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Standardization of Carboxyhemoglobin Determination by Microspectrophotometric Method and Application of The Method to Workers Occupationally Exposed to Carbon Monoxide

Mikrospektrofotometrik Yöntemle Karboksihemoglobin Tayininin Standardizasyonu ve Bu Yöntemle Mesleksel Olarak Karbon monoksit'e Maruz Kalanlarda Karbon monoksit İnhalasyonunun Saptanması

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Carbon monoxide (CO) is a toxic gas known since prehistoric times when man first discovered fire. Accidental CO poisonings due to incomplete combustion of organic materials used for making fire or due to exposure to natural CO sources first reported by LEWIN (29) and others (28). Although the main source of CO is incomplete burning of materials, several natural sources of CO in both biological (1,2,32) and nonbiological origin (11) have also been identified.

As civilization developed and modern techniques spread over larger areas, the sources of CO increased both around our occupational and nonoccupational environment. In many countries the incidence of acute CO intoxications still take the second place (21) while in some, the total number of deaths due to CO approaches the number of deaths because of other chemicals (15).

The signs and symptoms of acute CO intoxication are well known and they only appear with carboxyhemoglobin (COHb) levels above 10 %. But these levels are seldom met in subjects exposed to traffic exhaust or industrical CO sources occupationally. As

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clinical effects only depend upon the concentration of CO entering the body, the sensitivity and reproducibility of the method used for the determination of COHb levels below % 10 is very important (8, 14). There are at least 133 successful methods for the determination of CO in blood (9) but only a few them are convenient for the environmental and industrial application (3, 31).

In the first part of this research the standardization of COHb by direct microspectrophotometric method of COMMINS and LAWTHER (13) adapted by BUCHWALD (5), in our laboratory is presented. The second part of the study is the application of the method to the workers of the Factory of Electricity Gas, Ankara who occupationally exposed to CO. CO in the working area was also determined by infrared gas analyser to relate the concentration of at-
occupationally exposed to CO. CO in the working area was also determined by infrared gas analyser to relate the concentration of at-
mospheric CO with COHb levels.

EXPERIMENTAL DATA

MATERIAL and METHOD

1. Standardization of COHb determination.

Equipment:

Pure CO: Obtained in our laboratory using formic acid (HCOOH) and H_2SO_4 (30).

Pure O_2 bottle: (Habaş, purity 99.5 %)

Ammonia solution: 1 ml Concentrated NH_3, specific gravity 0.880, diluted to 800 ml with deionized water.

Blood samples: Obtained from the hematology Department of Ankara Yüksek İhtisas Hastanesi which were collected from normal male subjects confirmed by hematological analysis in the hospital.

Spectrophotometer: Pye Unicam, sp 1700

Heparinized capillary tubes: (Hettich, 1.4 mm x 75 mm) Flowmeter.

Method:

The principle of the direct microspectrophotometric method for the COHb determination depends on the absorbance difference of oxyhemoglobin (O_2Hb) and COHb in the Soret band. We used BUCHWALD'S method (5) with some little modifications.

Blood samples were collected in heparinizied capillary tubes. The tubes were quickly and completely filled with blood from a finger pricked with a Frankel needle. The tubes were sealed at both ends with plasticine and stored at the refrigerator until analysis. Duplicate samples were obtained from each person. The blood sample (about 0.02 ml) was diluted with 18 ml ammonia solution in a volumetric flask. This solution was divided into three parts. The first portion was transferred into the spectrophotometer cell (I). The second portion was saturated with oxygen (O_2Hb % 100, II) and the third with CO (COHb % 100, III) by bubbling the gas through the solutions about a rate of about 50 ml/min for 15 and 2 minutes respectively.

Using O_2Hb (II) as reference, the absorbances of I and III were measured at 415, 420 and 428 nm (nanometer). The COHb saturation of the sample (I) was calculated from the equation given below (5):

$$\text{COHb } \% = 100\ a_1 / A_{III}$$

$$a_2 = a_{420} - 1/2\ (a_{415} + a_{428})$$

$$A_{III} = A_{420} - 1/2\ (A_{415} + A_{428})$$

where a_1 is the difference of absorbances of I and A_1 is the difference of absorbances of III at wavelengths shown above.

