

Estimating precision and accuracy of GC-TCD method for carbon dioxide, propane and carbon monoxide determination at different flow rate of carrier gas

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Abstract

Investigation on precision and accuracy of gas chromatography equipped with thermal conductivity detector (GC-TCD) method for the measurement of CO₂, C₃H₈, and CO as pollutant models at different flow rate of helium (He) carrier gas ranging from 17.50 to 36.25 ml/min were conducted. It was found that percentage of relative standard deviation (%RSD) values for both precision and accuracy show an overall gradual decrease as the carrier gas flow rates increased up to 25 ml/min. After that, the %RSD was found to increase with a further increase in the flow rate. These findings indicate that the flow rate of 25 ml/min was found to be the most precise and accurate level among all flow rates tested under experimental conditions of this study. While the %RSD values obtained at all flow rate are given in details. Consequently, our results suggest that the flow rate of carrier gas was a determining parameter for varying the precision and accuracy of the GC-TCD method. Owing to the fact that carrier gas acts as a transporter of components of the mixture in the form of vapor or gas through the column, setting of the flow rate of carrier gas should in proper level to achieve a precision and accuracy of the GC-TCD method.

Keywords: precision, accuracy, gas chromatography, vehicle emission, pollutant.

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High concentrations of air pollutants emitted during vehicle and industrial operations are of great concern because they play an important role in atmospheric environment. Some common pollutants found in atmospheric environment include oxides of nitrogen, sulfur dioxide, carbon dioxide, carbon monoxide, volatile and persistent organic compounds [1–3]. The presences of those harmful substances have significantly decreased the air quality, which create serious human health concerns. For people who live under poor air quality, the pollution has the potential for serious adverse health effects such as human respiratory ailments like asthma and bronchitis [4], immaturity health effect like loss of children's IQ point and babies born with birth defects [5,6], and the risk of life-threatening conditions like cancer all leading to decrease in the human life expectancy [7].

Continuous increase of the air pollutant concentrations in the atmospheric environment has devised the more stringent of regulations with the purpose to keep the concentration at allowable levels. However, the more stringent of regulation alone might be not

enough to ensure an adequate protection of atmospheric environment, but an efficient control of the regulation via regulatory monitoring programs and its enforcement are also crucial. In conjunction with enforcement of the regulatory monitoring programs, the usage of analytical chemistry instrument for gaseous pollutant measurement remains of vital importance. In the area of concern, several analytical chemistry techniques having reliable and rapid procedure have been exploited such as those based on chromatography [8], infrared spectroscopy [9], fluorometry [10], and ring down spectroscopy techniques [11]. Among others, the chromatography-based technique is one of the most preferred techniques over the last century owing to its distinct advantages including separation of very complex mixtures, relatively simple equipment, procedures that are applicable to a broad spectrum of chemicals, and adaptable to micro- and macro-size samples [12]. Nowadays, the gas chromatography (GC) is easily available worldwide to both government and private sector including university, research institute and industry. In spite of the progress that has been made, there is still effort remaining that can be directed toward development of GC applications for gaseous pollution measurement. Practically, to achieve high quality results from a GC measurement, several conditions must be taken into account during its operational like detector temperature, oven temperature, and flow rate of carrier gas [13]. Among others, carrier gas is one of the most

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important one. Results from our preliminary study (data not shown here) show that the GC's key parameters (such as peak area, peak height, retention time, detector response, and resolution) are highly affected by flow rate change of the carrier gas [14]. It is in very good agreement with some experimental results as can be found in literatures [13,15,16]. Despite the fact that experimental studies related to the effects of carrier gas flow rate on the GC's key parameters have been well-documented, exploring the effect of flow rate of carrier gas on precision and accuracy in the GC method is still facing challenges. It might be an acceptable idea that modification of the flow rate of carrier gas may lead to significant change the separation efficiency and effective speeds of transport. In addition, understanding how rate modifications of carrier gas flow is generally designated to achieve a high-quality measurement results that is otherwise unreliable.

