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## FOREWORD

This report describes a project executed by the Norwegian Institute for Air Research (NILU) in cooperation with the Institute for Aviation Medicine. The project was financed by the Royal Norwegian Council for Scientific and Industrial Research (Committee for Toxic Compounds). The goal of the project was to measure carbon monoxide exposure of individuals working in Rådhusgata, in downtown Oslo. Rådhusgata is a street where a freeway must cross Oslo. The street is a city canyon lined with buildings, 5 or 6 stories high, on either side and a row of traffic lights.

## SUMMARY

Carbon monoxide is a gas that is generated with incomplete combustion and is therefore especially prominent in traffic pollution. Air pollution guidelines have been set to assure that concentrations of CO in blood (HbCO) do not exceed levels that could endanger health. In Norway, this level is set at 1.5% HbCO.

It was therefore of interest to measure concentrations of HbCO in individuals working on one of Norway´s most polluted streets, Rådhusgata. In order to have a better measure as to how working in a polluted environment affected concentrations of CO in blood, it was decided to measure both in the morning, when each had arrived at work, and again at the end of the working day. Air concentrations of CO were continually measured at each business establishment.

This study was one in a series that is trying to better describe individual´s exposure to air pollution. It has long been recognized that it is insufficient to describe air pollution exposure by simply measuring air quality at stationary outdoor monitoring stations. Individuals differ in their movements, and thus to their exposure to various compounds. After the development of portable equipment, in this case a CO monitor, it has been easier to develop methods to measure exposure. It is desirable to correlate exposure to CO in air with those levels measured in blood. The Norwegian Institute of Air Research (NILU) is developing a method of measuring the body burden of CO, thus dose, without the need of taking blood samples. The method under development is to measure concentrations in samples of end-expired breath.

Outdoor hourly concentrations of CO were frequently above the 8 hour air quality guideline of 9 ppm. The concentrations of CO in indoor air often mirror concentrations outdoors. This is especially noticeable in shops that lie on the ground level, where doors facing a street are frequently open. However, levels in office buildings on the second and third floor also reflected outdoor levels, although the ratio between indoor/outdoor concentrations was less. Measures made to improve air quality in buildings, such as better windows, relocating air intake to

the roof or courtyard instead of the main street, were effective in decreasing the concentrations of air pollution indoors. Values of CO were markedly lower in buildings with a fasade facing the courtyard, as opposed to those having fasades facing the main street, Rådhusgata.

Values of HbCO did not increase much during the working day for non-smokers. Values at the end of the day did not exceed 1.5% HbCO. Values of HbCO were slightly higher on the days with highest CO concentrations, but the differences were not of physiological importance. Concentrations of CO in outdoor air were slightly over or at the air quality guideline limit, showing that these guidelines are effective in assuring that blood concentrations remain under those levels known to produce health effects in the most sensitive populations in non-smokers. Smoking is much more important than the measured concentrations in outdoor air in producing elevated CO concentrations in blood.

Since the possibility did exist that levels did not rise during the working day because they already had reached high values in the morning due to the transportation to work, blood concentrations of CO were compared for those who drove to work as opposed to those who took the train or bus. The mean concentration of HbCO for those non-smokers who drove was 0.6% as opposed to 0.5% for those who took the train and 0.4% for those who took the bus.

The same tendencies were observed when examining concentrations of CO in end-expired breath samples (CO-EEB). The mean concentration of CO-EEB for those non-smokers who drove to work was 6.5 ppm as opposed to 5 ppm for those who took the train and 4.8 for those who took the bus.

Comparing HbCO with CO-EEB values nearly confirmed the relationship based on physiological principles reported by McIlvaine et al. (1969):

$$\text{HbCO in } \% = 0.18 \times \text{CO-EEB}$$

The relationship found in this study was:

$$HbCO \text{ in } \% = 0.16 \times CO\text{-}EEB - 0.39$$

(-0.36 in the morning or -0.42 in the afternoon)

CO-EEB was measured using methods identical to those in the earlier study in Drammen, a less polluted area (Clench-Aas et al., 1988). Average values of CO-EEB measured there were 3.8 ppm for non-smokers as opposed to 4.6 ppm in morning samples of those individuals who worked in Rådhusgata, and 5.7 ppm in the afternoon samples. Thus the non-smoking inhabitants of Oslo, and especially those working in Rådhusgata have a higher body burden of CO. Average values of CO-EEB for smokers in Drammen were 24.0 ppm whereas they were 19.3 and 25.7 ppm for smokers in Rådhusgata in the morning and afternoon respectively. Since the Drammen samples were also taken in the afternoon, there are no differences between Drammen and Rådhusgata values for CO-EEB in smokers.

# SAMMENDRAG

Karbonmonoksid er en gass som dannes ved ufullstendig forbrenning, den er særlig viktig ved trafikkforurensning. Det finnes anbefalte grenseverdier for konsentrasjon av CO i uteluft. Grenseverdiene skal sikre at konsentrasjonene av CO i blodet ikke overskrider 1.5% HbCO. (% HbCO er den andel av hemoglobinet som har bundet til seg CO, og dermed ikke kan transportere oksygen.) Ved denne konsentrasjonen av CO i blodet kjenner man ikke til negative helseeffekter.

HbCO ble målt i personer som arbeider langs en av Norges mest forurensede gater, Rådhusgata i Oslo. For å kunne vurdere effekten av oppholdet i eller ved Rådhusgata, ble HbCO målt både like etter ankomst til arbeidsplassen om morgenen, og om ettermiddagen samme dag. Samtidig ble konsentrasjonen av CO i luften målt både innendørs og utendørs.

