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ENHANCEMENT OF PASSENGER SAFETY SYSTEM BY EXTRACTION OF TOXIC GASES FROM CAR CABIN

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Abstract—This paper presents a solution to the growing concern of high concentrations of volatile organic compounds (VOCs) inside vehicle cabins, which pose various health risks to individuals. As individuals spend a significant amount of time in vehicle conditions, they are continuously exposed to a variety of airborne chemicals. The emission of VOCs increases with temperature, but not directly for each mixture, making it a challenging problem to address. To address this issue, a fully automatic system is proposed, consisting of a gas sensor that measures the VOC levels inside the vehicle cabin and compares them with pre-programmed exposure standards in an Arduino processor. If the VOC levels exceed the standard, the Arduino signal activates the power window motor and AC fan simultaneously, rapidly extracting the harmful VOCs present in the cabin. By implementing this system, individuals can minimize their exposure to harmful chemicals while commuting, improving their overall health and well-being.

Index Terms—MQ-138 gas sensor, Volatile Organic Compound, Cabin Environment, Material Emission, Air Pollution, Health Risk Assessment

INTRODUCTION

Vehicle cabins are an integral part of our daily lives as we spend a significant amount of time commuting to work, running errands, and engaging in various activities. While we spend only a fraction of our day inside vehicles, the health risks associated with in-cabin air quality cannot be ignored, especially about certain pollutants.
To assess the severity of this issue, several vehicles of varying makes, models, and ages were selected, and the concentrations of volatile organic compounds (VOCs) were measured under uncontrolled conditions. For instance, Zhang et al conducted a study where they estimated the levels of benzene, toluene, xylene, and formaldehyde in 822 vehicles parked in an underground garage.

High levels of VOCs in vehicle cabins have been a growing concern due to their potential health risks. The emission of VOCs increases with temperature, making it a challenging issue to address. In this paper, we propose a fully automatic system that utilizes a gas sensor to measure VOC levels inside the vehicle cabin and compares them to pre-programmed exposure standards in an Arduino processor. If the VOC levels exceed the standards, the Arduino signal activates the power window motor and AC fan simultaneously, rapidly extracting the harmful VOCs present in the cabin.

By implementing this system, individuals can minimize their exposure to harmful chemicals while commuting, improving their overall health and well-being. The paper also examines existing

data on the effects of VOCs inside vehicle cabins and determines the time taken for the extraction of VOCs using this method. "Source apportionment of volatile organic compounds (VOCs) in vehicle cabins diffusing from interior materials. Part I: Measurements of VOCs in new cars in China." Building and Environment 175 (2020): 106796.Kadiyala

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These references provide valuable insights into the growing concern about in-cabin air quality and the associated health risks. Lv et al. measured the concentrations of VOCs in new cars in China, while Huang et al. investigated the influence of temperature and vehicle age on long-term VOC emission rates in a new electric vehicle.

Kadiyala and Kumar developed a methodology to identify and rank the important factors affecting in-vehicle particulate matter, while Xu et al. reviewed the air quality inside motor vehicle cabins. Riediker et al. assessed exposure to particulate matter, VOCs, and other air pollutants inside patrol cars.

These studies contribute to our understanding of the sources and effects of VOCs and other air pollutants inside vehicle cabins, highlighting the need for effective solutions to minimize exposure and improve in-cabin air quality.[1-5] The test vehicles were found to have significant levels of aliphatic mixtures, aromatic mixtures, and aldehydes, which were identified as the major VOCs. The concentration of TVOCs in the vehicles was found to reach as high as 8000 µg/m3.

