

Analysis of Liquefied Petroleum Gas (LPG) Sensing With Different Model of Sensor

Salina Muhamad^{a,1} and Firdaus Azhar^{a,2}

^aDepartment of Engineering, Faculty of Engineering and Life Sciences, Universiti Selangor, 45600 Bestari Jaya, Selangor

¹msalina@unisel.edu.my

²ahmadfirdaus_1995@yahoo.com

Abstract: There are a few reported cases in our country regarding Liquefied Petroleum Gas (LPG) leakage explosions that involve a fatality. The LPG gas sensor is established in dealing with the early detection of LPG leaks to minimize their occurrence. However, there are limited studies involving different models of readily available LPG gas sensors other than the MQ-6 gas sensors. Therefore, this research aims to conduct a performance analysis of the other models which are DMQ-9 & MiCS5524 along with the MQ-6 gas sensor itself. Four experiments were conducted and focused on important parameters of gas sensors which are sensitivity, selectivity, sensor response towards the variation of space, and distance. Arduino microcontroller and software were the brains of this study. Fifty millilitres & 100 ml of LPG were used to test the sensitivity of each sensor in 'Experiment 1', while 2 conditions which with and without the presence of smoke were used to test the selectivity of each sensor in 'Experiment 2'. 'Experiment 3' varied the size of the container to observe the sensor response towards the different volumes of space while 'Experiment 4' varied the distance of the sensor from the LPG source. The result obtained indicated that the MiCS5524 gas sensor seems to have the best overall performance compared to DMQ-9 and MQ-6 gas sensors. This study is expected to contribute to the knowledge of the consumer to choose which sensor is the best to use depending on the situation to prevent an LPG explosion.

Keywords: Gas sensor; Liquefied petroleum gas; MQ-6; DMQ-9; MiCS5524

1. Introduction

Liquefied petroleum gas (LPG, which is made up of hydrocarbons such as CH₄, C₃H₈, C₄H₁₀, and others) is widely utilised in both home and industrial settings, as well as a vehicle fuel (Yousufuddin and Mehdi, 2008; Kokula, 2020). As gas is potentially explosive and deadly at greater concentrations, detecting leaks has become critical in averting such mishaps.

There have been a few cases reported locally and internationally regarding this issue (Ministry of Human Resources, 2009). One of the case was believed to have happened when the person involved lit a cigarette and blew out the walls in two bedrooms, a living room and another separating neighbouring unit (Lo Tern Chern and Rena Lim (2019)). The windows of several nearby units were also shattered. The 62-year-old man who sustained serious injuries succumbed to his injuries while warded at Penang General Hospital. Previously, another case was reported in Johor Bahru. A fire and explosion occurred in a storage facility for liquefied petroleum gas (LPG). The storage was in the form of two-story shophouses. One person was killed, one received a bad burn, and four others received minor injuries as a result of the tragedy. The explosion's vibrations were felt over 3 kilometres and caused major property damage. Approximately 400 cylinders with capacities of 14 kg and 15 kg were reported to be in the store during the disaster. Two LPG-filled vehicles parked on the premises were also destroyed.

Table 1 shows the number of accidents in Japan that happened between 1968 and 2017 as well as the number of deaths and injuries. According to the data, the number of accidents climbed significantly during the 1960s and 1970s as the number of LPG-using households increased, peaking in 1979 with 793 accidents and 63 fatalities The High Pressure Gas Safety Institute of Japan (2018).

Table 1. Accident occurrences and casualties by year provided by The High Pressure Gas Safety Institute of Japan

Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Number of accidents	217	299	368	540	497	581	638	570	793	761	714	570	559	545	496	515	401	390	306	262	194	146	112	82	88
Rate to the previous year (%)	0	38	23	47	▲8	17	10	▲11	39	▲4	▲6	▲20	▲2	▲3	▲9	4	▲22	▲3	▲22	▲14	▲26	▲25	▲23	▲27	7
Number of deaths	33	52	59	74	40	65	56	72	63	60	50	43	51	36	35	42	29	37	36	27	13	31	7	3	12
Number of injuries	301	398	389	679	543	523	684	640	825	758	723	650	645	529	550	477	381	336	327	233	171	162	135	83	80