Control of the method was carried with standard COHb solutions prepared after KNIGHT et al (20). A standard curve was obtained plotting concentrations (from 0–20) against optical heights calculated after COMMINS and LAWTHER (13).

The sensitivity, repeatability and reproducibility of the method were also estimated.

2. Determination of CO inhalation degree of the workers occupationally exposed to CO.

The male workers employed by the Electricity and Towngas, Maltepe, Ankara, were examined. The factory, established in 1929, produces 220 000 M^3 town gas daily. The working areas where the subjects can expose to CO were selected:

a) 26 generator workers, employed for the control and feeding of the generator furnaces.

b) 12 pipe controlers, whose job are to check any gas leakage from the pipes used to distribute town gas to the city.

c) 8 compressor workers who work in the open door to compress town gas to the depots.

d) 20 enclosed garage workers who employed for the service and repairing of vehicles of the factory.

e) 19 drivers in charge of the factory transport.

f) 6 laboratory technicians employed for the chemical analysis of town gas, coal and other chemicals used in the factory.

g) Control group: 6 smoking male subjects were selected as a a control group among the normal who do not exposed to CO occupationally. Smoking subjects are chosed among the males who smoke 15-20 cigarettes per day.

Control subjects work at the Faculty of Pharmacy, Ankara University.

All the subjects investigated in our research were male subjects.

Method:

Blood samples were taken from the workers just before the work (BW) and after the work (AW). The working period was 8 hours. Blood samples were collected at 8.00 o'clock in the morning and at 16.30 o'clock in the afternoon. A questionnaire card for each subject was completed to provide the following information: Sampling date and time, name, age, smoking habits (number of cigarettes per day and during the sampling time), history of working, health complaints such as head ache. The major part of our survey took place during the November 1974 to the end of March 1976.

3. Determination of CO in the working atmosphere.

Atmospheric CO in the working area mentioned above was determined by a portable infrared CO analyzer (Mijnhardt). CO was measured at several times of the day and points of the working area to get the maximum, minimum and mean concentration levels. CO was also determined outside of the working environment.

RESULTS

(FINDINGŞ)

1 . The spectra of 100 % O_2 Hb and 100 % COHb in the wavelengths range 400–430 nm (Soret bands) is presented in figure 1.

Figure 2, shows the resultant spectrum obtained by subtracting the absorbance of O_2Hb solution from the absorbance of COHb.

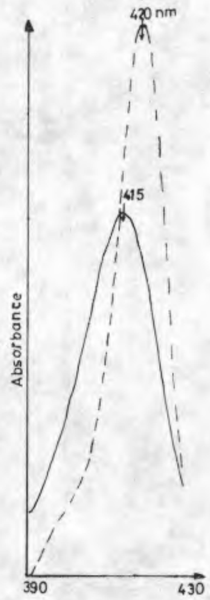

Figure 1. Absorption spectra of dilute blood solutions.
——: 100 % O_2Hb
– – –: 100 % COHb

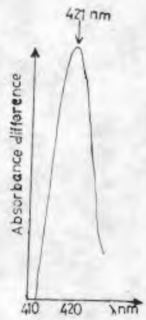

Figure 2. Resultant spectrum of COHb.

2 . The standard curve obtained plotting optical heights against concentrations of standard carboxyhemoglobin solutions is presented in Figure 3. The curve shows linearity up to 20 % COHb concentrations.