Denne undersøkelsen er ledd i et forsøk på å beskrive befolkningens virkelige eksponering for luftforurensninger. Det er godt kjent at forurensningen målt i ett punkt i en by ikke er tilstrekkelig til å beskrive den belastsningen enkeltpersoner utsettes for. Menneskene beveger seg i forskjellige mikromiljøer med sterkt varierende forurensninger. Etter at små, bærbare CO-monitorer er blitt tilgjengelige, kan man lettere måle den belastningen som enkeltpersoner utsettes for. Et av hovedmålene med denne undersøkelsen var å finne korrelasjonen mellom den CO-belastningen en person er utsatt for, og den resulterende konsentrasjonen av CO i blodet. Norsk institutt for luftforskning (NILU) forsøker også å videreutvikle en metode for å estimere CO i blod uten å måtte ta blodprøver. CO-konsentrasjonen i utåndingsluft (CO-EEB) ble derfor sammenlignet med CO-konsentrasjonen målt i blodprøver.

CO-konsentrasjonen utendørs i prøveperioden var ofte over eller på grenseverdien for 8-timers eksponering (9 ppm). CO-konsentrasjonen målt innendørs gjenspeiler vanligvis utendørs konsentrasjon, særlig i butikker på gatenivå (her åpnes gatedøren ofte). I annen og tredje etasje ser man ofte de samme variasjonene i CO-konsentrasjonen som

utendørs, men med noe lavere nivå inne enn ute. Man ser gode resultater av tiltak for å redusere forurensningene innendørs (tettere vinduer, friskluft-inntak fra bakgård eller over tak, etc.). CO-konsentrasjonen målt innendørs var vesentlig lavere i bedrifter med fasade mot bakgården enn i bedrifter med fasade mot Rådhusgata.

For ikke-røykere økte verdien av HbCO bare litt over dagen. Ettermiddagsverdien overskred ikke 1,5%. Økningen i HbCO var noe større de dager det ble målt høye nivåer av forurensning. Forskjellene var ikke av helsemessig betydning. Siden uteverdiene var litt over eller på grenseverdien 9 ppm, viser forsøkene at grenseverdien er tilstrekkelig lav til å holde HbCO på et betryggende nivå. CO-innholdet i blodet blir langt sterkere påvirket av røyking enn av den trafikkforurensningen som ble registrert.

I noen unntakstilfeller ble forsøkspersonene utsatt for høyere CO-belastning under reisen til arbeidsplassen enn under oppholdet på arbeidsplassen. Morgenverdiene av HbCO for ikke-røykere ble korrelert til reisemåten. Gjennomsnittsnivåer for de som kjørte bil, var 0,6% HbCO. De som tok tog, hadde gjennomsnittlig 0,5% HbCO. Bussreisende lå lavest med 0,4% HbCO i gjennomsnitt.

Tilsvarende resultater ble funnet for CO i utåndingsluft (CO-EBB). Gjennomsnittlige morgenverdier for ikke-røykere var 6,5 ppm for bilreisende, 5 ppm for togreisende og 4,8 ppm for bussreisende.

Ut fra fysiologiske prinsipper har McIlvaine et al. (1969) utledet sammenhengen mellom CO-konsentrasjonen i blod og utåndingsluft:

$$\% \text{ HbCO} = 0,18 \text{ X CO-EEB}$$

Denne eksperimentelle undersøkelse har gitt svært like resultater:

$$\% \text{ HbCO} = 0,16 \text{ X CO-EEB} - 0,39$$

(-0,36 om morgenen og -0,42 om ettermiddagen)

Den samme metode for måling av CO-EEB ble brukt i Drammensundersøkelsen (Clench-Aas et al., 1988). Det ble der bare gjort målinger om ettermiddagen. Luftforurensning fra biltrafikk er lavere i Drammen enn i området rundt Rådhusgata i Oslo. Gjennomsnittsverdier for CO-EEB var 3,8 ppm for ikke-røykere i Drammen mot 4,6 ppm/5,7 ppm (morgen/ettermiddag) for ikke-røykere i Oslo. Personer som arbeider i sentrale deler av Oslo har altså en høyere generell CO-konsentrasjon i blodet enn folk som arbeider i Drammen. For røykere var verdien av CO-EEB (om ettermiddagen) gjennomsnittlig 24 ppm i Drammen. I Oslo var verdien av 19,3 ppm/25,7 ppm (morgen/ettermiddag). For røykere fant man altså ingen forskjell mellom prøvene tatt i Drammen og i Rådhusgata i Oslo.

# CONTENTS

# CARBON MONOXIDE EXPOSURE IN INDIVIDUALS WORKING ALONG RÅDHUSGATA, OSLO NORWAY 1987

## 1 INTRODUCTION

It is generally considered dangerous to people´s health to work in areas with heavy pollution. Therefore many people that work along roads with heavy traffic are concerned over the possible damage to their health.

In 1986, the Norwegian Institute for Air Research (NILU) was requested by the Royal Norwegian Council for Scientific and Industrial Research (Committee for Toxic Compounds in the Environment) to study to what degree individuals that work along a highway with heavy traffic in downtown Oslo, Norway are exposed for carbon monoxide. The stretch of highway (Rådhusgata) being studied is in an older part of the city, and is a typical city canyon.