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of accidents	101	68	75	79	78	87	90	120	105	105	219	239	234	185	204	227	260	210	187	182	140	195	212	202	192
Rate to the previous year (%)	15	▲33	10	5	▲1	12	3	33	▲13	0	109	9	▲2	▲21	10	11	15	▲19	▲11	▲3	▲23	39	9	▲4	▲9
Number of deaths	14	6	9	5	8	2	4	7	2	1	0	4	4	4	5	1	1	3	1	2	0	0	1	0	1
Number of injuries	109	64	82	66	73	69	64	86	88	58	78	98	79	148	83	88	85	52	76	60	52	50	46	32	29

Source: The High Pressure Gas Safety Institute of Japan (2018)

Those incidents actually indicate that the installed gas sensor is either not working or not sensitive enough to warn of the gas leakage. The Ethyl Mercaptan, which refers to the substance that is injected into the LPG cylinder to give a strong odour if leaking, seemed not effective enough to overcome this problem. Installing a good and high-quality LPG sensor is very crucial and plays an important role in this issue (Padvi et al., 2021). Therefore, there is a need to conduct research and analyze the performance of available gas sensors. Four experiments were conducted to compare 3 types of available LPG sensors in terms of sensitivity, selectivity, sensor response towards the variation of space, and distance. The result is expected to help consumers to choose the best sensor to use based on the situation/location.

2. Methodology

This research begins by selecting 3 types of LPG sensors that are available on the market, which were MQ-6, DMQ-9 and MiCS5524. The selection of those sensors was based on the ability to detect the LPG as stated by the manufacturer. Mechanism studies for each sensor were then conducted. Based on that, a set of coding was built for each sensor accordingly using Arduino IDE (Integrated Development Environment) as has been reported elsewhere (Rohitha et al., 2023). Next, the research proceeds by conducting 4 experiments to inspect the sensitivity, selectivity, sensor response towards the variation of space, and distance. Fig.1 shows the detailed flowchart for this study. Note that the use of LPG would not exceed 100 ml of concentration as the leakage of LPG gas cylinder will be in low amounts in the atmosphere. Hence, it is better to stick to a low amount of concentration to prove the effectiveness of the sensor.

All experiments were conducted in a 65% humidity environment at 27 °C. Each of the sensors has been preheated for at least 48 hours to make sure it reaches maximum accuracy and stability. The biggest difference in the operating specifications between this sensor is the heating temperature of the sensing material. MQ-6 shows a temperature of 52 °C, while DMQ-9 is at 71 °C and MiCS5524 is at 31 °C. Each sensor also has a different type of sensing material (doping) where Tin Oxide is the main material.

