Revisiting the Physics behind Siphon Action

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ABSTRACT

Siphon action has been in use since ancient Greek times to the present day. The miracle of this attractive and fascinating action has still not revealed the exact mechanism of its operation. In this research project, some experiments are described for correcting the common misconception that the operation of siphon depends. This research article mainly discusses the behaviour of the siphon action at different hydrostatic pressures and different atmospheric pressures. Observed data were analyzed in a MATLAB environment and a Microsoft Excel environment. A combined mechanism in which both gravity and pressure contributing to siphon operation is proposed, but there is no need of pulley analogy model or liquid chain model to explain the siphon action.

1. INTRODUCTION

The Dictionary definition of 'siphon' action has been wrong for nearly a century (Posted by James Kingsland, Monday 10 May 2010, 14.58 BST, guardian.co.uk). This unbelievable statement was published in many news websites which in May 2010 as their headline. So far, the prestigious Oxford English Dictionary and numerous on line dictionaries state much the same wrong definition. The definition in the Oxford English Dictionary, and many other dictionaries, state that atmospheric pressure is the force behind siphon action. But some physicists claim that the dictionary definition of the word "siphon" has been incorrect since 1911, because contrary to common belief, new investigations have shown that atmospheric pressure does not push the liquid up the siphon. But, still there is continuing debate among scientists as to which view is correct. This project aims to investigate the factors related to siphon action of liquids and pin point its real cause.

2. DESIGNING AND CONSTRUCTION

2.1 Pressure Sensor Circuit

To generate the analog signal corresponding to exhalation air pressure MPXV4006G sensor was used and it outputs a high level analog signal that is proportional to the pressure. Output varies through 0.2 V to the 4.7 V due to pressure. The circuit is shown in the Fig. 1. It was fixed on the lower side of the siphon container cap.

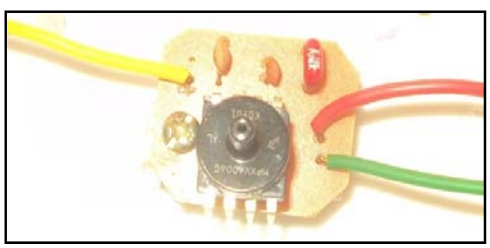

Fig. 1: Pressure sensor circuit

2.1 Siphon container

The container was constructed as part of this research. Exhalation air pressure was needed to be converted into some kind of analogue signal. This was done by using the pressure sensor which is included in the siphon container. It measures the differential pressure when the exhalation air hits the sensor. In order to read this analogue signal, some kind of analogue to digital conversion was needed. As the Programmable Integrated Circuit (PIC) was mostly available and is a familiar device, it was used in the project as an analogue to digital converter. The conversion was done through the PIC microcontroller and the output was fed in to the Personal Computer (PC) through the serial port.

The constructed Siphon container is shown in Fig. 2.

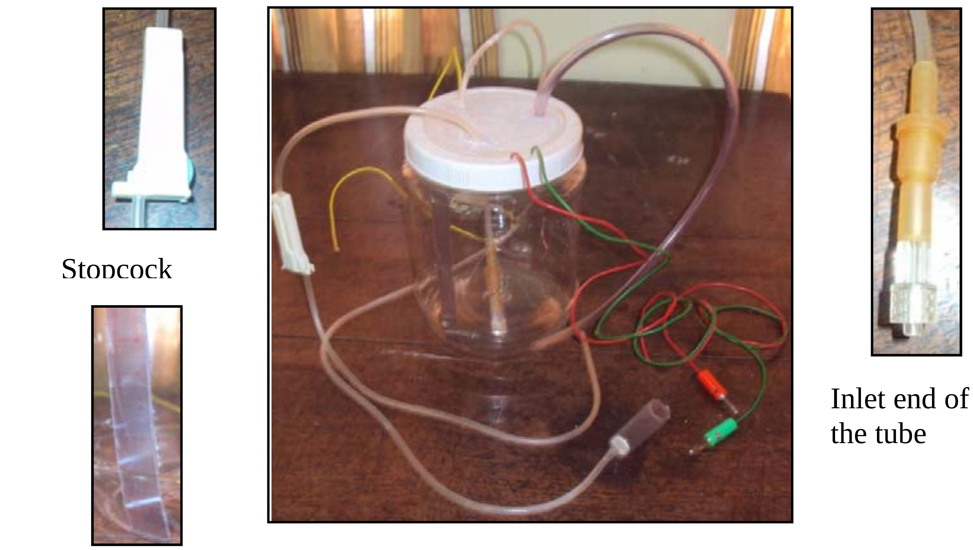

Fig. 2: Siphon container

This siphon container has the following features.