Carbon monoxide (CO) is a gas that is generated with incomplete combustion and is therefore especially prominent in traffic pollution. CO in the lungs crosses into the blood where it is taken up and bound by hemoglobin. It is easier for CO than for oxygen to bind to hemoglobin. Therefore CO can hinder oxygen uptake by hemoglobin. In addition, it is more difficult for hemoglobin bound to CO (HbCO) to release oxygen to the tissues. High levels of CO can therefore cause oxygen shortage.

The concentration of CO in air should be low enough to assure that concentrations of CO in blood (HbCO) do not exceed 1.5% in non-smokers. The limit is set to 1.5% in Norway, whereas it is set to 2.5% in the U.S.A. Individuals suffering from cardiovascular disease can begin to show symptoms of their disease at levels of 2.5% HbCO. Calculations have shown that to assure that CO concentrations in the blood remain under these levels, it is necessary that air concentrations do not exceed 23 ppm for 1 hour or 9 ppm for 8 hours.

Although concentrations of CO in the blood of people in different situations have been measured in many studies, few studies have included relations of blood concentrations to real exposure. In U.S.A. there have been several studies performed where people´s exposure to CO was followed during a few days with portable monitors. These studies have shown that people can be exposed to higher concentrations of CO than those measured by permanent stations situated close to roads (Hartwell et al., 1984).

This was also the conclusion in a similar study done by our research team in an earlier study in Drammen (Clench-Aas et al., 1988). Despite generally low levels of exposure to CO, being in a traffic related environment contributed about 4 ppm CO to exposure, having an attached garage to a building contributed an extra ppm to exposure; using a fireplace or smoking indoors contributed around 1 ppm to exposure whereas smoking in a car contributed in additional 2.5 ppm CO. Few people in that study were exposed to high CO concentrations in the workplace.

Therefore, NILU designed a study in the winter of 1987 in Rådhusgata to measure concentrations of carbon monoxide both outside in the street and indoors where people work. These two sources of information were coupled with a diary to calculate each individuals exposure for CO. In addition, each individual´s blood and end-expired breath was also measured for CO twice a day, in the morning and again at the end of the working day.

## 2 GOAL OF THE INVESTIGATION

This investigation had three main goals:

1) Describe the concentration of carbon monoxide that individuals working in areas with heavy traffic are exposed to.

2) Compare concentrations of CO outdoors and indoors in typical work environments along a street with heavy traffic.

3) To further develop and test methods of controlling levels of CO in the body by comparing concentrations of CO in blood and end-expired breath.

## 3 DESCRIPTION OF THE GEOGRAPHIC AREA

The investigation was done in downtown Oslo, Norway in the winter of 1987. The street, Rådhusgata, is a portion of a major highway that crosses the city (Figure 1). In 1990 the traffic along this highway will be removed by being chanelled through an underground tunnel. At the time of the investigation the street has one-way traffic heading west (three lanes), and an estimated 3000 vehicles per hour during the morning rush hour and 2300 vehicles per hour during the afternoon (estimates done in 1985). Traffic density was measured in Rådhusgata in the winter of 1979 (Figure 2) (Larssen and Friberg, 1980). There is a sharp rise around 6 AM and a sharp decline around 6 PM, with two peaks during the day.

The current investigation was confined to a portion of the street lined by 5 to 6 story buildings (city canyon). Shops and offices were chosen on both sides of the street and covered mostly the first three floors of the buildings (Figure 1).