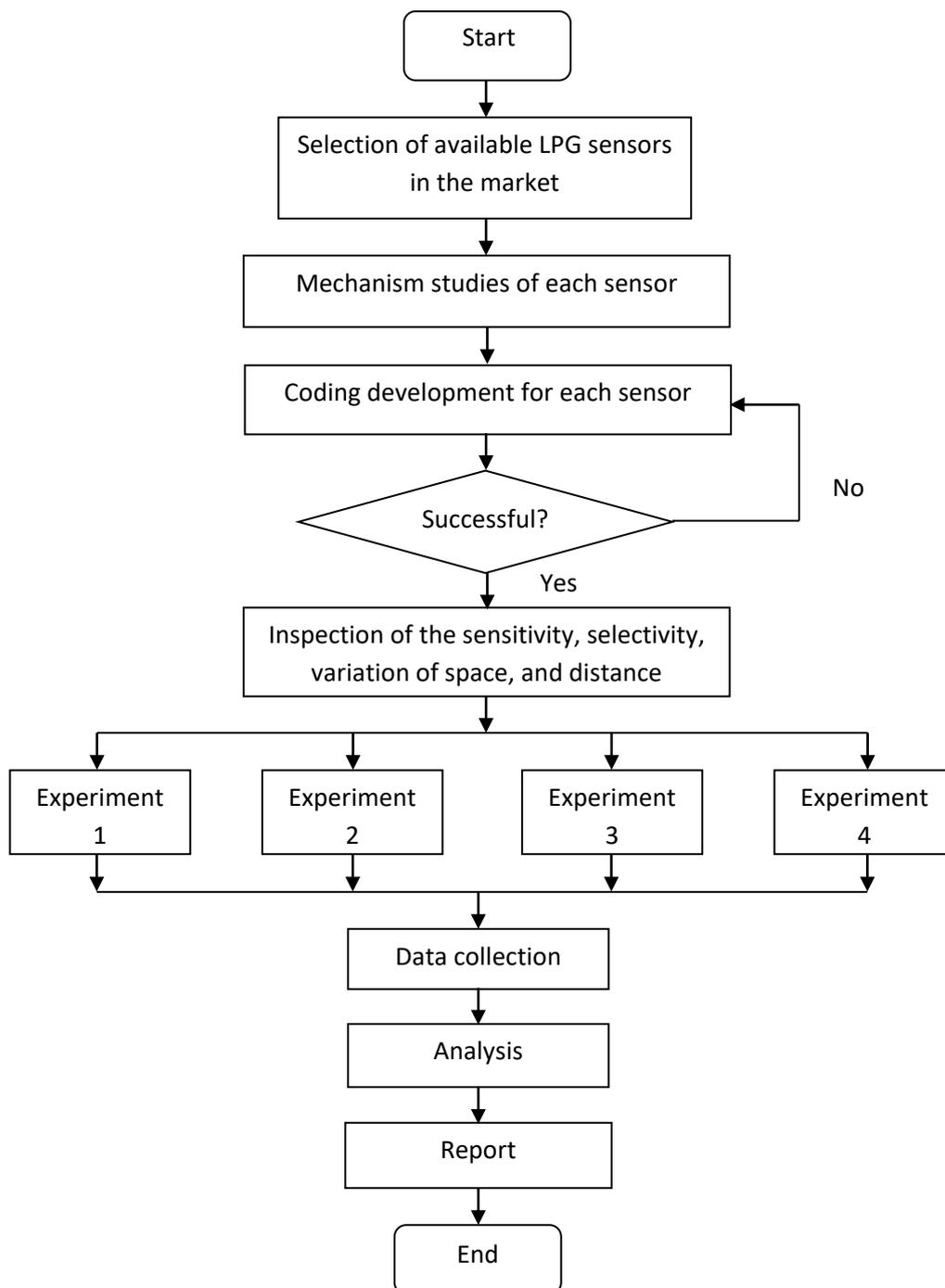


Fig. 1. Research flowchart

2.1 Experiment 1

Experiment 1 is conducted to test the sensitivity of the sensor. The components involved in this experiment consist of sensors, a mini fan, container, LPG gas, syringe, breadboard, Arduino microcontroller and LCD display along with the setup. Airtight

container size of 2.5 L was used as a chamber throughout this experiment. LPG concentration was set at 50 ml and 100 ml. The experiment begins by preheating the sensor for 48 hours before placing it inside the test chamber. Then, LPG gas was injected through the small hole before the mini fan was turned on to ensure the gas circulated evenly inside the container. All measurements will be taken after 10 seconds of injecting gas into the chamber to give some times for the LPG circulation. Each test was performed 5 times to get the average reading.

2.2 Experiment 2

Experiment 2 is about the selectivity test of the sensor. An airtight chamber of 9 L was used throughout the experiment. LPG concentration was set at 100 ml. The experiment begins by preheating the sensor for 48 hours before placing it inside the test chamber. This testing will be divided into two conditions. The first condition was without the presence of the smoke, while the second condition was with the presence of the smoke. Both reading will be taken 10 seconds after the gas being injected into the chamber. Each test will be performed 5 times to get the average reading.

2.3 Experiment 3

Experiment 3 is about sensor response towards the size of the chamber used to observe the changes in concentration detection. An airtight chamber of 2.5 L, 9 L, and 22 L was used throughout the experiment. LPG concentration was set at 100 ml. The experiment begins by preheating the sensor for 48 hours before placing it inside the test chamber. All readings will be taken 10 seconds after the gas is injected into the chamber. Then the chamber size will be switched after the reading of the LPG has been taken. Each test will be performed 5 times to get the average reading.

2.4 Experiment 4

Experiment 4 is about sensor response towards the distance variation of the LPG sensor to the LPG source with different values of resistance. The distance that will be used in this experiment is 5 cm and 10 cm while the resistance value is set at 5k Ohm and 10k Ohm. Basically, the experiment is to show how resistance value manipulation will improve the sensor sensitivity at a certain distance. Once the distance and resistance value have been set, the LPG will be injected using consistent pressure throughout the experiment. Each test will be performed 5 times to get the average reading.

3. Result & Discussions

3.1 Result of Experiment 1

Figures 2, 3 and 4 show the sensors' sensitivity towards higher and lower concentrations of LPG. Fig. 2 shows the performance of MQ-6 which drastically drop at a lower concentration of LPG than at higher concentrations. However, the reading was relatively stable where the range for high concentration was between 2098.35 to 3087.13 ppm. As for the low concentration, the range was between 396.06 to 312.17 ppm. Fig. 3 shows that DMQ-9 is less sensitive at a higher concentration compared to MQ-6 and MiCS5524 but it performed much better in a lower concentration. It also gives a very stable reading throughout the test compared to the other 2 sensors. For higher concentrations, the

range was between 1886.28 to 1647.53 ppm, whereas for lower concentrations, the range was between 1172.14 to 1427.03 ppm. The performance of MiCS5524 is shown in Fig. 4. Unstable reading can be clearly seen at higher concentrations even though the reading shows the best sensitivity among the 3 gas sensors.

