Engineering: An Interactive Educational Approach", 1st edition, 2018, Springer
9. Alan Dennis, Barbara Wixom, David Tegarden, "Systems Analysis and Design: An Object-Oriented Approach with UML",6th edition, Wiley, 2020