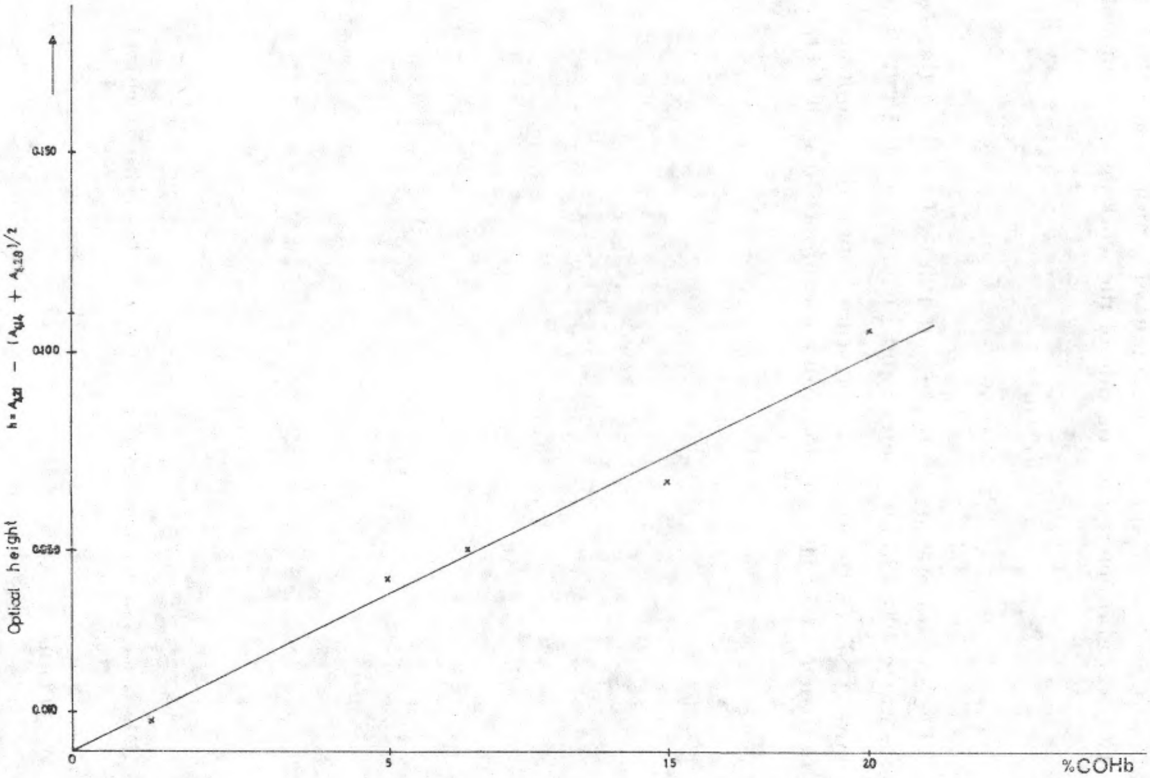

Figure 3. Standard curve of
COHb (against optical height)

3. The standard COHb concentrations gave higher results when controlled with microspectrophotometric method (standard deviations S_d change between 0.106–2.560). The results are shown in Table I.

Tablo I. Comparision of standard COHb concentrations with microspectrophotometric method

% COHb standard solution I	The concentration obtained with spectrophotometric method II		Standard deviation (Sd) (between I and II)
		Mean	
0	0	0	
2	2.41– 1.88	2.15	0.106
5	5.99– 5.63	5.81	0.573
8	9.45–10.21	9.83	1.294
10	11.06–11.97	11.52	1.075
15	15.96–17.28	16.62	1.146
20	22.33–24.88	23.62	2.560

The precision and the reproducibility and repeatability of the method depending on time is presented in Table II. The COHb % of the same samples were determined within 12 hours after sampling, and the third and the seventh days.

4. The mean values of the survey are summarized in Tables III and IV prepared according to smoking habits. The mean COHb saturation levels BW and AW, difference and variation in COHb % during the working period are shown. Significance test (probability, t test (27) results are also introduced to the tables.

The statistical results are presented in Table V. The mean % COHb of workers determined BW and AW during the survey are compared with a) in the same group workers according to smoking habits, b) smoking workers with smoking control groups, c) non smoking workers with non smoking control groups.

Cumulative distribution of COHb % among smoking and non smoking workers both BW and AW are presented in figures 4 and 5.

5. Table VI gives the results of atmospheric CO concentrations measured in the working area. The mean CO levels determined in the ambient air of Ankara (12, 23) can also be seen at the table.