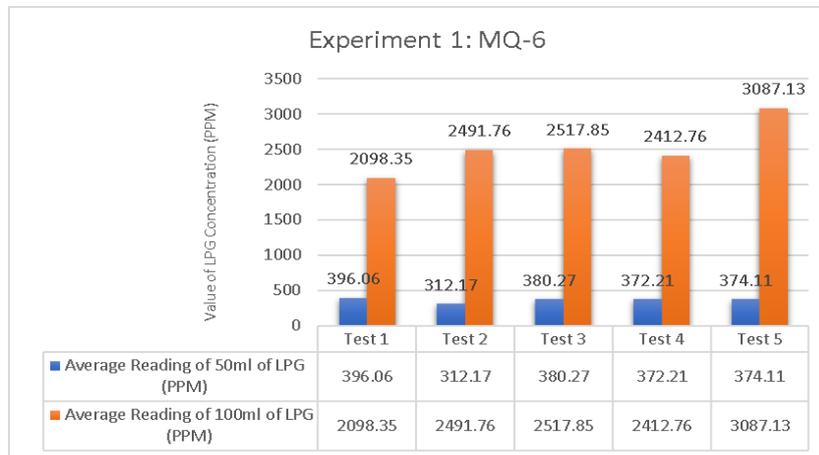


Fig. 2. Volume of LPG concentration detected by MQ-6

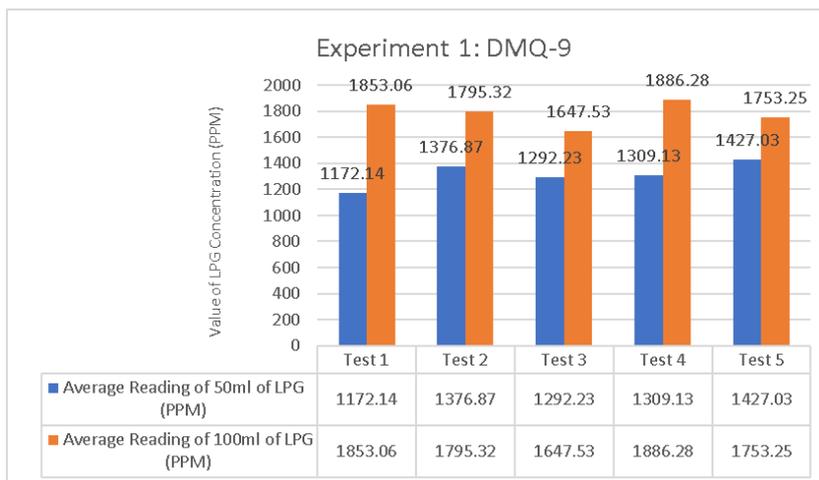


Fig. 3. Volume of LPG concentration detected by DMQ-9

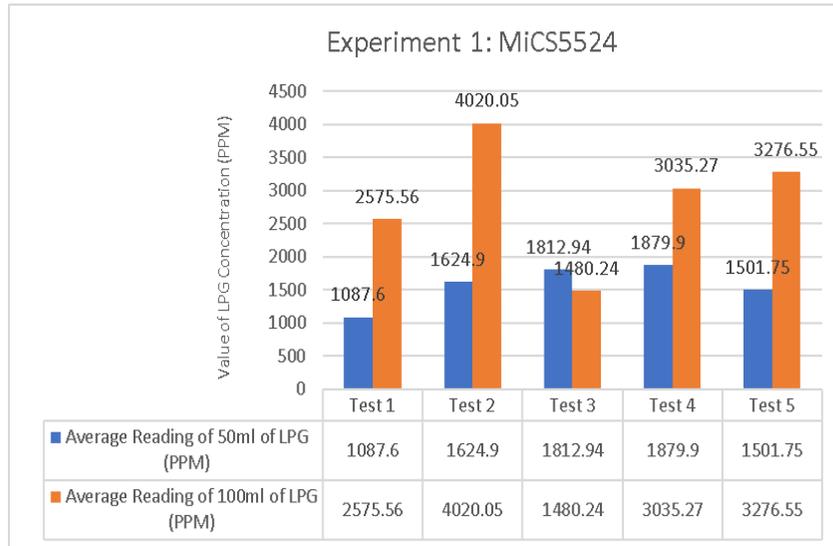


Fig. 4. Volume of LPG concentration detected by MiCS5524

3.2 Result of Experiment 2

Experiment 2 was conducted to observe the sensors' response toward the presence of other substances i.e, smoke. Fig. 5 shows that the MQ-6 gas sensor has a very good selectivity where an insignificant drop in reading was observed after the smoke was introduced. The response of DMQ-9 is shown in Fig. 6 and MiCS5524 is shown in Fig. 7. Both sensors are giving higher readings after the smoke