Capturing CO_2, CO, and HC: A Development of Filtering Device for Vehicle Exhaust with Monitoring and Notification Alert System

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Abstract — With the constant rise of vehicle owners over the past years, car pollution, with its exhaust gas emissions, contribute tremendously towards air pollution and global warming. This experimental study was conducted filter the amount of carbon monoxide (CO), carbon dioxide (CO_2), and hydrocarbons (HC) through the use of highly porous adsorbents (activated carbon and zeolites) via a constructed filtering device with a monitoring and notification alert system for vehicle exhaust. The filtering device that is attached to a car's exhaust muffler served as an enclosure for the filtering membranes which contained both the activated carbon and zeolites. The inlet of the device is attached to the muffler where the exhaust gasses enter, gets filtered through, and exits through the outlet where the gas sensors are located. Based on the result, with the filtering device, CO, CO_2, and HC measured an average of 2560 ppm, 74633.33 ppm, and 125.33 ppm vol, respectively. These results imply that the constructed filtering device can filter the exhaust car emissions by almost 50% and can provide accurate monitoring system. It is highly recommended to continue the project into a large-scale production to further promote the intentions of the innovation of the device such as conducting further study about its fabrication and design.

Keywords: *Activated carbon*, *Carbon dioxide*, *Carbon monoxide*, *Exhaust emissions*, *Filtering device*, *Hydrocarbons*, *Zeolites*
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1 Introduction

Environmental pollution, gas emissions, and energy crises remain alarming for most countries which is why many of them are trying to shift towards sustainability. Qatar is a leading fossil fuel producer because it heavily relies on oil and natural gas for its primary energy consumption [1]. The key driver for oil in demand is the transportation sector which comprises road transportation at 88 percent and civil aviation at 12 percent. The spread of human activity reached new heights, affecting the planet's natural environment. The earth's natural processes are being altered. It is well understood that certain gases in the atmosphere, such as nitrous oxide (N_2O), methane (CH_4), tropospheric ozone (O_3), carbon monoxide (CO), and carbon dioxide (CO_2), have increased dramatically over the previous century. Also, as the number of automobiles, factories, and other human activities increases, other gases that are not normally a part of the natural system, such as hydrocarbons (HC), chlorofluorocarbons (CFCs), and other gases, are increasing [2].

Qatar is vulnerable to the negative impacts of response measures as well as the adverse effects and impacts of climate change because its economy is highly dependent on natural gas exports. Data reports from the "Qatar CO_2 emissions" (2020) about Qatar's CO_2 emissions from the transportation sector indicate that Qatar increased from 0 metric tons in 1971, to 12 metric tons in the year 2020 with an annual average growth rate of 9.00%. With that, one of the most popular environmental applications in addressing this problem is through the use of adsorbent materials. It is found that granular activated carbon and zeolites were used for car exhaust emission treatment by assembling filters to be attached to a vehicle as a filtering device. They are feasible for diesel engine emission filtration systems and can remove 80% of pollutants in the exhaust gasses.

Thus, this study utilized activated carbon and zeolites, which are known for their high porous surface area and elemental composition in order to filter our car exhaust emissions from a vehicle. This ultimately leads to the question whether how much can specific adsorbents filter CO, CO_2, and HC.

2 Statement of the Problem

Generally, this study was conducted to create a prototype filtering device for vehicle exhaust with a monitoring and notification alert system. Specifically, it aimed to:

1. Determine the amount of CO, CO_2, and HC before and after using the constructed filtering device.
2. Determine the significant difference between the amount of CO_2, CO, and HC of the constructed filtering device and the Kombi Emission Analyser.
3. Test the notification alert system of the filtering device.
4. Test the monitoring system of the filtering device.

3 Significance of the Study

This study aimed to construct a prototype filtering device which is integrated with various internal filtering membranes that aimed to filter out harmful exhaust emissions such as CO2, CO, and HC. This study would be beneficial to the following entities:

Ministry of Environment and Climate Change. This study provides the Ministry of Environment and Climate Change an innovation towards not only the filtration of gasses such as CO2, CO and Hydrocarbons, which have been proven harmful towards the environment and the primary goal of the aforementioned ministry, which is the concerns of climate change. But also a means of monitoring and notifying the users of vehicles and transportation which is an active variable towards affecting the percentages of harmful gasses towards the environment. These endeavors allow the ministry to operate the primary goal of the preservation of the environment through the control of the issues on climate change.