Analysis of the examination results revealed that the main VOCs detected in the test vehicles were aliphatic mixtures, aromatic mixtures, and aldehydes. Additionally, the concentration of TVOCs in the vehicles was measured as high as 8000 µg/m3.
Aliphatic mixtures, aromatic mixtures, and aldehydes were identified as the primary VOCs in the test vehicles, according to the examination results. The TVOC concentration was found to be as high as 8000 µg/m3 in these vehicles.[6-7] Four common materials used inside vehicles (leather seats, dashboard, pillar, and ceiling) were found to emit high levels of VOCs in the cabin. Carbon monoxide, aldehydes, hydrocarbons, and several metals (Al, Ca, Ti, V, Cr, Mn, Fe, Cu, and Sr) were also detected at elevated levels inside the vehicles, with roadside levels higher than ambient levels.

The floor covering, made from a variety of materials, is a woven composite that may share molecular similarities with flammable fluids and can release numerous volatile compounds when exposed to heat.The vehicle cabin emits VOCs from four frequently used interior materials (leather seat covers, dashboard, pillar, and ceiling).

Elevated levels of carbon monoxide, aldehydes, hydrocarbons, and various metals (Al, Ca, Ti, V, Cr, Mn, Fe, Cu, and Sr) were measured inside the vehicles, with roadside levels higher than ambient levels. The floor covering is a woven composite made from various materials, some of which are of petrochemical origin and may have similarities with flammable fluids. When exposed to heat, these materials can decompose and release multiple volatile compounds.

Within the vehicle cabin, four commonly used interior materials (leather seat covers, dashboard, pillar, and ceiling) were identified as sources of VOC emissions. High levels of carbon monoxide, aldehydes, hydrocarbons, and numerous metals (Al, Ca, Ti, V, Cr, Mn, Fe, Cu, and Sr) were detected in the vehicles, with roadside levels exceeding ambient levels. The floor covering is composed of a woven composite of different materials, including some petrochemical-based ones that share similarities with ignitable fluids. Upon exposure to heat, these materials can break down and release various volatile compounds.[8-11]. Several researchers have found that CNTs are capable of effectively 78 adsorbing volatile organic compounds (VOCs), particularly acetone and benzene[12]. Some of the components of VOCs, such as benzene and trihalomethane, have been considered dangerous and toxic to humans, as they have the potential to cause immune imbalance and harm to the central nervous and hematopoietic systems[13-18].

Based on the test results, the typical ratios for benzene, toluene, ethyl benzene, and xylene were determined as 1.0/4.3/0.7/1.4 [19-22]. Previous studies have indicated that the levels of volatile organic compounds (VOCs) inside the cabins of new vehicles are notably higher than those found in older vehicles. Additionally, there are significant discrepancies in the concentrations among new vehicles[23-24]. The study aimed to identify the typical VOCs found inside new vehicles and their contribution to TVOC, rather than conducting a comprehensive assessment of human exposure. The authors hope this screening will prompt more advanced research on chemical exposure in the cabins of new vehicles[25].The results could offer valuable insights into the characteristics of indoor VOCs, their presence in households, and associated health risks. Specifically, the study revealed that indoor remodeling introduced hazardous chemicals that could pose health risks during certain periods [26]. The intentional amounts of lower aliphatic carbonyl compounds were significantly above the threshold values for odor detection, especially for acetaldehyde, acrolein, and butyraldehyde. Therefore, these compounds may be responsible for unpleasant odors, including those resembling burning and foul smells[27].Assuming that the VOCs emanating from the residue affect the perceived smell, it is evident from the thermodesorption tests that the combined VOC emissions exceed the odor threshold. This confirms the results of both the sensory and chemical tests, although the emission levels were significantly higher in the thermodesorption studies than in the ventilation studies, and it has been reported that the odor response to the additive decreases at high concentrations[28].