Table II. Limits of precision, reproducibility and repeatability of the method

Sample No.	% COHb				Sd between means ±	
	I		II	III		
	1 st day (within 12 hours)	Sd ±	3rd day	7th day	I and II	Iand III
1	7.52, 7.63 } 7.58	0.055	7.49, 7.59 } 7.54	7.21, 7.25 } 7.23	0.035	0.345
2	5.78, 5.72 } 5.75	0.03	5.68, 5.86 } 5.77	5.36, 5.24 } 5.30	0.02	0.45
3	4.00, 3.94 } 3.97	0.03	3.79, 3.72 } 3.76	3.15, 3.17 } 3.16	0.215	0.81
4	4.82, 4.71 } 4.77	0.055	4.67, 4.70 } 4.69	4.16, 4.25 } 4.21	0.08	0.56
5	4.27, 4.48 } 4.38	0.105	4.17, 4.35 } 4.26	4.08, 4.19 } 4.14	0.115	0.24
6	3.92, 3.88 } 3.90	0.02	3.72, 3.69 } 3.71	3.21, 3.27 } 3.24	0.195	0.66
7	7.49, 7.61 } 7.55	0.065	7.22, 7.55 } 7.39	7.15, 7.09 } 7.12	0.165	0.43
8	5.76, 5.89 } 5.83	0.065	5.77, 5.69 } 5.73	5.33, 5.12 } 5.23	0.095	0.60
9	6.44, 6.50 } 6.47	0.03	6.43, 6.22 } 6.33	6.06, 6.01 } 6.04	0.145	0.435
10	5.93, 5.78 } 5.86	0.075	5.59, 5.56 } 5.58	5.27, 5.02 } 5.15	0.28	0.71
Means of Sd ±		0.0525			0.135	0.524
Means of Sd %		0.9272			0.082	0.175

Table III. Mean COHb values of various nonsmoking workers in the Electricity and Town Gas Factory, Ankara

Group	No of subjects	Mean % COHb Before Work	After Work	Difference in % COHb and significance test
I. Generator workers	9	Range 1.37—3.34 Mean 2.38±0.19 Sd 0.594	2.28—9.55 6.34±0.79 2.385	+3.96 (t= 5.253 p< 0.001, significant)
II. Garage workers	8	Range 2.55—7.27 Mean 3.99±0.56 Sd 1.580	4.34—10.25 7.20±0.69 1.954	+3.21 (t= 4.563 p< 0.01, significant)
III. Drivers	8	Range 1.31—6.19 Mean 2.96±0.54 Sd 1.528	2.14—9.05 5.29±0.82 2.306	+2.33 (t= 4.910 p< 0.01, singificant)
IV. Leakage controlers	12	Range 0.57–2.24 Mean 1.45±0.15 Sd 0.516	0.69—3.64 2.25±0.27 0.928	+0.80 (t =3.870 p< 0.001, significant)
V. Compressor workers	2	Range 2.55—4.31 Mean 3.43	5.44—8.69 7.07	+3.63
VI. Laboratory employers	4	Range 0.97—1.50 Mean 1.23±0.66 Sd 0.265	1.87—2.22 2.04±0.39 2.41	+0.81
Controls	6	Range 0.60—1.47 Mean 1.19±0.15 0.372	1.16—1.82 1.52±0.13 0.325	+0.33 (t= 5.38, p<0.01)

DISCUSSION

The microspectrophotometric method for the determination of COHb we standardized is enough sensitive and repeatable for field applications in industrial toxicology. Some methods such as gasometric used by RAMSAY (25), microdiffusion technique used by GRAY (17) as a modification of Feldstein and Klendshoj's (16) have a disadvantage of determination hemoglobin (Hb) as to calculate COHb % saturation. BLACKMORE (3), COLLISON et al (10), PURVES (24) got satisfactory results with finger prick blood by gas chromatographic methods, but most of them need a special device for the instrument (3, 18) as well as having the disadvantage of calculation Hb.