Inlet tube and outlet tube
The inlet tube is used to control the water level which is in the container when operating the siphon. Outlet tube has a stop cock, which can be used to stop and start the siphon when it is necessary.

Pressure controller tube
The pressure controller tube was used to control the air pressure in the siphon container.

Pressure sensor circuit
Pressure sensor circuit is the important part of the container. Its function was, to generate an analog signal to corresponding pressure exhalation in the container.

Vertical meter scale
It was used to measure the vertical height of water which is in the container.

3. EXPERIMENTS AND DATA OBSERVATIONS

3.1 Explaining how hydrostatic pressure affects siphon action

The first experiment was designed to check whether there is any relationship between the hydrostatic pressure and siphon action. This was done by opening the inlet tube and pressure controller tube to the atmosphere. Because of that the inside pressure of the siphon container is equal to atmospheric pressure. When operating the siphon, the water level was decreased then the hydrostatic pressure was varied. At different states of the water level, the mass of the outlet water was measured in a known time period, as shown in Figure 3. The siphon tube was kept in the same way throughout the experiment as shown in Figure 3. The end of the outlet tube was kept at the same height all the time. It did not touch the beaker wall and was not immersed in water. The collected data are shown in Table 1.

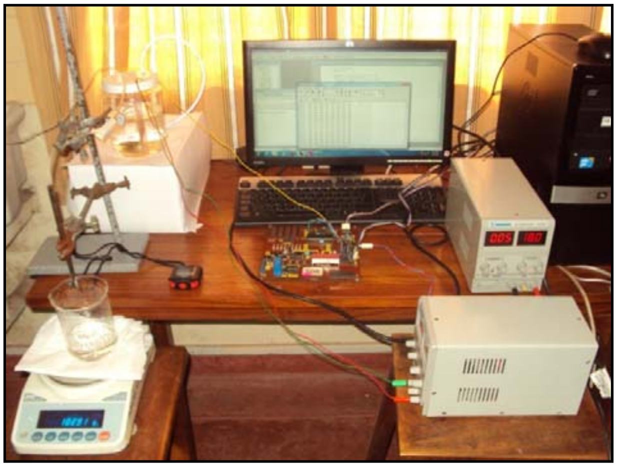

Fig. 3: The experimental setup used to explain how the hydrostatic pressure affects the siphon action

Table 1: Data collection-1

Height of the water level ± 0.05 cm	Collected outlet mass of water within a minute ± 0.01 g
12.00	124.12
11.00	120.89
10.00	117.20
9.00	107.04
8.00	105.18
7.00	99.87
6.00	95.94
5.00	92.55
4.00	88.93
3.00	84.80
2.00	80.15
1.00	74.05

3.2 Explaining how the air pressure on the reservoir affects siphon action

In the second experiment it was attempted to understand the relationship between air pressure in the siphon container and the siphon action. This was done by constructing a constant siphon. The inlet tube was connected to the external tap. This was done to equal the flow rate into the siphon container to the flow rate out to the siphon container while operating the siphon. In other words, the water level in the container is kept constant while operating the siphon. The pressure controller tube was opened to atmospheric pressure. Then the pressure in the container is equal to the atmospheric pressure. The pressure controller tube was connected to the pump, which varied the air pressure in the siphon container when started after the siphon action. Then the outlet flow rate was measured as in the previous case and collected data are shown in Table 2.

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Table 2: Data collection-2

Pressure in the container (kPa)	Mass of outlet water ± 0.01 g	Mass rate of water ± 0.01 g/s
101.326	96.06	1.60
101.424	99.98	1.66
101.522	105.89	1.76
101.620	107.64	1.79
101.718	117.87	1.96
101.816	121.01	2.01
101.914	124.73	2.07

3.3 Explaining how operating time affects the siphon action

In this experiment, the effectiveness of the operating time was tested for the siphon action. In this experiment a constant siphon was constructed, as in the second experiment. The pressure controller tube was opened to the atmosphere. Then the outlet flow rate was measured as in the previous case and collected data are shown in Table 3.