In previous investigations, the use of He as carrier gas in the application of gas chromatography equipped with thermal conductivity detector (GC-TCD) method has been mainly addressed at constant flow rate including 11.3 [17], 20 [18], 23 [19], 25 [20], 30 [21] and 35 ml/min [22]. Nevertheless, to our knowledge, there is no reported study focusing on the effect of flow rate of He carrier gas on the precision and accuracy of GC-TCD method. Hence, the effects of flow rate of He carrier gas on precision and accuracy of GC-TCD method is experimentally investigated in this study. The flow rate range of He carrier gas investigated herein was 17.5–36.25 ml/min with 3.75 ml/min intervals. To achieve the study purposes, three component of gaseous vehicle emission including carbon dioxide (CO₂), propane (C₃H₈) and carbon monoxide (CO) were used as practical example and investigated using GC-TCD. These three gaseous pollutants were used because they are listed by the United Nation as the technical requirements for the type approval of motor vehicles, which is further adopted by Indonesian Government for vehicle emission standard requiring reporting and testing of both new [23] and used car [24].

EXPERIMENTAL

Materials

Two different cylinders of gravimetric certified standard gas mixtures (SGM) in N₂ matrix were purchased from a commercial available source (MESA specialty gas company, USA). One SGM (denoted as SGM-A) containing mixture of 2.18 mol% carbon dioxide (CO₂), 1.81 mol% propane (C₃H₈) and 3.44 mol% carbon monoxide (CO) was used as test standard in all experiment runs. Another SGM (denoted as SGM-B) containing mixture of 4.14 mol% carbon dioxide (CO₂), 0.65 mol% propane

(C₃H₈) and 0.94 mol% carbon monoxide (CO) was only used as test sample during method accuracy assessment.

GC instrumentation system and operating conditions

The GC instrumentation used was Agilent model 6890 series (Agilent, CA, USA) equipped with a single stage dual-packed column (Figure 1) for separating the target gas component (CO₂, C₃H₈, and CO) from their mixture. In such dual-packed column, a packed J&W porapak Q column (6 ft×1/8 in o.d.×2 mm, 80–100 mesh particle size) was connected in series to a packed J&W molsieve 5A column (9 ft×1/8 in o.d.×2 mm, 80–100 mesh particle size). The detection was performed by using a thermal conductivity detector (TCD) and the output signal was monitored using OpenLAB CDS Chemstation version A.2.3.57, which is installed on a HP personal computer (HP Pavilion Slimline 400 PC series). For introducing the gas sample into the GC system, a Brooks 5890E mass flow controller (Brooks Instrument, Hatfield, PA, USA) was used to ensure a consistent sample flow. The mass flow controller (MFC) was installed just before the injection system consisted of a stainless steel tubing having 1/16 in in diameters up to the loop inlet, a 2 ml stainless steel loop (Agilent, CA, USA).

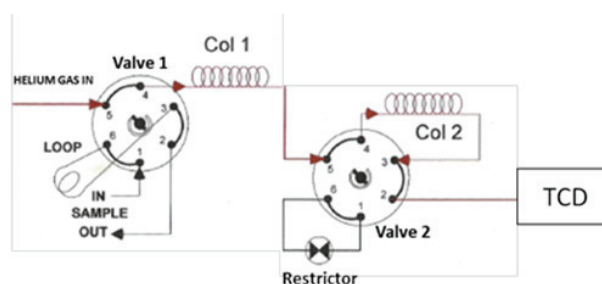


Figure 1. A schematic diagram of a single stage dual-packed column of GC-TCD used in this study (for interpretation of the references to colour in the figure the reader is referred to the web version of the article).