Ministry of Transport and Communication. This study would open the opportunity for the Ministry of Transport and Communications and other Departments of Transportation to be aware of the amount of exhaust emissions that vehicle owners are producing. Even with the presence of mandatory testing on local emission testing centers, this study alerts the ministry if any of vehicle owners are not abiding to the standardized and accepted levels of car exhaust emissions, thus, mitigating and lessening the adverse impacts of these gasses in our environment when left unchecked.

Vehicle Owners. Having established that this study focuses on car exhaust emissions, vehicle owners can benefit from this study by not only being aware of the effects of their cars' exhaust emissions to the environment but also give them the opportunity to frequently check the status of their cars. Accordingly, this will allow them to abide by the law at any point because they are aware that they are being monitored by governmental bodies.

Academic Institutions. Given that certain amounts of CO2, CO, and HC gasses, to an extent, can be harmful to the environment and people's health, academic institutions can integrate the findings of this study into their curriculum in order to provide exemplifications on related topics found in their learning standards, lessons, assignments, and materials.

Future Researchers. This study would allow future researchers to utilize the findings and other interconnected facts, data, and resources which can aid their own studies. This paper provides a unique set of information that is locally produced and attributed based on the demography and local sources of Qatar.

4 Research Design & Methodology

This study utilized an Experimental Research Design in order to meet the study's objectives. "Experimental design is the process of carrying out research in an objective and controlled fashion so that precision is maximized and specific conclusions can be drawn regarding a hypothesis statement." The researchers wish to establish the effect of the chosen adsorbents to the gasses through a filtration system. This research design under quantitative research is pivotal in order to ensure precision, accuracy, and effectiveness [3].

In constructing the filtering device, metal plates, steel mesh, and pipes were utilized (see Fig. 1). First, the basis in constructing the device was a blueprint created through Blender which included three separate designs: the main box which measured 5.5x10x4 inches, the electrical box which measured 2.5x8x4 inches, and the filtering membranes which measured 5.5x2x4 inches. Along with that, the inlet in the shape of a pipe has a diameter and width of 2 inches, while the cubic outlet has a width and height of 2 inches where both the inlet and outlet are 4 inches long. The aforementioned materials were then measured, cut, and welded together to finally create the device.

For the construction of the monitoring system (see Fig. 2), the Arduino Uno was used as the microcontroller of the device. The SCD30 Sensirion for CO_2 monitoring, the MQ-7 for CO monitoring, and the GSM SIM900 module to send SMS texts were utilized and programmed in Arduino IDE using C++ language.

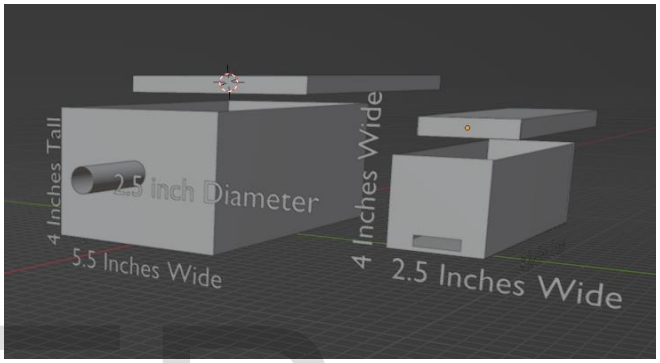

Figure 1. 3D Blueprint of Constructed Filtering Device

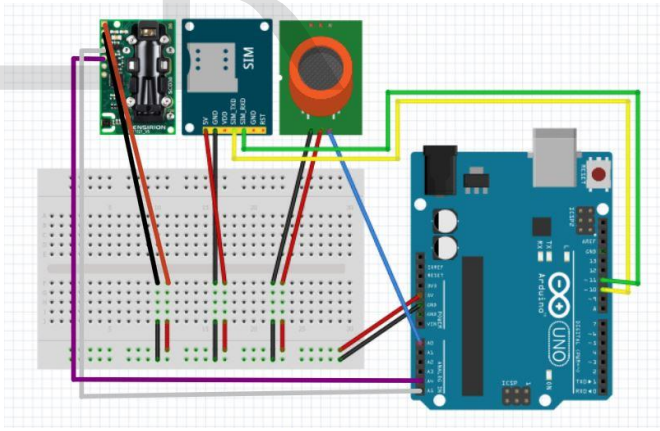

Figure 2. Circuit Diagram of the Notification and Monitoring System

Upon the construction of the filtering device, the experimentation was conducted at Bosche Car Service, a local emission testing center. For the testing of the device, three tests were conducted for each of the pretest and posttest. For the first testing, it focused on measuring the amount of carbon monoxide (CO), the second test for carbon dioxide (CO_2) and the third test for hydrocarbons (HC). Each test was monitored by both the filtering device's monitoring system and the Kombi Emission Analyser.