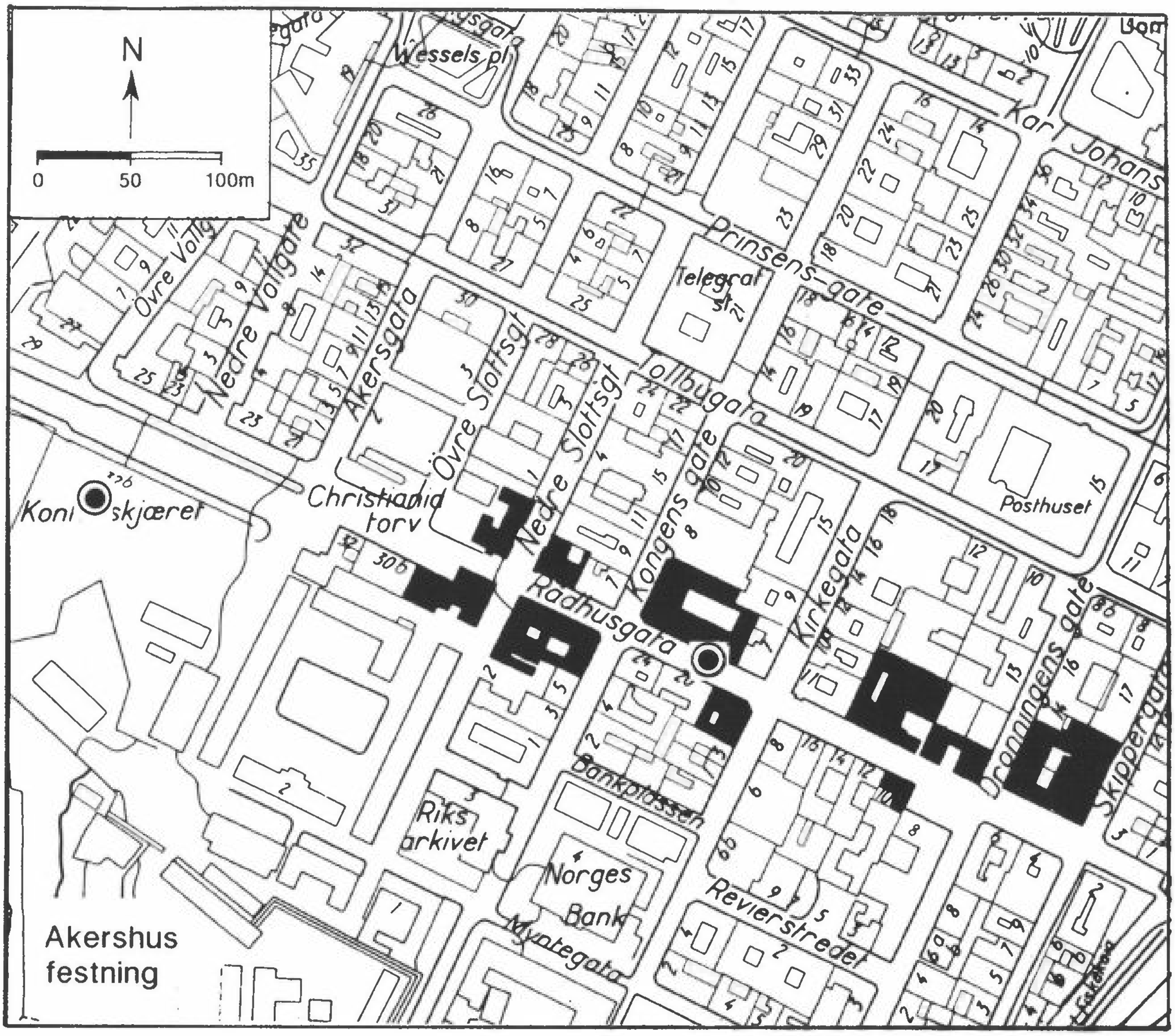



Figure 1: Map of the area where the investigation was done, showing the actual buildings included the study in black.
(◉) Stationary site.

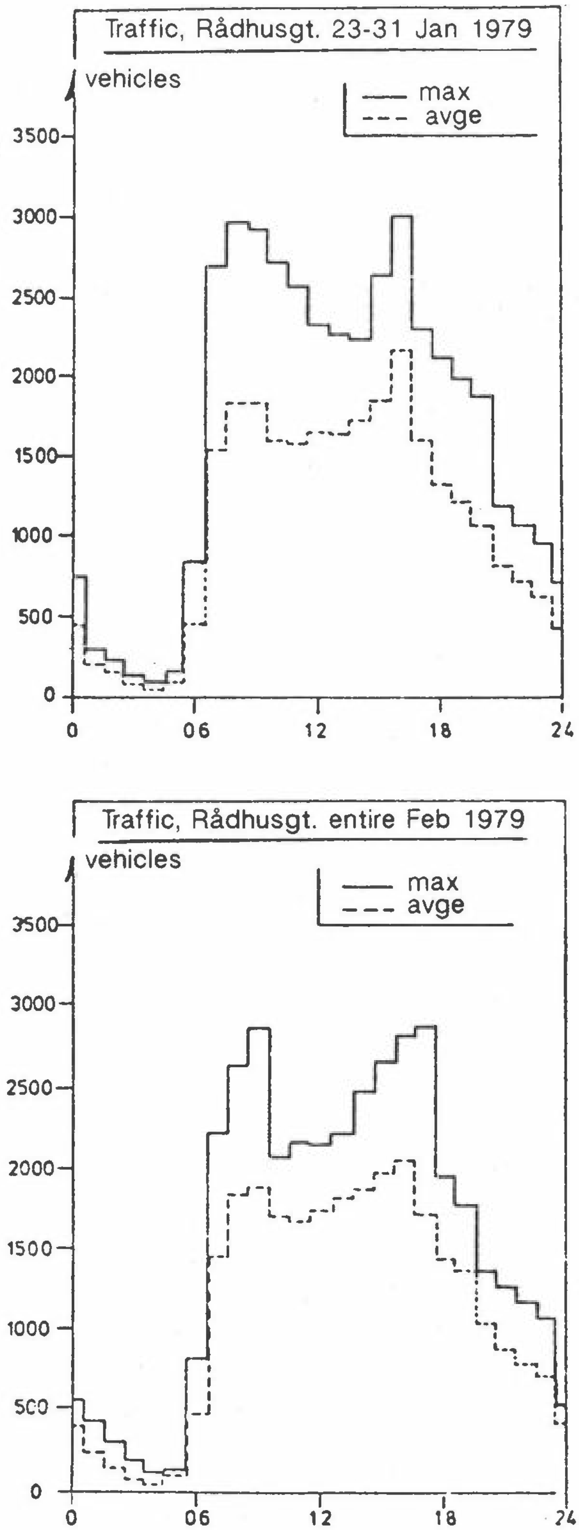



Figure 2: Hourly traffic density in Rådhusgata in the winter of 1979.

# 4 MATERIALS AND METHODS

## 4.1 SUBJECT SELECTION

Shops and offices situated in buildings lining a five block section of Rådhusgata were contacted and asked to participate in the study. The businesses were themselves responsible for asking their employees to volunteer for the study. 24 business establishments were included in the study (Figure 1). Six of them were shops at street level in addition to one restaurant and two banks. The remainder were offices. There were a total of 126 participants, of whom 59 were men and 67 women, and 57 were non-smokers, 20 occasional smokers and 49 smokers.