Gaseous sample analyses

Analyses of the gas components in the sample were conducted based on our previous experimental procedure [14], where all analyses were carried out under the same condition except for the carrier gas flow rate. The details of the analyses procedure [14] is as follows: a certain amount of gas sample from aluminum sample cylinder was introduced to the column in the GC system through an MFC at flow rate of 100 ml/min. The injector and detector temperatures are 200 and 250 °C, respectively. The elution of the studied gas mixture was achieved with following temperature program: 40 °C for 10 min, 40 to 160 °C at 60 °C/min, and 160 °C was held for 2 min. The data was estimated by automated integration of the area under the resolved chromatographic profile, using the HP computer (Hewlett Pack-

ard Pavilion Slimline 400 PC series) of OpenLAB CDS Chemstation version A.2.3.57. In addition, the concentrations of all components in the gas sample were determined by inserting the peak area of corresponding gas component into their calibration curve. The calibrations curves were made using procedure as described in the next section.

The following flow rates of He carrier gas were investigated: 17.5; 21.25; 25.0; 28.75, 32.5 and 36.25 ml/min and their effect on the precision and accuracy of the GC-TCD method were assessed. This flow rate range was employed because it is recommended as the instrument technical specification that would otherwise diminish its performance.

GC instrument calibration

The GC-TCD instrument was calibrated before each analysis run using a series of SGM containing all gas components (CO₂, C₃H₆ and CO) at different concentration level. The calibration curve was made by plotting the peak area of gas components in the SGM versus their concentration.

Calculation procedure

The precision of the GC-TCD was assessed in term of repeatability and reproducibility. The repeatability precision study was established by measuring the response of the target gas component in the certified SGM-A and expressed as percentage relative standard deviation (%RSD) of seven replicate injections ($n = 7$). The RSD is calculated by means of the following expression:

$$RSD = \frac{100}{\bar{y}} \sqrt{\frac{\sum (y_i - \bar{y})^2}{n-1}} \quad (1)$$

in which y_i is individual value expressed as peak area, \bar{y} is mean of peak area value of n injection replication, and n is number of injection replication. The repeatability of the method is categorized acceptable when RSD value is less than 0.67 of coefficient of variability Hortwitz (CV-Hortwitz) [25]. The CV-Hortwitz is a predicted RSD and its value was obtained by using the Hortwitz function (Eq. (2)) [25,26]. The lower RSD value is ascribable to the better repeatability of the flow rate level. In addition, the differences between RSD of the two consecutive flow rates were statistically analyzed using the least significant difference test in one-way analysis of variance (ANOVA). A 95% confidence limit ($p < 0.05$) was applied for the indication of significant difference between the two consecutive flow rate levels:

$$CV\text{-Hortwitz}(\%) = 2^{(1-0.5\log c)} \quad (2)$$

in which c is the concentration of gas components in decimal fraction.

Moreover, the precision in terms of reproducibility was carried out by injecting the certified SGM-A with similar procedure to that of repeatability precision except different day of time interval was used instead of the same day. The determinations of reproducibility precision were completed for 22 days with 7-day interval between courses of measurement. The acceptance criteria were set up where the RSD value is below the CV-Hortwitz value ($RSD \leq CV \text{ Hortwitz}$). At a certain flow rate level, the more reproducible of the GC-TCD measurement will be obtained when the lower the RSD value of response was achieved. Similar to the repeatability, statistical analysis for the reproducibility were also conducted under similar criteria to indicate the significance different between RSD of the two consecutive flow rate levels. In addition, the assessment of reproducibility was also conducted by setting up a control limit chart. The control limit chart normally has five lines which is consisting of one average line (AL), two warning limit (WL) lines, and two control limit (CL) lines. The AL represents the mean of the control values. Two WL lines are located at a distance of \pm two times the standard deviation (SD) from the AL line ($AL \pm 2SD$), while two CL lines are located at a distance of \pm three times the SD from the AL ($AL \pm 3SD$) [27].

