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# Arduino UNO-Based pH and Viscosity Sensor Prototype for Comparative Analysis of Urine Characteristics in Pregnant and Non-Pregnant Women

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**ABSTRACT**
This study aimed to design and validate a microcontroller-based instrument prototype for comparing urine characteristics between pregnant and non-pregnant women. Using a Research and Development (R&D) approach, the study proceeded through two main stages: validation of the instrument against a laboratory-standard device and implementation on biological samples. The device's main components consist of an Arduino UNO with 10-bit ADC resolution, a pH-4502C sensor with a glass electrode, and a through-beam optical sensor integrated into a 1/2-inch PVC pipe. Accuracy testing showed very high instrument performance, with a mean error of 0.81% (99.18% accuracy) for pH measurement and 0.15% (99.84% accuracy) for viscosity measurement. Comparative analysis of the study subjects showed a physiologically significant difference: the average pregnant woman's urine sample had a pH of 7.05 and a viscosity of 5.33 mPas, while the average non-pregnant woman's urine sample had a pH of 6.19 and a viscosity of 6.86 mPas. These findings show that pregnant women's urine tends to be more alkaline and more dilute, consistent with theories of urinary system changes during gestation.

**Keywords:**
pH-4502C Sensor, Viscosity Sensor, Urine, Arduino UNO, Pregnant Women.

## Introduction

Urine is a renal excretion product that carries crucial information about the body's metabolic status and homeostasis. Normal urine generally has a pH of around 6.0, with a water content of up to 96%. In women, however, pregnancy triggers significant physiological and anatomical transformations in the urinary system. These changes are driven by fluctuations in estrogen and progesterone, increased blood plasma volume, and mechanical pressure from the uterus on the bladder (Ratnawati, 2020). This adjustment directly affects the physical and chemical parameters of the urine produced (Rahmawati & Wulandari, 2019). Monitoring urine characteristics during pregnancy is an essential preventive step for detecting pathological conditions such as dehydration, urinary tract infection, impaired renal filtration function, and even preeclampsia risk. Given the limited accessibility of laboratory equipment in some segments of society, an accurate, economical, and portable detection instrument is needed to support independent health screening for pregnant women.

Acidity level is measured on the pH scale (0–14), while thickness, or viscosity, measures a fluid's resistance to flow due to molecular friction. Biologically, pregnancy induces a state of hyperventilation that lowers blood carbon dioxide and bicarbonate levels (Myers et al., 1932), causing urine to become more alkaline. In addition, the increase in *glomerular filtration rate* (GFR) of up to 50% during pregnancy causes urine to become more dilute than in the non-pregnant state (Valovska & Pais, 2018).

## Methods

*Research Design*

This study used a *Research and Development* (R&D) framework to produce and test the validity of a medical sensor prototype.

*Hardware Specifications*

The device was designed with the integration of the following components:

- Arduino UNO: The main processing unit, using a 10-bit ADC resolution (*Analog to Digital Converter*) for sensor signal conversion.
- pH-4502C Sensor: Uses a sensitive glass electrode connected via a BNC connector for signal stability.
- Viscosity Sensor: A custom instrument using a *through-beam* (infrared transmitter and photodiode) housed in a 1/2-inch PVC pipe.
- 16×2 LCD: A display screen for visualizing *output*.

*Calibration Procedure*

- pH Calibration: Uses a buffer solution (buffer powder) with standard pH values of 4.01 and 6.85, cross-checked against a digital pH meter.
- Viscosity Calibration: Uses glycerin as the comparison standard. The reference value was established using a Brookfield Viscometer with a Rotor II configuration at 12 RPM to ensure the precision of the reference data.

*Data Acquisition*

The study subjects consisted of 5 pregnant women (gestational age 26–38 weeks) and 5 non-pregnant women (age range 20–30 years). Although data were collected from all subjects, the in-depth comparative analysis in the results is focused on representative averages to ensure the empirical integrity of the data.

## Results and Discussions

*Device Construction*

The device consists of a viscosity unit made of PVC pipe measuring 18 cm in length and 2.3 cm in diameter, while the pH unit measures 16 cm in length and 1.5 cm in diameter and is made of acrylic plastic; both are connected to the Arduino UNO, with the results displayed on the LCD screen (Figure 1). This prototype comprises three parts: the *input*, i.e. the detection results from the pH and viscosity sensors; data processing, carried out by the Arduino UNO to prevent errors; and the *output*, i.e. the readout displayed on the LCD screen.