5 Results and Discussion

Amount of CO before and after using the filtering device

Table 1 presents the pretest findings of Carbon Monoxide (CO) gathered by both the filtering device, and the Kombi Emission Analyzer, which is used as a standard in the emission center. It showcases the threshold at which the %vol and Parts Per Million (ppm) values are present in all three tests conducted at different intervals. Upon conducting three tests, the values obtained from the constructed filtering device were 0.448%vol, 0.446%vol, 0.446%vol, and for the Kombi Emission Analyzer, 0.446%vol, 0.445%vol, and 0.446%vol throughout the three tests respectively. In Parts Per Million (ppm), the values gathered from the constructed filtering device were 4480 ppm, 4460 ppm, 4460 ppm, and 4460 ppm, 4450 ppm, and 4460 ppm throughout the tests, respectively.

Based on the posttest result, it was revealed that in %vol, the posttest values for the constructed filtering device is 0.256%vol, 0.254%vol, and 0.254 %vol, and for the Kombi Emission Analyzer, the values were 0.257%vol, 0.256%vol, and 0.255%vol. In Parts Per Million, the values for the constructed filtering device were 2560 ppm, 2540 ppm, and 2540 ppm. Moreover, the values for the Kombi Emission Analyzer in ppm were 2570 ppm, 2560 ppm, and 2550 ppm throughout the tests, respectively.

These findings implies that the constructed filtering device can filter the amount of CO when attached to vehicle exhaust.

Table 1. Amount of CO before and after using the filtering device.

	Constructed Filtering Device		Kombi Emission Analyzer	
	In %vol	In ppm	In %vol	In ppm
Pretest				
Trial 1	0.448 %vol	4480 ppm	0.446 %vol	4460 ppm
Trial 2	0.446 %vol	4460 ppm	0.445 %vol	4450 ppm
Trial 3	0.446 %vol	4460 ppm	0.446 %vol	4460 ppm
Posttest				
Trial 1	0.256 %vol	2560 ppm	0.257 %vol	2570 ppm
Trial 2	0.254 %vol	2540 ppm	0.256 %vol	2560 ppm
Trial 3	0.254 %vol	2540 ppm	0.255 %vol	2550 ppm

Amount of CO2 before and after using the constructed filtering device

Tables 2 presents the amount of Carbon Dioxide (CO_2). Upon conducting several trials, the values obtained from the constructed filtering device were 7.45%vol (74500 ppm), 7.46%vol (74600 ppm), and 7.46%vol (74600 ppm) throughout the trials respectively. Meanwhile, the values obtained from the Kombi Emission Analyser were 7.46%vol (74600 ppm), 7.47%vol (74700 ppm), and 7.46%vol (74600 ppm) throughout the three tests respectively.

The result implies that the constructed filtering device can filter the amount of CO_2 produced in the vehicle exhaust.

Table 2. Amount of CO_2 before and after using the filtering device

	Constructed Filtering Device		Kombi Emission Analyzer	
	In %vol	In ppm	In %vol	In ppm
Pretest				
Trial 1	15.05 %vol	150500 ppm	15.07 %vol	150700 ppm
Trial 2	15.06 %vol	150600 ppm	15.06 %vol	150600 ppm
Trial 3	15.05 %vol	150500 ppm	15.07 %vol	150700 ppm
Posttest				
Trial 1	7.45 %vol	74500 ppm	7.46 %vol	74600 ppm
Trial 2	7.46 %vol	74600 ppm	7.47 %vol	74700 ppm
Trial 3	7.46 %vol	74600 ppm	7.46 %vol	74600 ppm

Amount of HC before and after using the filtering device

Table 3 presents the amount of HC before and after using the filtering device. Based on the results, it was revealed that the amount of HC produced by the vehicle exhaust upon several trials were 336 ppm, 336 ppm, 336 ppm, respectively. On the other hand, after using the constructed device, it is evident in the result that the filtering device was able to filter the amount of HC produced with a results of 125 ppm, 126 ppm, and 125 ppm, respectively.

These results implies that the constructed filtering device can filter the amount of HC produced in the vehicle exhaust.