was introduced. This is in accordance with the capability of both sensors to detect other substances and gases including smoke but doesn't have the capability to specify the detected substances. However, closed observation revealed that the reading from MiSC5524 will skyrocket when there are 2 substances on its detection list presence. It seems that for this experiment, MQ-6 is the least affected sensor with the presence of other substances.

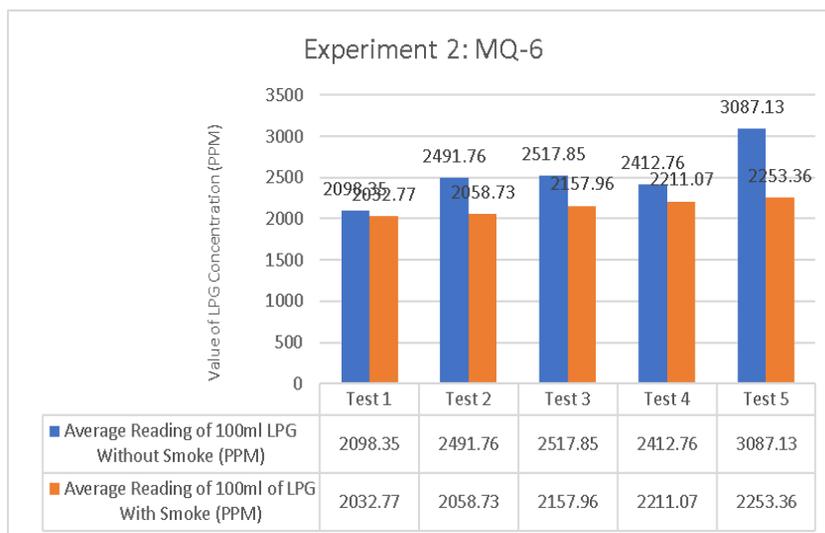


Fig.5. Volume of LPG concentration detected by MQ-6 with/without the presence of smoke

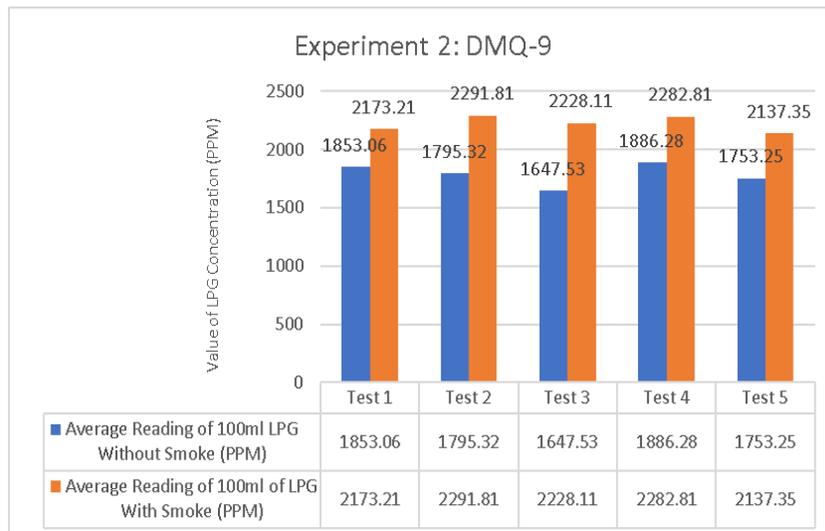


Fig. 6. Volume of LPG concentration detected by DMQ-9 with/without the presence of smoke