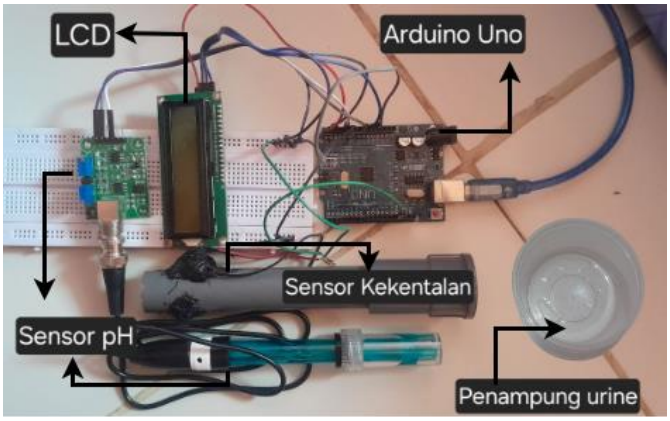



**Figure 1.** The device construction

*Instrument Accuracy Test*

Validity testing was carried out by comparing the prototype's readings against a laboratory standard device. The test results are summarized in the following table 1. This high level of accuracy

indicates that the 10-bit ADC used in the Arduino UNO is adequate for producing linear, precise data for urinary parameters.

**Table 1.** Validity testing

| Sensor Parameter | Mean Error (%) | Accuracy (%) | Status |
|---|---|---|---|
| Sensor pH-4502C | 0.81% | 99.18% | Very Accurate |
| Viscosity Sensor | 0.15% | 99.84% | Very Accurate |

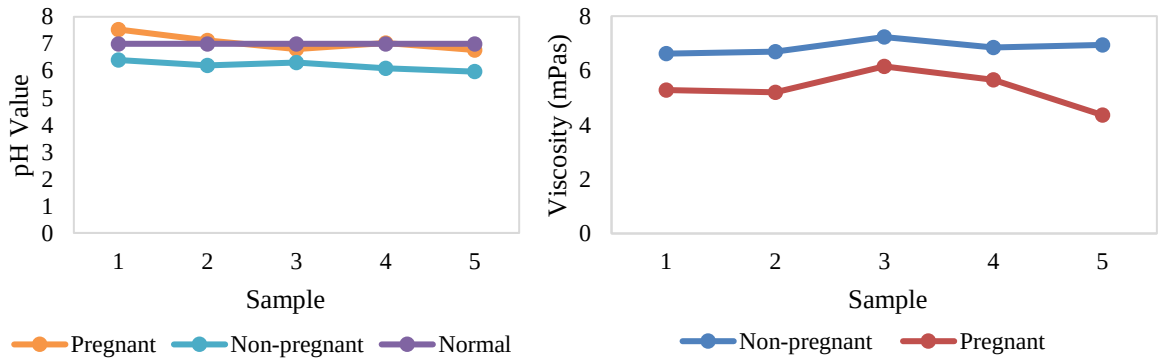
*Sample Comparison Analysis*

The results of implementation on pregnant and non-pregnant urine samples showed the following differences in characteristics show in Table 2.

**Table 2.** The results of implementation on pregnant and non-pregnant urine samples

| Sample Group | Mean pH | Mean Viscosity (mPas) |
|---|---|---|
| Pregnant | 7.05 | 5.33 |
| Non-Pregnant | 6.19 | 6.86 |

Figure 2 show the results of implementation on pregnant and non-pregnant urine samples. On average, pregnant women's urine was more alkaline (pH 7.05) than that of non-pregnant women (pH 6.19). The chart also shows this difference in pH and viscosity, consistent with the theory of Myers et al. (1932), in which the phenomenon is driven by renal compensation for hyperventilation through reduced bicarbonate excretion. Clinically, excessively alkaline urine in pregnant women should be monitored carefully, as it can act as a catalyst for calcium phosphate stone crystallization (urolithiasis) (Ali & Hotasi, 2020).




(a) (b)

**Figure 2.** The results of implementation on pregnant and non-pregnant urine samples

In physical terms, the viscosity of pregnant women's urine was found to be lower (5.33 mPas), indicating more dilute urine. This is supported by Valovska & Pais (2018) regarding the significant increase in *glomerular filtration rate* (GFR) during pregnancy. This decrease in viscosity is a normal indicator of renal adaptation; conversely, urine found to be very concentrated, or a sharp increase in viscosity, may be an early indication of declining renal function associated with preeclampsia risk (Cunningham, 2006).

## Conclusion

This study developed an Arduino UNO-based pH and viscosity sensor prototype with a high accuracy level (>98%). The device proved able to distinguish urine characteristics according to pregnancy status, with pregnant women's urine consistently found to be more alkaline and more dilute, consistent with the physiological parameters of a normal pregnancy.

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**Conflicts of interest**

The authors affirm that they have no conflicts of interest.

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