## 4.2 MEASUREMENT OF CARBON MONOXIDE IN INDOOR AND OUTDOOR AIR

Carbon monoxide concentrations, both indoors and outdoors, were measured using portable CO monitors. The portable CO monitor used in this study was developed early in the 1980s by the Environmental Protection Agency that loaned the monitors to us. It is a light yet accurate continuous personal monitor equipped with a data logger. It runs on a battery and has a running time of 24 hours. The measuring unit was developed by General Electric and the logger by Magus. The measuring system involves a chemical reaction between CO and $H_2O$ yielding $CO_2 + 2H^+ + 2e^-$. The hydrogen ions and the electrons traverse the membrane creating an electric current which is directly proportional to the amount of CO. The reaction is thermally regulated.

Portable CO monitors were strategically placed in each business establishment to reflect possible differences in CO concentrations. Monitor locations were chosen to cover the following:

- facing Rådhusgata, facing other streets with heavy traffic or a facing a courtyard
- different floors
- presence or absence of smokers

Features of buildings that could influence indoor values of CO were noted such as new windows, changes in ventilation as for example having air intake from the roof or from the coutyard side of the building.

The number of monitors in each place of business varied from 1 to 8 dependent on the size of the business.

CO was also measured at a stationary site located at curb-side in the middel of the area of interest (Figure 1). The portable type CO monitor was used here to insure comparability.

## 4.3 CALCULATION OF CARBON MONOXIDE EXPOSURE FOR EACH INDIVIDUAL

Each individual kept a diary over the time spent at work that day. They noted every time they moved from one place to another specifying floor and room, if possible. They also noted the time for each cigarette smoked.

The information from the diary was combined with the concentrations of CO measured indoors and outdoors that day for their business establishment. Each individual´s exposure to CO could then be derived.

## 4.4 MEASUREMENT OF CARBON MONOXIDE IN BLOOD

A blood sample (5 ml, heparinized vacutainer) was collected from each participant, once in the morning and again in the afternoon. The samples were temporarily stored on ice and measured within a couple of hours of sampling.

Hemoglobin and carboxyhemoglobin (HbCO) was measured by an "Hemoximeter OSM 3" built by Radiometer in Copenhagen. The instrument uses a photometric method to measure the different hemoglobin derivatives. Each derivative absorbs at a different maximum wavelength. HbCO absorbs at 535 nm. The blood is hemolyzed in a thermally controlled cuvette by vibration at a frequency of about 40kHz.

Each sample was measured at least twice, and the average of the measurements used. Variation between samples was minimal. The instrument was calibrated before and after each series of analyses with three different known levels of hemoglobin and HbCO.

### 4.5 MEASUREMENT OF CARBON MONOXIDE IN END-EXPIRED BREATH SAMPLES

Each individual was asked to breathe normally for a couple of minutes, then to take a deep breath and blow out. Then they were to take another deep breath, hold it for 20 seconds, blow half out and blow the rest into a plastic bag. The plastic bag was a special 3 liter bag with a valve opening. The bags were pumped empty between each trial. The mouthpiece was sterilized and replaced for each individual.

Each sample was analyzed immediately after sampling by connecting the bag to a portable CO monitor. The same monitor was used for each field day and for all the samples of end-expired breath.

## 5 RESULTS AND DISCUSSION

### 5.1 CARBON MONOXIDE CONCENTRATIONS IN OUTDOOR AIR

The results of this study confirmed that concentrations of CO in outdoor air are rather high in Rådhusgata. They also confirmed that values in indoor air are often nearly as high as in outdoor air, especially for those business establishments on the ground level, and especially for rooms where the entrance door is opened often. In addition, CO concentrations were at the same level over the first three floors.

Measured concentrations are presented in Figure 3. The air quality guideline for 8-hour CO concentration (9 ppm) is indicated. Only on one day were values under 9 ppm for the entire 8-hour period. On two of the days the values exceeded 9 ppm only during the afternoon rush hour traffic. On two days, values exceeded 9 ppm the entire day. For two days, values were only briefly under 9 ppm. Calculated 4 hour averages during the middle of the day are presented in Figure 4.

Concentrations of CO were thus clearly around or above the air quality standard of 9 ppm during the investigation.