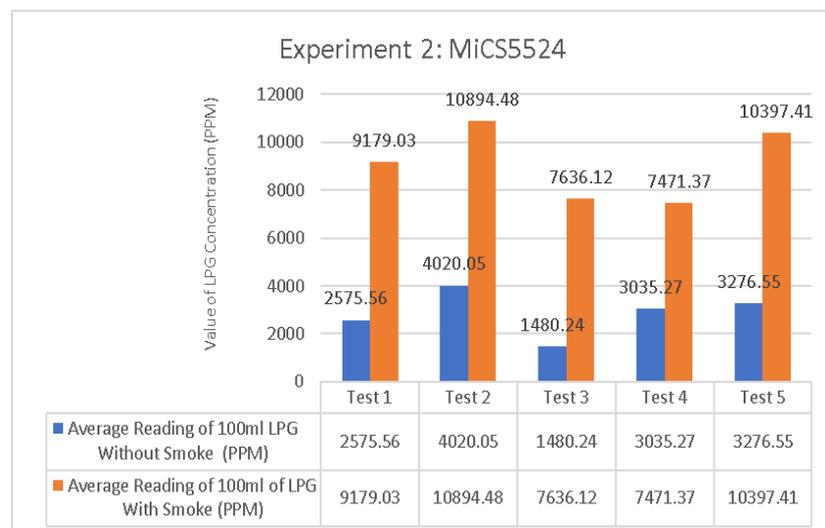


Fig.7. Volume of LPG concentration detected by MiCS5524 with/without the presence of smoke

3.3 Result of Experiment 3

Experiment 3 was conducted to observe the sensor response towards the variation of spaces. The size of containers used was 2.5 L, 9 L and 22 L and the amount of LPG used is 100 ml. Fig. 8 shows the MQ-6 responses where the reading was drastically dropped at a bigger space. A similar pattern was observed for DMQ-9 as in Fig. 9. Meanwhile, MiCS5524 is showing unstable reading as in Fig. 10 but the detection at a bigger space is noticed.