Table 3: Data collection-3

Operating time ± 0.01s	Mass rate of water ± 0.01 g/s	Mass rate of water ± 0.01g/s
30.00	1.95	1.72
60.00	1.92	1.72
90.00	1.96	1.72
120.00	1.94	1.72
150.00	1.93	1.72
180.00	1.95	1.72
210.00	1.94	1.72
240.00	1.96	1.72
270.00	1.93	1.72
300.00	1.95	1.72
330.00	1.95	1.72
360.00	1.92	1.72

3.4 To check whether the results are consistent or inconsistent with chain model explanation of the siphon operation

One or more bubbles were introduced to the siphon tube while operating siphon action. Then siphon action was observed. This procedure was repeated as many times as possible. Siphon action was continued properly, even though a bubble had been introduced in the outlet tube.

4. RESULTS AND DISCUSSION

4.1 Explaining how hydrostatic pressure affects siphon action

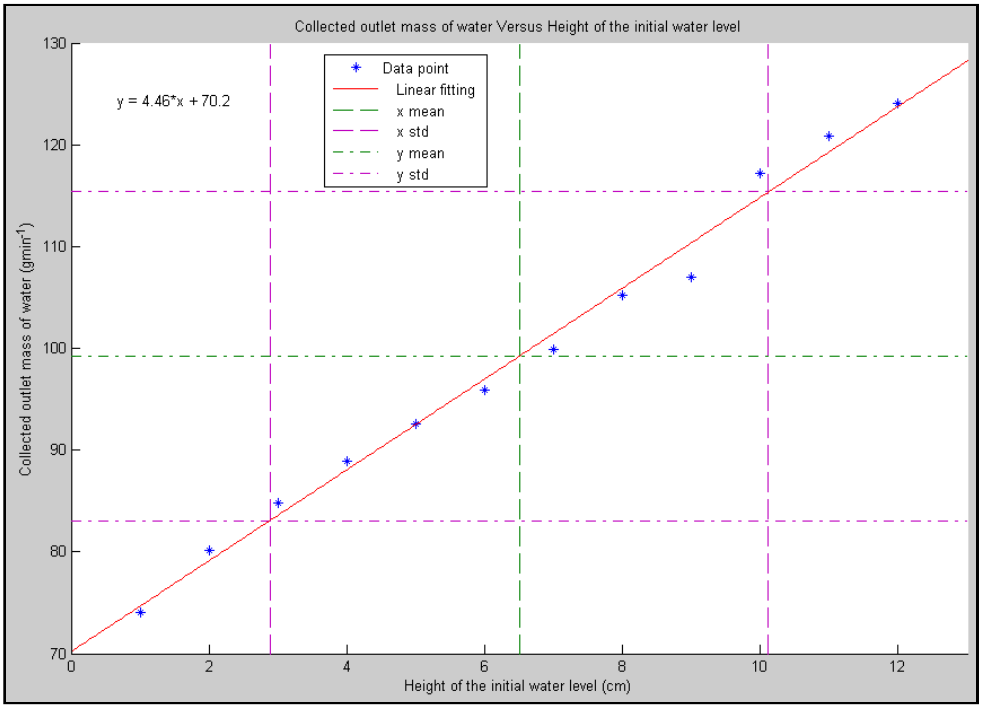

Fig. 4: Collected outlet mass of water versus height of the initial water

According to the observation in experiment 01, it is clear that when increasing the water level of the upper reservoir proportionally increases the outlet mass rate of water. When doing this experiment other related factors were constant. Actually temperature and pressure in the laboratory were constant throughout the experiment. It is of interest to note that the output mass rate of siphon action is proportional to height of the water level. However experiments which maintained a constant siphon had used distilled water at the beginning. So, the affect of dissolved air, foreign matter and tiny air bubbles in these circumstances can be overlooked.

4.2 Explain how the air pressure on the reservoir affects the siphon action

The pressure was varied over a very short range which was higher than the atmospheric pressure. However, it is consistent with pressure driving, due to hydrostatic pressure at the bottom of the siphon container. According to experimental results as shown in Figure 5, it is clear that, when increasing the air pressure in the container, the mass rate of outlet water proportionally increases. Another assumption made is that the vapor pressure of the liquid can be overlooked in that pressure region. Under this condition, it is reliable to suppose that the atomic structure of the water molecules has not changed. Although, it is possible to conclude thus, if the pressure in the container can reduce, definitely the mass rate of water decreases. Finally it is expected that this mass rate will

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be approximately zero, at a critical value of pressure. That means there is some critical pressure value at which the siphon does not operate.