The results indicate that pyrolysis during carbonization produced complex mixtures of volatile organic compounds, including carboxylic acids and phenolic compounds[29]. Six VOCs (hexanal, heptanal, benzaldehyde, nonanal, acetophenone, acid) common in estimated vehicles and ethyl acetate, butyl acetate, and butanol can cause an olfactory response under specific conditions[30-32]. There are notable differences in air quality between the inside of vehicle cabins and other indoor environments such as homes, which are linked to the characteristics of VCs present in vehicles. Identifying VOCs that are specific to vehicle cabins and rare or absent in other indoor environments can provide insights into unique features of in-cabin VOC sources. To investigate air quality literature, eight representative studies were reviewed, which included VOC field surveys of 3,881 homes in seven different countries. These studies provide information on VOC emissions and concentrations in the surveyed homes, with reported VOC numbers ranging from 8 to 193 and an average of 54 VOCs per study.[34=40]

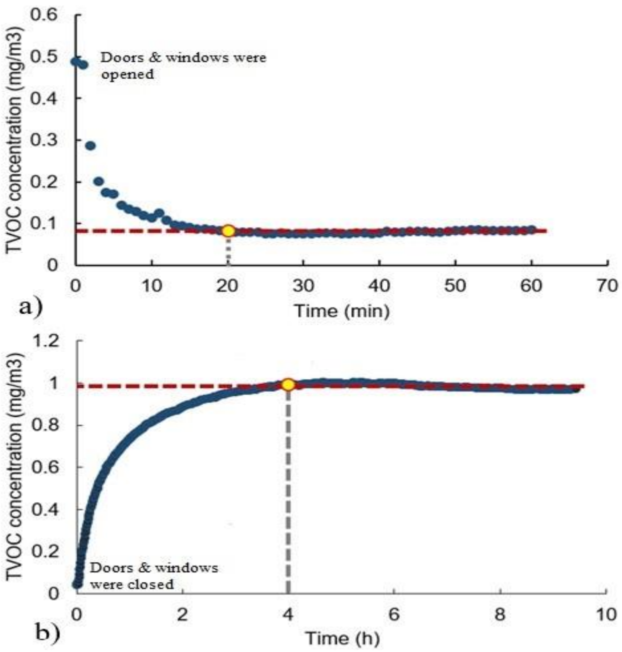

Fig.1. The variation of in-cabin TVOC concentration with time when vehicle was a) ventilated and b) closed in pre-experiment.

W. Huang et al. To obtain the VOC emission rates, the air exchange rates for each measurement were measured [3].

METHODOLOGY

A. Schematic Layout

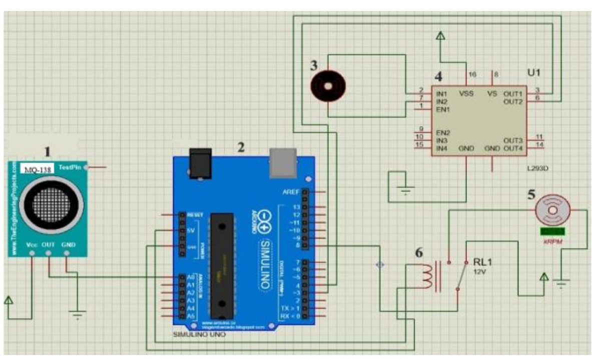

Fig. 1.Sc layout of prototype

- MQ-138 Gas Sensor:
- Arduino UNO
- Fan
- Motor Driver L293D
- DC Motor

B. Working Principle

This article presents a fully automated system that utilizes an MQ-138 gas sensor to measure the concentration of major volatile organic compounds (VOCs) inside a vehicle cabin. The sensor output is compared with a programmed standard level of human exposure using an Arduino (UNO). If the measured concentration exceeds this level, the power window motor and AC fan are activated simultaneously, with the fan operating at full speed. The high-speed airflow from the vents pushes the VOC-laden air inside the cabin out through the open windows. During this process, all AC vents in the car must be open, while the AC compressor cannot be activated.

AIR FLOW VELOCITY SAMPLING

Fig.2. Measuring air flow velocity from vents.

Arbitrary private vehicle Toyota Etios Liva- Gd, 2012 model with five seats is chosen for examination of air flow velocity produced by AC fan. By using the Anemometer instrument velocity of the air blown from individual vents has been noted in the below table.

TABLE I
READING TAKEN FROM INDIVIDUAL VENTS.