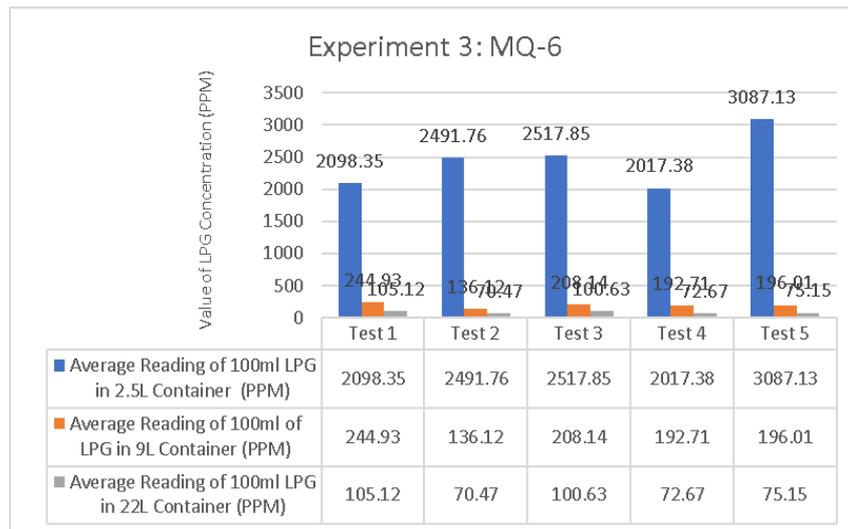


Fig.8. Volume of LPG concentration detected by MQ-6 at various spaces

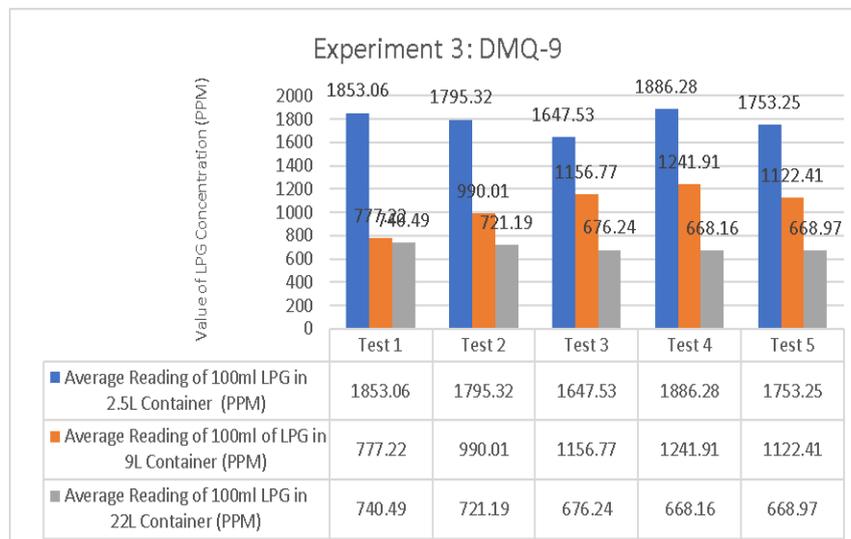


Fig. 9. Volume of LPG concentration detected by DMQ-9 at various spaces

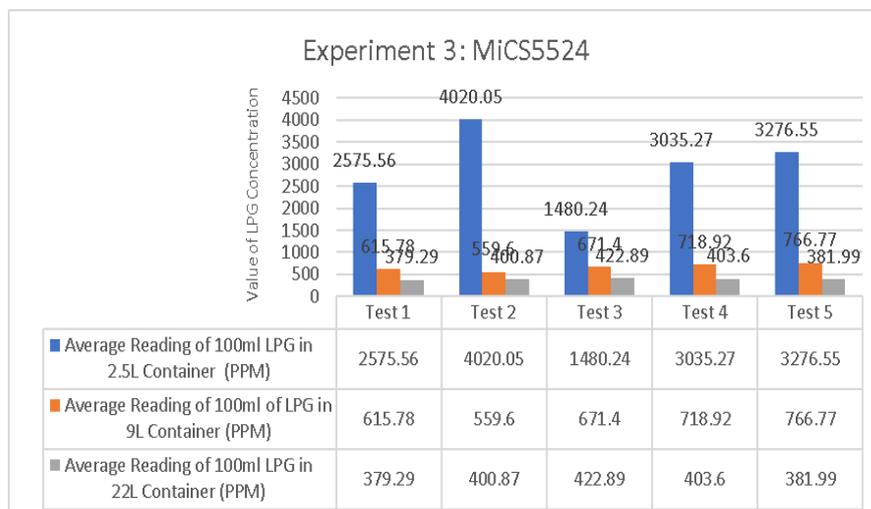


Fig. 10. Volume of LPG concentration detected MiCS5524 at various spaces

3.4 Result of Experiment 4

Experiment 4 was conducted to observe the sensors' response toward distance variation of the gas sensor from the LPG source along with resistance adjustment to see how it affects the sensitivity of the sensor. Fig. 11 shows the response from MQ-6 where the increase in the distance really affects its performance. At 5 cm, the average volume of 3150 ppm was detected and drastically dropped to below 100 ppm when the distance increased to 10 cm. The response of DMQ-9 as in Fig. 12 shows a similar pattern to MQ-6 with better performance at 10 cm of distance. The sensitivity of MiCS5524 as in Fig. 13 is better as compared to those 2 sensors where the reading is noticeable even at 10 cm.

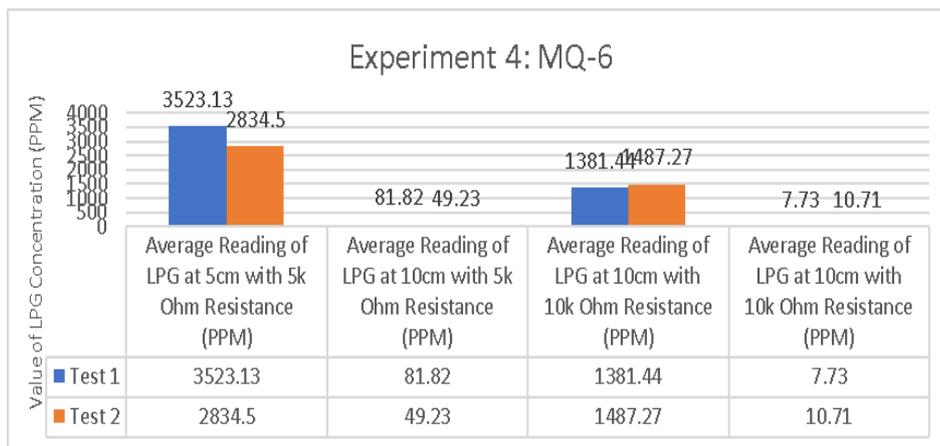


Fig.11. Volume of LPG concentration detected by MQ-6 at distance & resistance variation