The accuracy value is dependent on two factors, *i.e.*, the bias and precision [25,28]. The bias of method is the difference between the measured value and the value from certificate of SGM-B, which is calculated using the expression:

$$\Delta = \bar{X} - Y \quad (3)$$

in which \bar{X} is the average of measured value of SGM-B, and Y is value from certificate of SGM-B. In the method accuracy assessment, the precision of analytical method (σ , Eq. (4)) from repeatability and reproducibility are included. In addition, the uncertainty value from certificate of SGM-B also contributes to the estimation of σ value. Thus, the value of σ is obtained by combining those three components by using the following expression [26]:

$$\sigma = \sqrt{SD_b^2 + \frac{SD_w^2}{n} + \mu_{RM}^2} \quad (4)$$

in which SD_b is the SD from reproducibility precision. SD_w is the SD from repeatability precision, and μ_{RM} is the uncertainty of standard SGM-B stated in the certificate. The acceptance criteria is set according to the ISO Guide 33:2000 "Uses of certified reference materials" [29], where no bias of the method is found if the observed bias of method falls within $\pm 2\sigma$ at confidence level 95%:

$$-2Df < \text{bias} < 2Df \quad (5)$$

RESULTS AND DISCUSSION

Method Linearity

Results of GC-TCD calibration for all gas components are summarized in Figure 1. It can be seen in Figure 1 that calibration curve for all gas components show an excellent in term of their linearity properties.

Gas component	Slope	intercept	Linearity range (% mol/mol)	<i>n</i> (number of injection)	<i>R</i> ²
CO ₂	489.85	-47.15	0 - 13.50	8	0.9993
C ₃ H ₈	888.32	-13.73	0 - 2.18	8	0.9991
CO	437.10	-1.82	0 - 4.18	8	0.9996

Figure 2. Data indicating linearity of the GC-TCD method.

Response identity of target analyte

In a GC measurement, the response identity of target analytes is a very common criterion in the design of a GC method and it has to be identified clearly, before a quantitative analysis is carried out. In such identification process, it is necessary to establish that the analyte response in the form of signal produced is only due to the analyte and not from the presence of other components as interferences [28,30]. In a word, an adequate peak separation of different analytes should be obtained.

In this study, separation of the target analytes in the gas mixture including CO₂, C₃H₈ and CO were conducted on a GC system equipped with dual column. Based on this basic configuration, the separation process of the target analytes may have a consecutive step as follows: CO₂ was separated from the gas mixture in Column 1. After the CO₂ was detected (*R*_t = 2.99 min), the valve is switched to Column 2 and C₃H₈ is eluted from Column 2 to detector. After the C₃H₈ (*R*_t = 13.32 min) is detected, the valve is switched back to Column 1 and CO is eluted from column 1 to the detector and CO is then detected (*R*_t = 16.57 min). One can be noticed under this column configuration, neither column alone is able to separate those three target analytes using the GC-TCD system, but a combination of the two (column 1 and 2) results in complete resolution where the chromatogram of the separation result is shown in Figure 3. No other interfering peaks at or nearby the retention times of CO₂, C₃H₈ and CO were observed, demonstrating that a good separation of the target analytes has been well-achieved [31].

The flow rate of carrier gas is undoubtedly one of the factors affecting some key parameters of the GC measurement process and it will therefore lead to a corresponding variation in the quantification results. In a GC system, the carrier gas is an inert gas that does not react with the sample component. The GC carrier gas has a function to transport the components of the mixture in the form of vapor or gas through the column

where they are retained by the stationary phase in the column to a different extent [32]. The flow rate of carrier gas may have a significant contribution to the operational efficiency of a GC system [33]; thus probably affect to the precision and accuracy of the GC-TCD method.