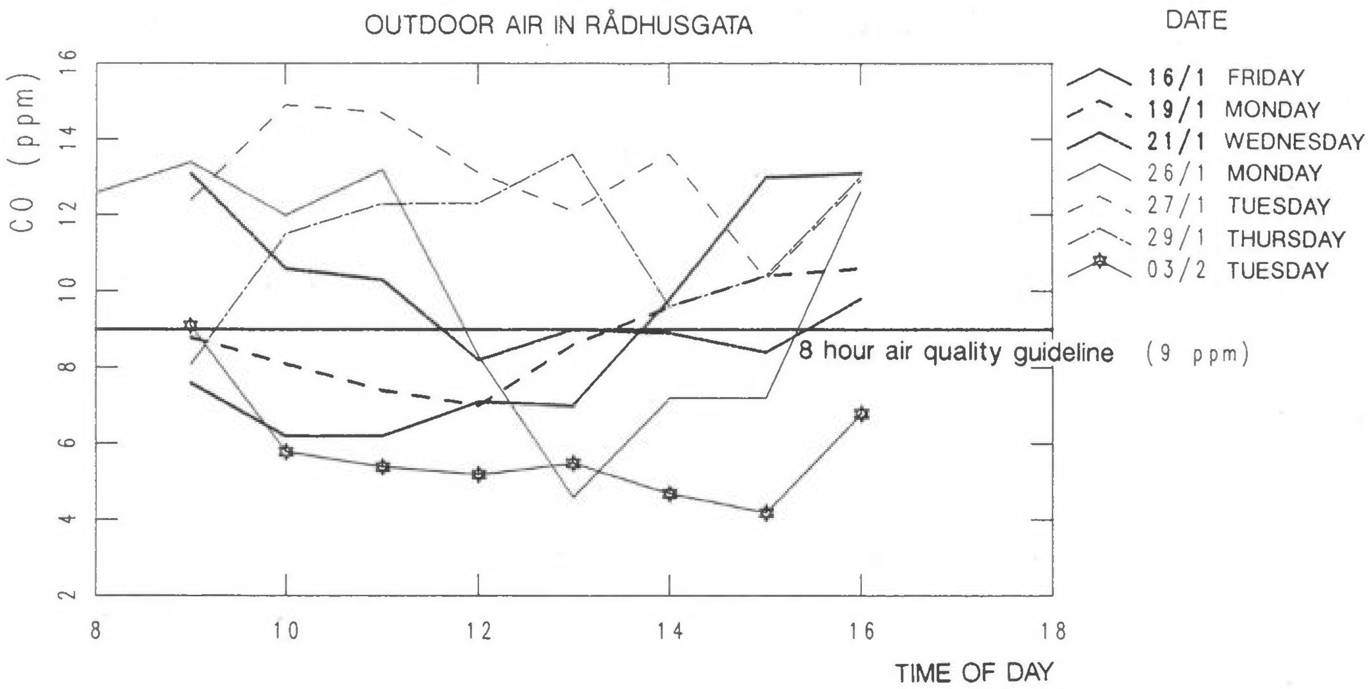
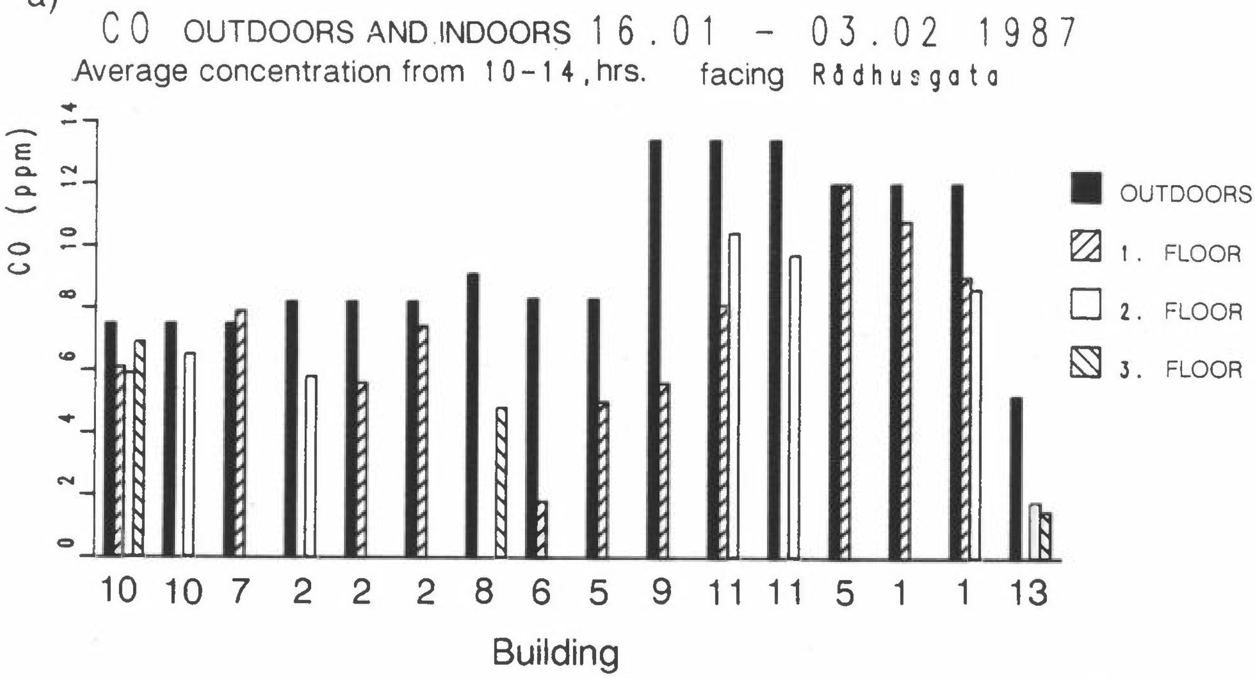



Figure 3: Values of CO measured outdoors in Rådhusgata for each field-day in January-February 1987.

a)




b)