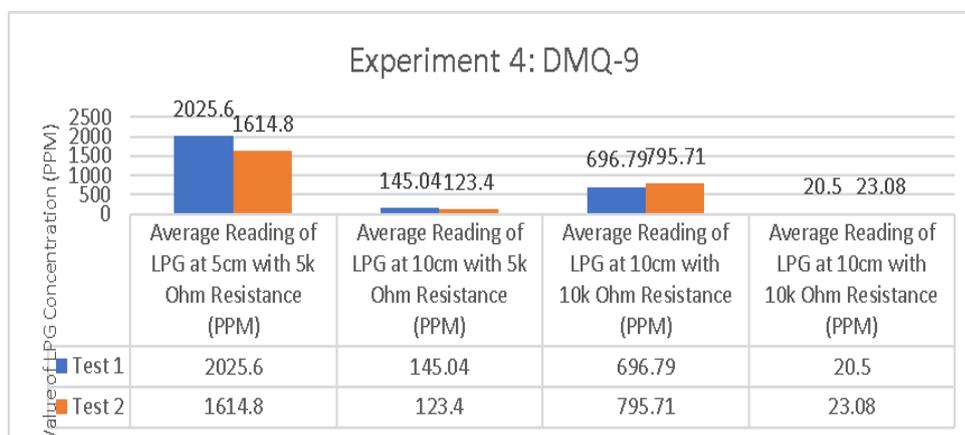


Fig.12. Volume of LPG concentration detected by DMQ-9 at distance & resistance variation

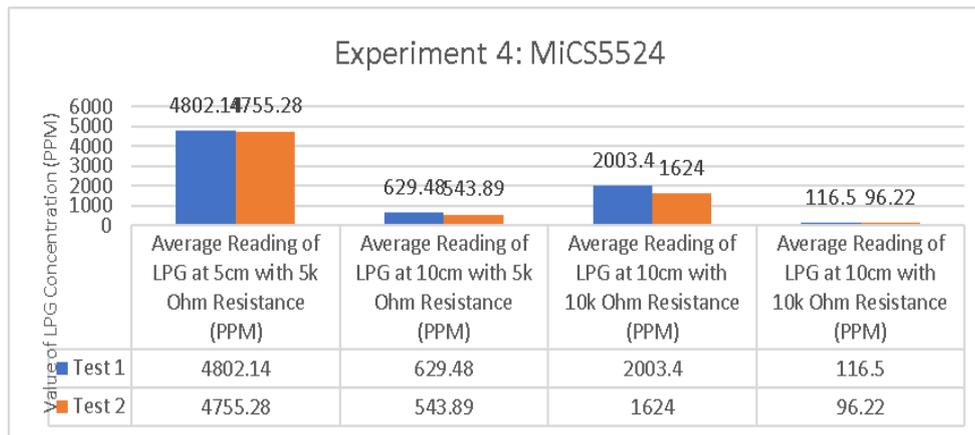


Fig.13. Volume of LPG concentration detected by MiCS5524 at distance & resistance variation

4. Conclusions

Analysis of the LPG sensing using MQ-6, DMQ-9 and MiCS5524 has been successfully conducted. The performance of MQ-6 will drastically drop when the intensity of the LPG is thinning, no matter by lower LPG concentration, bigger space or further distance. However, the MQ-6 gas sensor shows excellent performance in selectivity where the reading is almost unaffected by the smoke. Thus, the MQ-6 gas sensor seems to be the best choice to be placed in the household environment since residential areas usually have a high possibility to be exposed to smoke from burning waste. The disadvantage of this sensor is that it has to be placed very close to the LPG source to ensure the best performance from the sensor.

As for DMQ-9, it shows that the sensor has an opposite performance when compared to MQ-6 where it gives a lower reading in the presence of higher concentration and the opposite for the lower concentration of the LPG. DMQ-9 gas sensor also displays a very stable reading where the difference in the value of each test perform stayed within close range. This sensor seems to be a higher-end choice for a household as it gives better performance in lower concentrations. It also can suit a certain type of industrial premises because of its ability to detect carbon monoxide and methane gas. The disadvantage of this sensor is that it cannot be set to determine what kind of gas it needs to detect. So, the sensor has the possibility to trigger the alarm although it is not coming from the gas or substance that we are concerned about. Similar to DMQ-9, MiCS5524 shows a similar performance. Owing to a doping sensing material, MiCS5524 and DMQ-9 are able to detect multiple gases and substances, showing superior performance, especially in lower concentrations compared to the MQ-6 sensor. Possible doping materials that are used in both sensors are generally from noble metals such as Pt, Pd and Au that are well known for enhancing the sensitivity and selectivity of the gas sensor (Nikolic, 2020). However, MiCS5524 shows unstable readings throughout the experiments. Referring to the results, it can be concluded that DMQ-9 shows the best performance for all experiments.

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