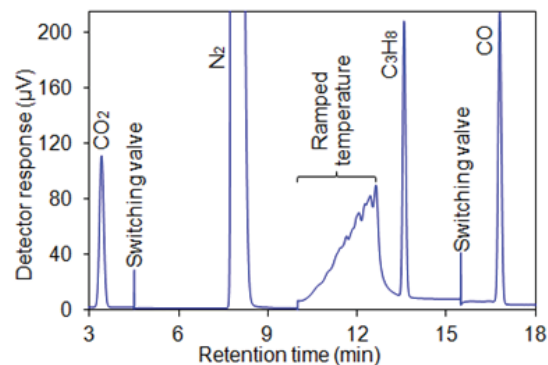


Figure 3. A typical chromatogram of gas component in SGM obtained using GC-TCD at carrier gas flow rate of 25.00 ml/min, showing the separation of CO₂, C₃H₈ and CO (for interpretation of the references to colour in the figure the reader is referred to the web version of the article).

Precision

Precision has become a critical factor in a GC measurement process [34]. In this study, the measurement precision was determined in terms of repeatability (intra-day precision) and reproducibility (inter-day precision).

The repeatability precision is the nature of variation observed arising when a successive GC measurement is carried out under the same method on identical test items in the same laboratory by the same operator using the same equipment within short intervals of time [35,36]. In the present study, the repeatability precision was carried out in the same day as time interval. The results showed that the repeatability precision (*RSD*) of the CO₂, C₃H₈ and CO at different flow rate of carrier gas was found in the range of 0.10–0.40%, 0.10–0.27%, and 0.12–0.23%, respectively. All the values (Figure 4) were in the acceptable range of repeatability precision for target gas components, because all the values lie below the 0.67 of CV-Hortwitz [25].

As it can be seen from Figure 4, the *RSD* of the repeatability precision shows an overall gradual decrease as the flow rates increased up to 25 ml/min, giving the lowest *RSD* values among all gas components. The lowest *RSD* values means that the most repeatable of flow rate. In addition, the *RSD* was found to increase with a further increase in the flow rate. Over all, it was found that the worst repeatability precision was obtained at the flow rate of 17.5 ml/min having the highest *RSD* values. It can be concluded that

Flow Rate (ml/min)	CO ₂			C ₃ H ₈			CO		
	0.67 CVH	%RSD	LSD test	0.67 CVH	%RSD	LSD test	0.67 CVH	%RSD	LSD test
17.50	2.38	0.40	s	2.45	0.27	s	2.22	0.23	s
21.25	2.38	0.17		2.45	0.15		2.22	0.19	
25.00	2.38	0.10	s	2.45	0.10	s	2.22	0.12	s
28.75	2.38	0.19		2.45	0.18		2.22	0.20	
32.50	2.38	0.23	ns	2.45	0.20	ns	2.22	0.21	s
36.25	2.38	0.23		2.45	0.20		2.22	0.22	

Notes: 0.67CVH = 0.67 x CV Hortwitz (%); LSD test = least significant difference test; s = statistically significant difference in %RSD between the two consecutive flow rate levels ($p < 0.05$); ns = not significant ($p > 0.05$).

Figure 4. The %RSD for repeatability precision at difference flow rate of carrier gas and their corresponding 0.67 of CV-Hortwitz values.

the repeatability precision for all gas components increases with increasing the flow rate of the He carrier gas up to 25 ml/min; however, further increase the flow rate above 25 ml/min lead to decrease in the repeatability precision. According to the results of statistical analysis, as shown in Figure 4, the changes of flow rate of carrier gas for the two consecutive flow rate levels has affected the repeatability precision of the GC-TCD method. Generally, it was found that the *RSD* values between the two flow rate levels are differ significantly ($p < 0.05$), except for the *RSD* of CO₂ and C₃H₈ at flow rate of 32.50 and 36.25 ml/min ($p > 0.05$).

The reproducibility precision, also called as intermediate precision, is the variation arising from repeated measurement results that are obtained with the same test method at different or longer time periods by different operator [37]. In this reproducibility precision estimation, the value in term of *RSD* of seven repeated measurements was compared and the results were listed in Figure 5. From the Figure 5, it can be seen that the *RSD* values of CO₂, C₃H₈ and CO component are less than their corresponding CV-Hortwitz. In a

word, all the *RSD* values of the reproducibility precision met the required criterion as the values of *RSD* are lower than their corresponding CV-Hortwitz [25].