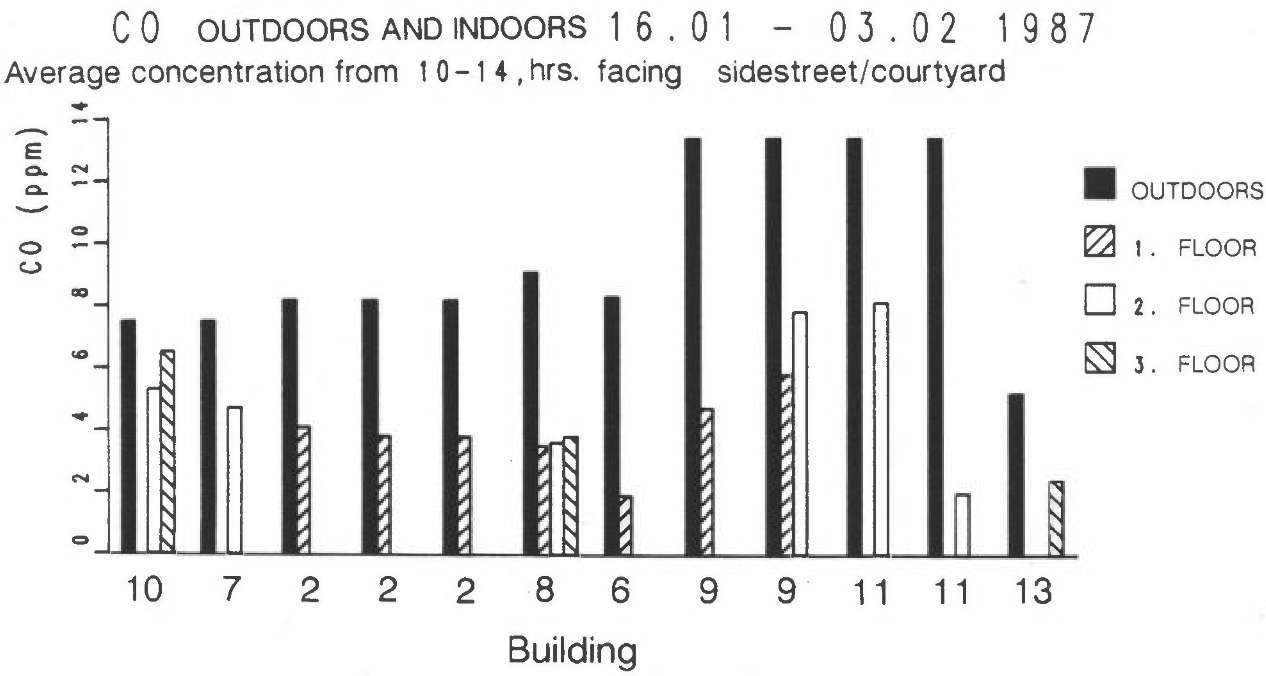



Figure 4: Average concentrations of CO measured indoors and outdoors for different business establishments in Rådhusgata.

## 5.2 CARBON MONOXIDE CONCENTRATIONS IN INDOOR AIR

Concentrations of CO in indoor air reflected outdoor concentrations in those buildings where no measures were taken to improve air quality. Concentrations indoors were similar for the first three floors. CO concentrations in those establishments that had relocated air intake to the roof or courtyard and/or had modernised their windows had lower concentrations of CO indoors. Values measured for each establishment are in Appendix 1.

Rooms with windows facing Rådhusgata seem to have higher values for CO indoors than rooms in the same building which have windows facing a courtyard or side street. Figure 5 compares the results of measurements made indoors in an office in Rådhusgata with values measured outdoors. The different offices have comparable ventilation systems, the building has recently been restored and has new windows. In one of the offices CO concentrations in the middle of the day increased above those values measured outdoors. It is unknown why this happened. Tobacco smoking could be an explanation but it is also possible that concentrations of CO outside of that particular building or in that block were higher than those measured at the stationary site.

Measurements made over the first three floors in the same building seem to show no sign of decreasing CO concentration with increased elevation. Figure 6 shows an example of this, results of measurements in a building having a facade towards Rådhusgata. The building had not been renovated, windows not replaced or ventilation system changed to improve air quality. Concentrations of CO measured indoors follow those measured outdoors on all three floors although at a somewhat lower level.

The building in Figure 7, has a fresh air intake from the roof and lies slightly withdrawn from the main road. The highest values measured indoors are those in the part of the building facing Rådhusgata. Generally, concentrations of CO measured indoors are much lower than those measured outdoors, and they do not follow the trends measured outdoors.

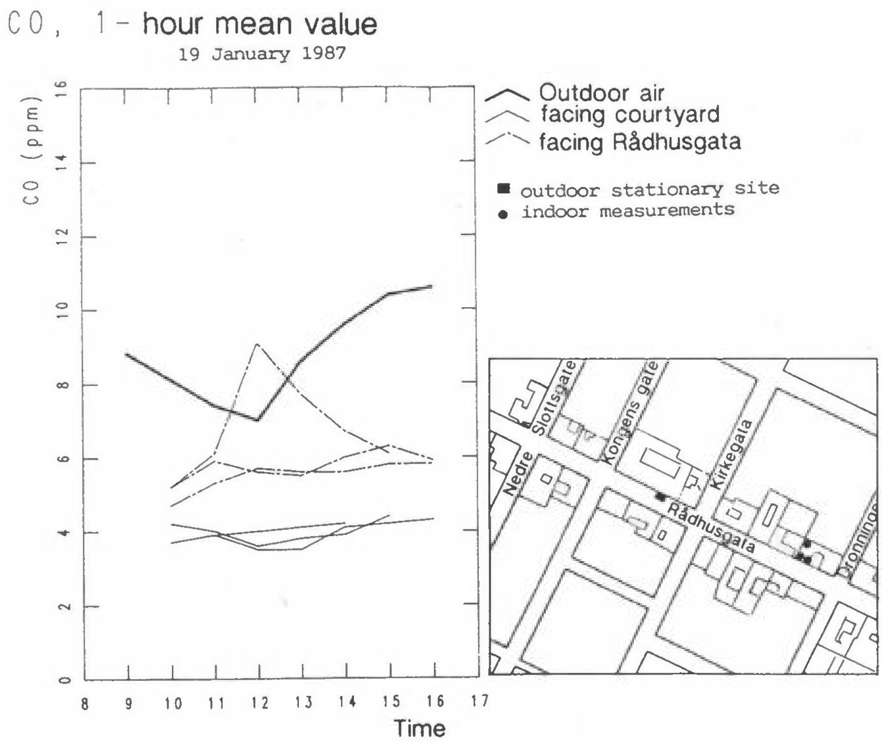



Figure 5: Differences in indoor concentrations of CO relating to room facing Rådhusgata or room facing courtyard.