Tablo IV. Mean COHb values of smoking workers in the Maltepe Gas and Electricity Factory

Group	No of subjects	Mean % COHb Before Work	After Work	Difference in % COHb and significance test
I. Generator workers	17	Range 1.69—7.76 Mean 4.91±0.39 Sd 1.626	5.05—13.18 9.37±0.68 2.808	+4.46 (t= 9.404 p< 0.001, significant)
I. Garage workers	12	Range 4.90—10.08 Mean 6.68±0.54 Sd 1.856	7.29—15.09 11.15± 0.70 2.408	+4.47 (t= 12.252 p< 0.001, significant)
III. Drivers	10	Range 1.49—10.79 Mean 6.75±1.07 Sd 3.37	1.70—16.34 10.50±1.29 4.072	+3.75 (t=12.253 p< 0.001, significant)
IV. Leakage	7	Range 1.75—4.78 Mean 2.65±0.56 Sd 1.481	1.92—7.08 4.37±0.68 1.791	+1.72 (t =3.829 p< 0.01, significant)
V. Compressor workers	6	Range 4.34—14.75 Mean 6.80±4.15 Sd 3.43	5.37—18.08 9.67±4.92 7.06	+2.87
VI. Laboratory employees	2	Range 1.50—2.87 Mean 1.93 Sd 0.69	3.50—6.62 5.06 2.41	+3.31
Controls	6	Range 1.97—4.53 Mean 2.79±0.44 Sd 1.075	2.22—5.56 3.84±0.49 1.196	+1.05 (t= 4.578; p<0.01)

BUCHWALD'S method (5) we used gave sensitive results with 0.03 ml blood. As it is a comparative method, it is not necessary to determine the concentration of Hb of blood. The sensitivity was found below 1 % COHb and the blood samples can be stored at least for one week without any decrease in its CO content (Mean Sd ± 0.524, Mean relative Sd 0.175 % between the first and seventh day results). The precision of the method we used was estimated very high (Mean Sd ± 0.0525). The accuracy and sensitivity of our method is well enough as compared with gas chromatographic method of RODKEY (26) and biochemical method of WHITEHEAD and WORTHİNGTON (33). The method can be standardized with standard COHb solutions up to 20 %. We obtained better results

Table V. Statistical comparision of mean COHb levels with cotrol groups

Groups compared	COHb % mean levels Before Work	After Work
I. Generator workers		
1. Smoking–nonsmoking Generator workers	4.91	9.37
	2.38	6.34
	t= 5.733	t= 2.894
	p< 0.001 significant	p< 0.001 significant
2. Nonsmoking generator workers nonsmoking controls	1.19	x_1: 1.52
	2.38	x_2: 6.34
	t= 4.737	t= 5.989
	p< 0.001 significant	p< 0.01 signigicant
3. Smoking generator workers smoking controls	2.79	3.84
	4.91	9.37
	t= 3.595	t= 6.599
	p< 0.01 significant	p<0.001 significant
II. Garage workers		
1. Smoking–nonsmoking workers	6.68	11.15
	3.98	7.20
	t= 3.48	t= 4.037
	p< 0.01 significant	p<0.001 significant
2. Nonsmoking workers nonsmoking controls	1.19	1.52
	3.98	7.20
	t= 4.818	t= 8.079
	p< 0.01 significant	p< 0.001 significant
3. Smoking workers smoking controls	2.79	3.84
	6.68	1.15
	t= 5.620	t= 8.609
	p< 0.001 significant	p< 0.001 significant
III. Drivers		
1. Smoking–nonsmoking workers	6.68	10.50
	2.96	5.289
	t= 3.172	t= 3.421
	p< 0.01 significant	p<0.01 significant
2. Nonsmoking workers nonsmoking controls	1.19	1.515
	2.96	5.289
	t= 4.569	t= 3.44
	p< 0.001 significant	p< 0.01 significant
3. Smoking controls	2.79	3.84
	6.67	10.50
	t= 3.44	t= 4.838
	p< 0.01 significant	p< 0.001 significant
IV. Leakage controlers		
1. Smoking–nonsmoking workers	2.65	4.37
	1.43	2.25
	t= 2.075	t= 2.808
	p> 0.05 not significant	p< 0.01 not significant
2. Nonsmoking workers nonsmoking controls	1.19	1.52
	2.45	2.25
	t= 1.199	t= 2.462
	p> 0.05 not significant	p< 0.05 not significant
3. Smoking workers smoking controls	2.79	3.84
	2.65	4.37
	t= 0.188	t= 0.631
	p> 0.05 not significant	p>0.05 not significant