Although the reproducibility precision values across the carrier gas flow rate level are acceptable (Figure 5), it was observed that flow rate of 25.00 ml/min showed its exceptional repeatability precision having the lowest %RSD values. From the Figure 5, the *RSD* values of CO₂, C₃H₈ and CO obtained at 25 ml/min are 0.90; 0.89 and 0.96, respectively. This finding has obviously suggested that the flow rate of 25 ml/min was found to be the most reproducible measurement, while flow rate of 17.50 and 36.25 ml/min were found to be of the poorest reproducibility. Moreover, the statistical analysis (Figure 5) indicates that there was significance correlation between the flow rate changes and reproducibility level of the GC-TCD method. The *RSD* values of the two consecutive flow rate levels were significantly different, which illustrates that the reproducibility performance (*RSD*) of the GC-TCD method may be related to the change of the carrier gas flow rate.

Flow Rate (ml/min)	CO ₂			C ₃ H ₈			CO		
	0.67 CVH	%RSD	LSD test	0.67 CVH	%RSD	LSD test	0.67 CVH	%RSD	LSD test
17.50	3.56	2.10	s	3.66	3.61	s	3.32	1.68	s
21.25	3.56	2.05		3.66	3.19		3.32	1.24	
25.00	3.56	0.90	s	3.66	0.89	s	3.32	0.96	s
28.75	3.56	1.47		3.66	1.46		3.32	1.31	
32.50	3.56	1.76	s	3.66	1.61	s	3.32	1.84	s
36.25	3.56	1.83		3.66	1.98		3.32	2.43	

Notes: CVH = CV Hortwitz (%); LSD test = least significant difference test; s = statistically significant difference in %RSD between the two consecutive flow rate levels ($p < 0.05$).

Figure 5. The %RSD for reproducibility precision at difference of carrier gas flow rate and their corresponding CV-Hortwitz.

In general, the *RSD* of reproducibility precision for all measurement at different of carrier gas flow rate (Figure 5) has the higher values in comparison to that of *RSD* of repeatability precision (Figure 4), indicating that reproducibility of the GC-TCD method was worse than repeatability. From the whole finding, one may expect that there were some user-related effects [38]. In addition, it is also essential to have in mind a concept of fit for purpose for establishing the reproducibility of GC measurements. Within this concept, the quality control of the measurement results is required and for what the purposes of the measurement results [39]. Therefore, setting up a control program is extremely important. The control limit (warning and action limit) remains the most common control program in the area of GC measurement [27]. The evaluation of control program was emphasized on the flow rate level of 25 ml/min because of its excellent in term of reproducibility over all flow rate levels. Figure 6a–c present the chart of control limit for the measurement obtained at different days using carrier gas flow rate of 25.00 ml/min. It can be seen from Figure 6 that all control data values obtained from measurement in all time period lie within or inside the warning limit, implying that no error of reproducibility measurement are found. On the other hand, if the control data values fall outside the limit, no reproducible measurement are

obtained and remedial action have to be taken to identify the source of error and remove such errors [39].

Accuracy

In analytical chemistry method, the accuracy reflects the closeness or the agreement between the measured result of a measurement and an accepted/true value [25]. Accuracy is a combination of the bias and precision of an analytical procedure [25,26,28,35]. In this study, the accuracy means the closeness of measured values of target gas components (CO_2 , C_3H_8 and CO) in SGM-A sample cylinder to the known values of gas components (CO_2 , C_3H_8 and CO) in SGM-B reference standard cylinder. Taking into account the repeatability results of precision studies as previously discussed, the accuracy was only evaluated at three level of flow rate having the lowest *RSD* among the tested flow rate. Hence, the evaluation of the method accuracy was focused for the following flow rate levels: 21.25, 25.00 and 28.75 ml/min. Assessing accuracy of the measurement was established by measuring seven replication of the certified gas mixture containing target gas components (CO_2 , C_3H_8 and CO), then the bias and precision were calculated and the results are listed in Figure 7. From the Figure 7, it was clearly observed that all bias value of CO_2 , C_3H_8 and CO measured at those three different flow rates are lower than their corresponding