Table 3. Amount of HC before and after using the filtering device

		Kombi Emission Analyzer
Pretest		In ppm vol
	Trial 1	336 ppm vol
	Trial 2	336 ppm vol
	Trial 3	336 ppm vol
Posttest		
	Trial 1	125 ppm vol
	Trial 2	126 ppm vol
	Trial 3	125 ppm vol

Difference between the readings of the amount of CO and CO2 of the constructed filtering device and Kombi Emission Analyzer

Table 4 presents the difference between the readings of the amount of CO and CO_2 of the constructed filtering device and Kombi Emission Analyzer. For CO, based on the result, it was revealed that there was no significant difference in the pretest with a probability value of 0.180 which was greater than 0.05 significant alpha. Further, there was no significant difference in the posttest with a probability value of 0.102 which was greater than 0.05 significant alpha.

For CO_2, based on the result, it was revealed that there was no significant difference in the pretest and posttest with a probability value of 0.157 which was greater than 0.05 signifi-

cant alpha.

Thus, these results imply that the readings of the constructed filtering device are comparable to the Kombi Emission Analyzer. This infers that the constructed filtering device can accurately monitor the amount of CO and CO_2.

Table 4. Significant Difference between the Readings of the Constructed Filtering Device and Kombi Emission Analyzer

	P-value	Remarks
CO		
Pretest	0.180	ns
Posttest	0.102	ns
CO2		
Pretest	0.157	ns
Posttest	0.157	ns

Notification alert system of the filtering device

Table 5 presents the notification alert system of the constructed filtering device. Upon several trials, it was revealed that the notification alert system of the device can notify the owner of the vehicle once the amount of CO and CO_2 exceeded with the maximum accepted value.

Table 5. Notification Alert System

	Trial 1	Trial 2	Trial 3	Mode	Interpretation
GSM Sim 900	1	1	1	1	Notified

Scale:
0 - Not notified
1 - Notified

Monitoring system of the constructed filtering device

Table 6 presents the monitoring system of the constructed filtering device. Based on the result, it was revealed that the device can accurately monitor the amount of CO and CO_2 produced in the vehicle exhaust.

Table 6. Monitoring System

	T1	T2	T3	Mode	Interpretation
CO Sensor	1	1	1	1	Accurately Monitored
CO2 Sensor	1	1	1	1	Accurately Monitored

Scale:
0 - Not Accurately Monitored
1 - Accurate Monitored

6 Conclusions and Recommendations

Based on the findings of the study, the following conclusions were formulated:

Activated carbon and zeolites serve as a great adsorbent which could filter out harmful exhaust car emissions such as CO, CO_2, and HC by almost 50%.

The monitoring system of the constructed device, when compared to the Kombi Emission Analyzer, is proven accurate in monitoring the amount of CO and CO_2.

The notification alert system works effectively in sending out SMS whenever a certain maximum accepted value of emission standards is reached.

Based on the conclusion, the researchers highly recommend the following:

Since the study is proven to reduce CO and CO_2 emissions through the use of the filtering device, it is highly recommended to continue the project into a large-scale production to further promote the intentions of the innovation

Second, it is highly recommended to test the individual capabilities of each adsorbent, namely: activated carbon and zeolites

Third, it is recommended to add more types of adsorbents into the filtering membranes with hopes of reducing more levels of these greenhouse gasses

Fourth, it is recommended to conduct tests with regards to mileage in order to assess the longevity and further efficiency of the filtering device

Lastly, to improve the design of the prototype and analyze more cost-efficient ways to mass produce the innovation.

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References

[1] J. Meltzer, N. Hultman, C. Langley (2014), Low-Carbon Energy Transitions in Qatar and the Gulf Cooperation Council Region. Global Economy and Development at Brookings. https://www.brookings.edu/wp-content/uploads/2016/07/low-carbon-energy-transitions-qatar-meltzer-hultman-full.pdf

[2] I. Naser (2020), Development of Emissions Reduction Tube for Diesel Engines. Qatar University, College of Engineering. http://qspace.qu.edu.qa/bitstream/handle/10576/12657/Ihab-Naser_OGSApproved%20Thesis.pdf?sequence=1

[3] A. McIntosh and J Pontius (2017), Chapter 1 - Tools and Skills, Science and the Global Environment, https://doi.org/10.1016/B978-0-12-801712-8.00001-9

[4] Qatar CO_2 Emission (2020), from https://countryeconomy.com/energy-and-environment/co2 emisons/qatar#:~:text=CO2%20emissions%2C%20in%20Qatar%20in, from%20least%20to%20most%20pollutant.

[5] Sarkan, B.; Jas kiewicz, M.; Kubiak, P.; Tarnapowicz, D.; Loman, M. Exhaust Emissions Measurement of a Vehicle with Retrofitted LPG System. Energies 2022,15,1184. https:// doi.org/10.3390/en15031184