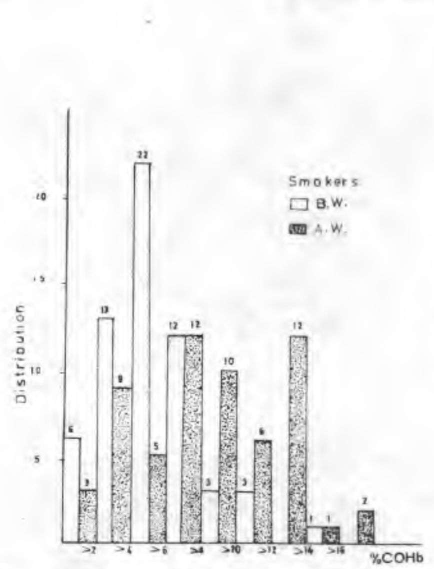

Figure 4. Cumulative distribution of COHb % among smoking workers.

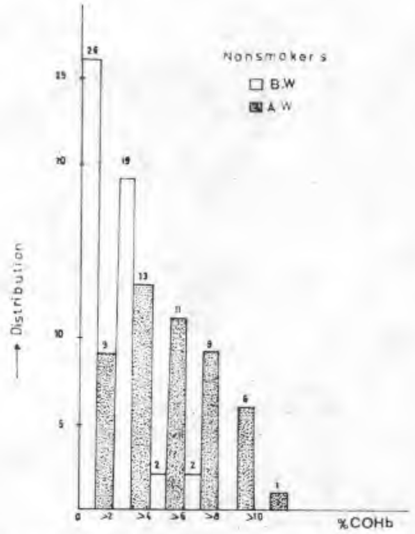

Figure 5. Cumulative distribution of COHb % among nonsmoking workers.

to dilute the blood with ammonia solution after equilibrated with O_2 and CO on the contrary of KNIGHT et al (20). The application of the method we standardized to the industrial area gave interesting results:

a) Mean COHb of generator workers BW and AW and its accumulation during the working period significantly higher than the control groups both smoking (S) and nonsmoking (NS). The subjects work in a closed area where the CO concentration is generally under MAC (16–20 ppm). But during the feeding of fire they expose to a very high CO (1000 ppm) for a short time (1/2–1 minute) which is repeated 130–133 times per working day. 1000 ppm CO is accepted as fatal concentration if inhaled for an hour (15,19). During our investigation some of the workers complained of severe head ache and nausea, but some of them refused to answer our question. The COHb levels of the generator workers are higher than de BRUIN'S (14) and LÜDERITZ'S (22) findings in nonsmoking policeman and drivers, lower than RAMSEY'S (25) findings in garage workers and BREYSEE'S (4) results in workers exposed to CO from the operation of gasoline for light trucks in holds of ships.

Table VI. CO, concentrations in the working area examined in the research

Sampling site	CO in air (ppm)*	
1. Area of generators (enclosed) a) Near the generators when the furnace doors are open (in 1–2 minutes)	~ 1000	
b) General working atmosphere in the enclosed area	16–20	
2. Garage station (enclosed) a) Near the vehicles when they operate (service) and all the doors are closed (4 vehicles)	400–1000 600	(varies) (more stable value)
b) Far from the vehicles when they operate and all the doors are closed	30–60	
c) General working atmosphere (doors are open) i– near the vehicles ii– far from the vehicles	 240 19	
3. Ambient air of the factory a) round the garage (within 2 metres) b) far from the garage (20 metres)	 19–20 >16	
4. Ambient air of Ankara* a) Means of winter months 1971–1972 b) February 1972	 5.4–8.6 1.5–12	Range