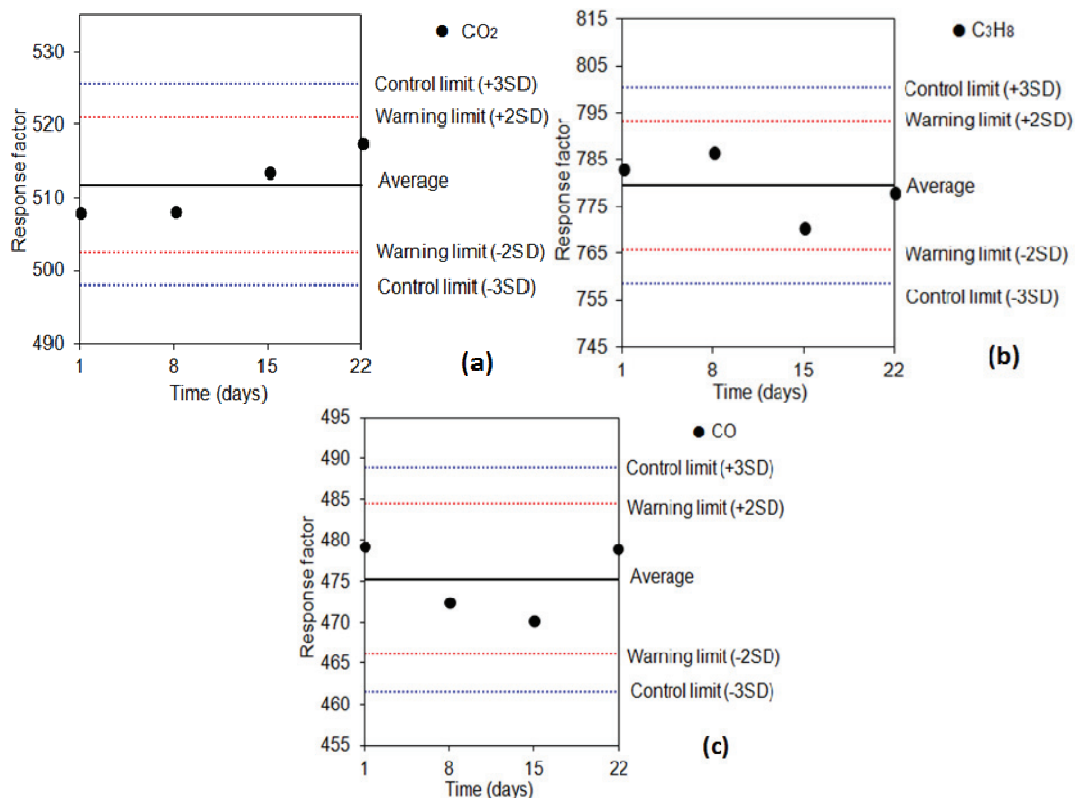


Figure 6. The chart of control limit for the measurement obtained at different days using carrier gas flow rate of 25.00 ml/min for: a) CO_2 , b) C_3H_8 and c) CO_2 gas component (for interpretation of the references to colour in the figure the reader is referred to the web version of the article).