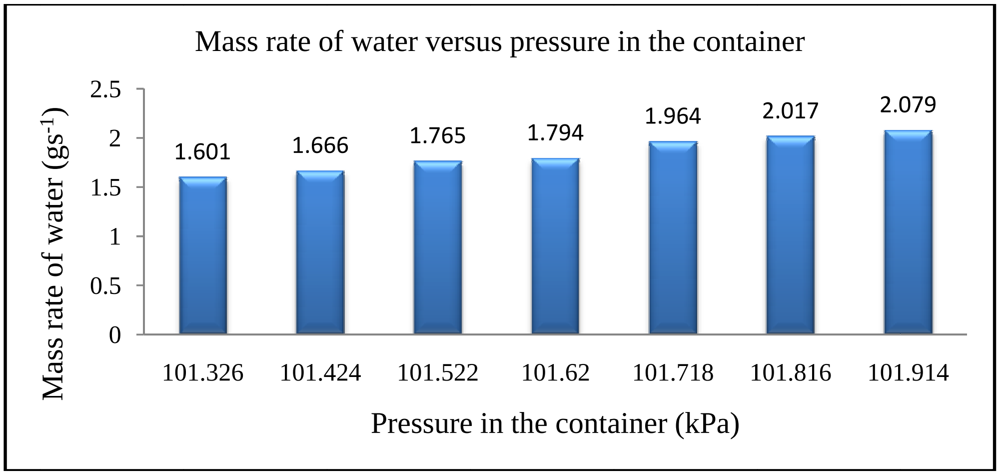

Fig. 5: Mass rate of water versus pressure in the container

4.3 Explaining how operating time affects siphon action

A constant siphon was established when doing this experiment and also the related pressure was constant throughout the experiment. So, all factors were constant throughout the experiment except time. When considering Figure 6, the outlet water rate was constant at each stage. Under this process, effective pressure and gravity remained as constant. The outlet water rate was not changed even though the time passed. According to analyzed data in experiment 03, it is clear that siphon action does not depend on the operating time.

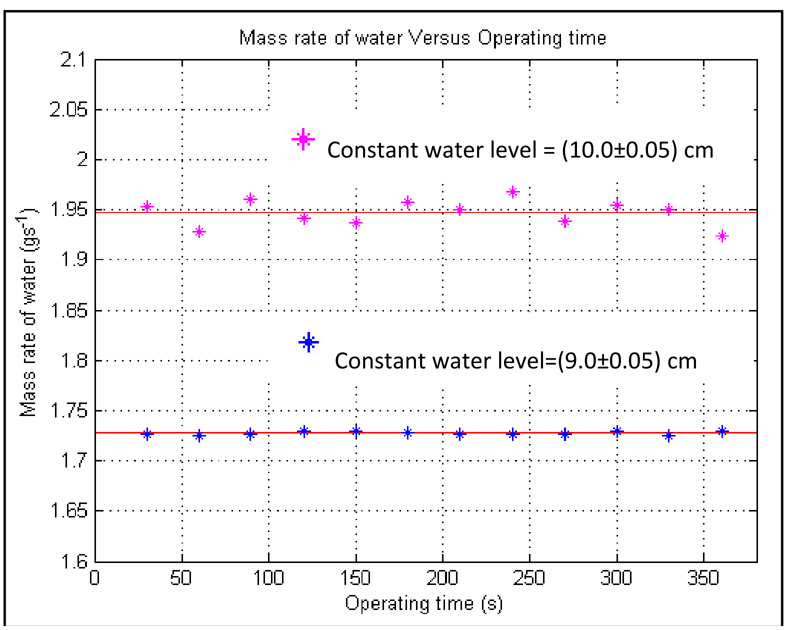

Fig. 6: Mass rate of water versus operating time

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5. CONCLUSION

The conclusion was that a combined mechanism operated in which both gravity and pressure contribute to siphon operation, but without the need of forming a "fluid chain." In further support of this mechanism, the siphon pressure at the siphon bend is below the atmospheric. The new definition for siphon on is proposed as below.

"An inverted 'U' shape pipe or tube which is, placed between fluids with their surfaces at different heights, which continuously transfers fluid over the bend from one end to the other through the combined effects of air pressure and gravity".

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