* These data are obtained from other researchs (12,23)
1 ppm CO– 1.145 mg/m' (25' C and 760 mm Hg) (11)

b) Mean COHb levels of garage workers were the highest results among the other workers as expected (3.98 $\pm$ % BW – 7.20 $\pm$ 0.69 % AW COHb in nonsmokers and 6.68 $\pm$ 0.54 % BW – 11.15 $\pm$ 0.70 % AW COHb in smokers). CO concentration they exposed during the working period was generally over MAC (60 ppm) and frequently very high (240 ppm). In cold weather (winter) when the doors of the building were closed and the aspiration was not sufficient to change the air, COHb results of the subjects support this unhealthy situation. CHOVIN et al (7) calculated that a worker in a underground garage can breathe air containing on the average more than 50 ppm CO (20 ppm the lowest, 200 ppm the highest concentration). 50 ppm of CO would result in COHb saturation of about 8 % after 5 hours as reported in literature (6).

c) Mean COHb levels of drivers showed a significant difference from other works published (2.96 ± 0.54 % BW - 5.29 ± 0.82 % AW in nonsmokers and 6.75 ± 0.54 % BW and 10.50 ± 1.29 % COHb AW in smokers). CLAYTON et al (9) reported that 50 % of the drivers in his research have COHb % less than 3 %. According to de BRUIN'S (14) results the COHb increase during working hours is 1.9 % to 2.15 %. In our results, only 20 % of the nonsmoking drivers had less than 3.0 % COHb saturation. This difference can only be explained that the drivers usually spend their free time resting in the enclosed garage mentioned above.

The workers employed as compressor workers, controlers and laboratory technicians also had significantly higher COHb levels than controls. Only the COHb levels of leakage controlers who work outdoors and where the atmospheric CO concentration was generally 16 ppm, were not significantly higher than the control groups.

Our COHb results of smoking and nonsmoking control groups can be comparable with microdiffusion and biochemical methods previously done by us (31).

CONCLUSION

1. The direct microspectrophotometric method for the determination of COHb % we adapted to our laboratory is reliable for its sensitivity, accuracy and repeatability. It can be standardized with standard COHb solutions and is applicable to field research in industrial toxicology.

2. Mean % COHb levels of subjects employed by the various area of the factory of Electricity and Towngas, Ankara, showed significantly higher results as compared with control groups. The increase in COHb level after a day's exposure also presented a significant difference from the COHb of controls both in smokers and nonsmokers ($p<0.001$).

3. Atmospheric CO measurements in the working areas support the high COHb levels of the employees. It is generally known

that a COHb level of 5 % comprise a potential risk or early CO intoxication (neuropsychological signs).

Our findings show that some measurements such as controling the atmospheric CO and determination COHb levels of the workers at certain periods have to be taken by the associated organizations for the health safety of workers.

SUMMARY

1. The microspectrophotometric method of COMMINS and LAWTHER adapted by BUCHWALD was standardized in our laboratory for the determination of % COHb. The sensitivity of the method was found far below 1 % COHb and the precision (Sd ± 0 .525 and relative Sd 0 .9272 %) very satisfactory. It has also been shown that the accuracy of the method can be controlled with the calibration curve prepared with standard COHb solutions. As it is possible to estimate CO in small samples of blood (0 .03 ml), it can be easly applicable to problem areas.

2. The COHb levels of different groups of male employees who occupationally exposed to CO in the factory of Electricity and Town Gas, Ankara measured with the method we standardized. Blood samples have been taken before and after exposure. Totally 97 workers have been examined. The results have been compared with smoking and nonsmoking control groups.

The mean COHb levels of the generator workers was on the average 2 .38 ± 0 .19 % (9 nonsmokers), 4 .91 ± 0 .39 % (17 smokers) before work and increased to respectively 6 .34 ± 0 .79 % and 9 .37 ± 0 .68 %; of the enclosed garage workers 3 .99 ± 0 .56 % (8 nonsmokers), 6 .68 ± 0 .54 % (12 smokers) before work and increased to respectively 7 .20 ± 0 .69 % and 11 .15 ± 0 .70 %; of the drivers 2 .96 ± 0 .54 % (8 nonsmokers), 6 .75 ± 1 .07 % (12 smokers) before work and increased to 5 .29 ± 0 .82 % and 10 .50 ± 1 .29 %; of the gas leakage controlers 1 .45 ± 0 .15 %(12 nonsmokers), 2.65 ± 0 .56 % (7 smokers) before work and increased to 2 .25 ± 0 .27 % and 4 .37 ± 0 .68; of the compresor workers 3 .43 % (2 nonsmokers), 6 .80 ± 4 .15 (6 smokers) before work and increased to respectively 7 .07 % and 9 .67 ± 4 .92