Parameter	Carrier gas flow rate								
	21.25 (ml/min)			25.00 (ml/min)			28.75 (ml/min)		
	CO ₂	C ₃ H ₈	CO	CO ₂	C ₃ H ₈	CO	CO ₂	C ₃ H ₈	CO
Bias (% mol/mol)	-0.011	-0.016	-0.036	0.044	-0.039	-0.039	-0.180	-0.039	-0.075
Precision method (σ) (% mol/mol)	0.132	0.061	0.048	0.126	0.025	0.044	0.129	0.040	0.084
$\pm 2\sigma$ (% mol/mol)	0.264	0.122	0.097	0.251	0.050	0.087	0.258	0.079	0.169

Note: All the bias values fall within the acceptance criteria $-2\sigma < \text{bias} < 2\sigma$

Figure 7. Accuracy of the GC-TCD for the measurement of CO₂, C₃H₈ and CO in the SGM obtained using GC-TCD at different flow rate of carrier gas and their corresponding theta values.

$\pm 2\sigma$ value. This finding indicated that the GC-TCD method applying those three different flow rate are accurate, on the basis of criteria given [29].

It may simply be that, although the flow rate of carrier gas discussed above affords an obvious effect on the precision and accuracy of the GC-TCD method, contribution of different characteristic of individual gas component, like their chemical structure, on such precision and accuracy is indistinguishable. Generally speaking, changes in the precision and accuracy of the GC-TCD method was found only due to modification of the flow rate of carrier gas. However, in a GC-TCD technique, the difference in thermal conductivity between the carrier gas and the individual gas component may affect to the precision and accuracy of a measurement. Therefore, there is a need for further study on the relationship between He carrier gas flow rate and individual chemical structure of gas component for a measurement in term of precision and accuracy of GC-TCD method.

CONCLUSION

A complete and good separation of individual peak of the target analytes CO₂, C₃H₈ and CO was achieved and no other interference peaks appeared in company with peaks of CO₂, C₃H₈ and CO were identified. It was found that the precision and accuracy of the GC-TCD method varies directly with the flow rate of carrier gas. The flow rate of carrier gas at level of 25.00 ml/min was found to be the most precise and accurate in comparison to other flow rate levels based on the given criteria, so the flow rate of carrier gas at 25.00 ml/min is considered as the most valid GC-TCD method under experimental condition of the present study. A further study focusing on the effect of individual chemical characteristics of the gas component on the precision and accuracy of the GC-TCD method should be carried out.

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IZVOD**PROCENJIVANJE PERCIZNOSTI I TAČNOSTI GC-TCD METODE ZA ODREĐIVANJE UGLJEN-DIOKSIDA, PROPANA I UGLJEN-MONOKSIDA PRI RAZLIČITIM PROTOCIMA GASNOG NOSAČA**

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(Naučni rad)

U radu je sprovedeno istraživanje preciznosti i tačnosti metode gasne hromatografije opremljene toplotnim konduktivnim detektorom (GC-TCD) za merenje CO₂, C₃H₈ i CO postavljenih za modele zagadjivača pri različitim iznosima helijuma (He) kao gasnog nosača u rasponu od 17,50 do 36,25 ml/min. Pronadjeno je da je vrednost standardne devijacije (*RSD*) i za preciznost i za tačnost pokazala sveukupni postepeni pad sa povećanjem protoka gasnog nosača sve do 25ml/min. *RSD* se i dalje povećavala rastao sa povećanjem protoka i preko ove vrednosti. Ovi nalazi su ukazali na to da je protok od 25 ml/min je najpouzdaniji od svih protoka testiranih pod eksperimentalnim uslovima u toku ovog istraživanja. Detaljno su prikazane sve vrednosti *RSD* koje su dobijene. Rezultati ukazuju na to da je protok gasnog nosača ključni parametar za preciznost GC-TCD metode. Imajući u vidu da je gasni nosač transporter komponenti kroz kolonu, uspostavljanje optimalnog protoka gasnog nosača je važno kako bi se dostigla preciznost i tačnost GC-TCD metode.

Ključne reči: Preciznost • Tačnost • Gasna hromatografija • Izduvni gasovi vozila • Zagadjivač