SI.NO	AC VENTS	AIRFLOWVELOCITY (m/s)
1.	VENT 1	7.2
2.	VENT 2	8.5
3.	VENT 3	8.9
4.	VENT 4	6.6

Average air velocity from vents =7.8 m/s

From the above table we can see the fluctuated values of air velocity blown from individual vents. So by considering the average air velocity of the respected four vents ,the calculation for time taken to extract the gas from the vehicle cabin has been calculated below.

CALCULATION

Sample car chosen: Toyota Etios Liva - Gd (2012)

Volume of the cabin (V) = 2729(lit) or $2.729m^3$

Area of discharge (A) = (0.42x0.05) x4 = $0.084m^2$

Average velocity from AC vents (v') = 7.8m/s

Rate of discharge (Q) = Av' (or) Q= V/t

Q = Av' = 0.084x7.8 = $0.6552m^3/s$

Q =V/t

t= V/Q = 2.729/0.6552 = 4.16s

Time taken to extract the VOC gas inside cabin: 4.16

COMPONENTS

A.MQ-138 Gas Sensor:

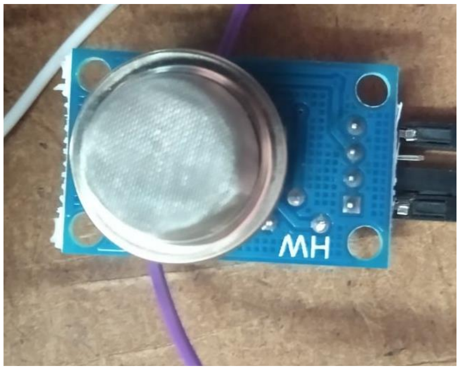

Fig. 3.MQ-138 gas sensor.

Delicate material of MQ138 gas sensor is SnO2, which with lower conductivity in clean air. At the point when VOC gas exists, the sensor's conductivity gets higher alongside the gas focus rising. Clients can change the difference in conductivity over to compare yield sign of gas focus through a straightforward circuit. The MQ138 gas sensor has high affectability to benzene, toluene, liquor, methanol, additionally can screen hydrogen and also other organic vapours well. It can distinguish sorts of organic gases and is a sort of minimal cost sensor for sorts of uses. It has great affectability to natural fume gas in wide reach, and has benefits like long life expectancy, minimal effort and basic drive circuit etc. It has great affectability to organic vapour gas in wide reach, and has benefits like long life expectancy, ease and straightforward drive circuit etc.

PROTOTYPE

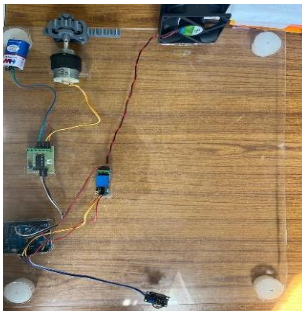

Fig. 2.Actual image of prototype.

We have designed a prototype based on this concept using a MQ-138 gas sensor, (UNO) microprocessor, AC fan and power window setup using DC motor with the power supply of 9V battery source and 12v adapter. This kit demonstrates the actual working concept in a car.

The Arduino UNO is the best board to begin with hardware and coding. The UNO is the most utilized and recorded leading body of the entire Arduino family. It contains all that expected to help the microcontroller; just associate it to a PC with a USB link or force it with an AC-to-DC connector or battery to begin.

VII.CONCLUSION

The objective of this study is to take the crucial first step towards VOC source distribution, which involves identifying the specific VOC species that require attention, as well as their concentration levels in vehicle cabins. To achieve this goal, a sample prototype was introduced and field testing was conducted to measure the air flow velocity within a selected private-use vehicle. The time required for the extraction of commonly occurring VOCs inside the cabin was determined, and the following conclusions can be drawn from this investigation:

- The MQ-135 gas sensor is utilized to measure the concentration of highly volatile organic compounds like benzene, toluene, and xylene present within the vehicle cabin.

- The average time required to remove commonly emitted VOCs from the cabin of the selected private vehicle based on the field examination of air flow velocity is 4.16 seconds.

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