%; of the laboratory technicians 1.23 ± 0.66 % (4 nonsmokers), 1.93 % (2 smokers) before work and increased to 2.04 ± 0.39 %; 5.06 respectively as a consequence of exposure during 8 hours working. The meanCOHb levels BW and AW, and increase in a working day generally presented a significant high difference in workers.

3. Atmospheric CO levels in the working areas measured by using a portable infrared CO analyser. The findings of CO in air around the workers agree with the high COHb levels.

It is concluded that some measurements must be taken by the associated organizations to prevent the workers from high CO inhalation.

ÖZET

1. Bu çalışmada, kanda CO tayini için laboratuvar koşullarımıza uygun bir yöntem standardize edilmiştir. Bu amaçla COMMİNS ve LAWTHER'in direkt spektrofotometrik yönteminin BUCHWALD tarafından saha için adapte ettiği yöntemden yararlanılmıştır. Yöntem duyarlık (% 1 altında), kesinlik (Sd ± 0.0525 ve relatif Sd % 0.9272) ve tekrarlanabilirlik bakımından endüstri toksikoloji alanında kullanılabilecek yeterlikte bulunmuştur. Ayrıca yöntemin optik yüksekliğe göre hazırlanan COHb standard çözeltisi ile de (% 20 COHb e kadar) standardize edilebileceği gösterilmiştir.

2. Bu yöntem Ankara Elektrik ve Havagazı Fabrikasında CO e maruz kaldıkları düşünülen iş yerlerindeki işçilere uygulanmıştır. Toplam 97 erkek işçide sabah işe başlamadan ve iş bitimi sonunda COHb tayin edilerek bu değerler 12 kontrol grubu ile karşılaştırılmıştır.

Sonuç olarak jeneratör işçilerinde bir iş gününde COHb değişimi (9 sigara içmeyende % 2.38 ± 0.19 – % 6.34 ± 0.79; 17 sigara içende % 4.91 ± 0.39 – % 9.37 ± 0.68); garaj işçilerinde (8 sigara içmeyende: % 3.99 ± 0.56 – % 7.20 ± 0.69 ve 12 sigara içende: % 6.68 ± 0.54 – % 11.15 ± 0.69); şöförlerde (8 sigara içmeyende: % 2.96 ± 0.54 – % 5.29 ± 0.82 ve 10.50 ± 1.29); havagazı ateşçilerinde (12 sigara içende % 1.45 ± 0.15 ± – % 2.25 ± 0.27); 7 sigara içmeyende: % 2.65 ± 0.56 – % 4.37

± 0.68); kompresör işçilerinde (2 sigara içmeyende % 3.43 – 7.07; 6 sigara içende: % 6.80 ± 4.15 – % 9.67 ± 4.92); laboratuvar teknisyenlerinde (4 sigara içmeyende: % 1.23 ± 0.66 – 0.66 – % 2.04 ± 0.39; 2 sigara içmeyende: % 1.93 – % 5.06) saptanmıştır. Kontrol gruplarına göre gerek sigara içenlerde ve gerekse sigara içmeyenlerde bir iş günü sonunda COHb yükselmesi, iş öncesi ve iş sonrası COHb değerleri kontrol gruplarına göre yüksek bulunmuştur ($p < 0.001$).

3. Bu iş yerleri havasında CO infrared CO analyzer ile saptanmıştır. Jeneratörlerin bulunduğu yerde ve garajda özellikle iş sırasında zaman zaman CO miktarının MAC çok üstüne çıktığı ve tehlikelikeli düzeyde olduğu saptanmıştır.

Bu nedenle, ilgili kuruluşlarca bu iş yerlerinde çalışan kimselerin CO inhalasyonuna maruziyetlerini önleyici önlemlerin alınması gerektiği kanısındayız.

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