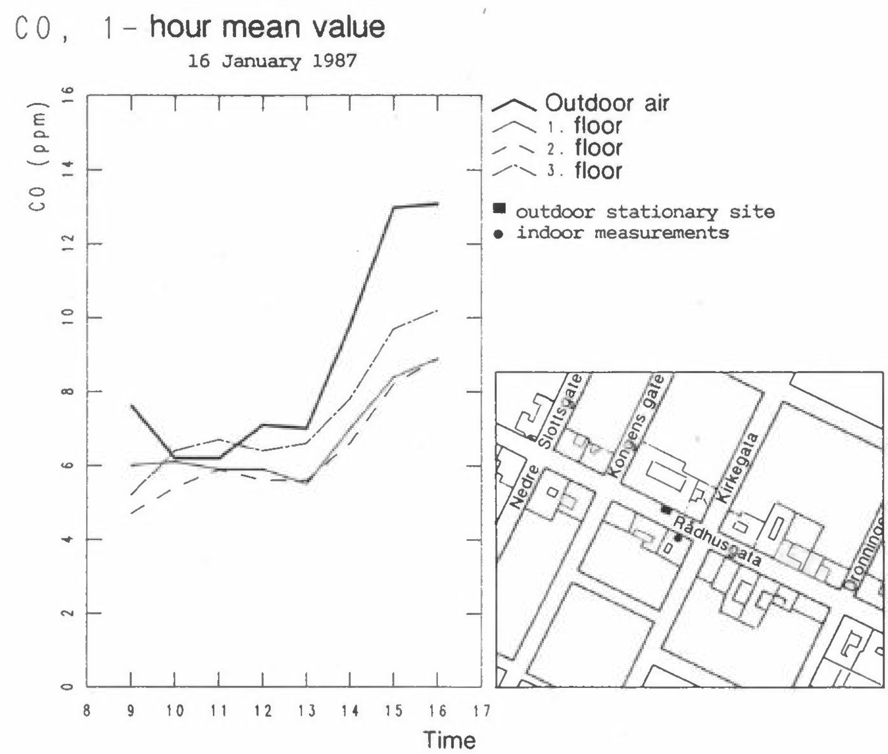



Figure 6: Comparison of concentration of CO measured on the floors in the same building.

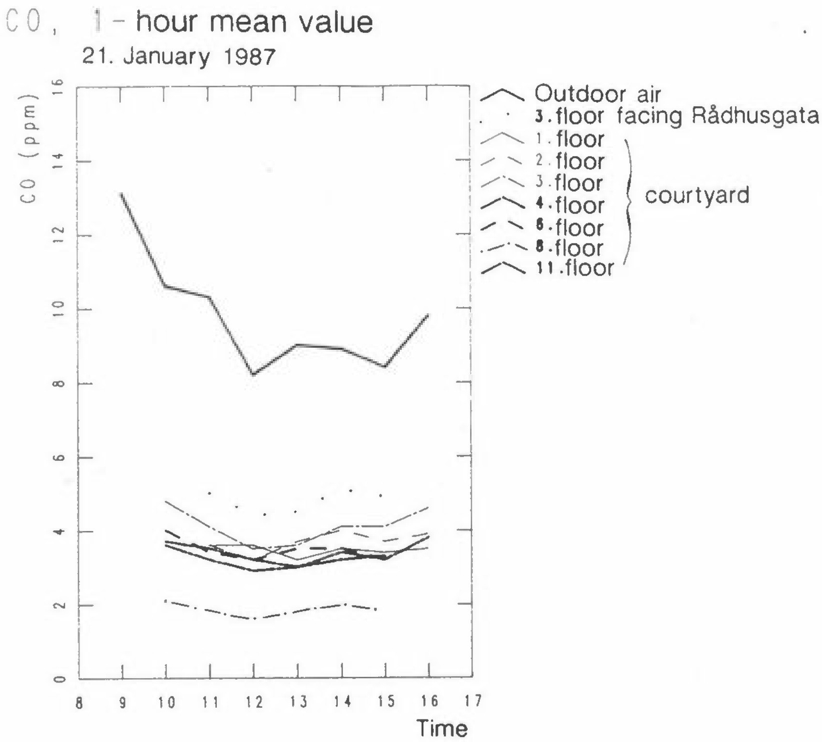



Figure 7: Concentrations of CO measured in a single building with fresh air intake from the roof.

All the measurements shown in Figure 8 were made on the ground floor. Measurements were made in a room where the entrance door faced Rådhusgata, with no measures to improve indoor air quality. Concentrations indoors follow closely those measured outdoors. The other two curves were from measurements in a modern building with sealed windows. The entrance door faces Kongens gata, not far from Rådhusgata. Even though CO concentrations increase slightly during the day, they are substantially lower than those measured in the other building having an entrance on Rådhusgata. They show no sign of following outdoor concentrations.

Figure 9 shows the result of measurements in an older office building on Rådhusgata compared to simultaneous outdoor measurements. Average concentration of CO over the 8 hour measurement period was 13 ppm. No measures were taken in this building to improve air quality, either by renovating or improving the building tightness or altered ventilation system. Individuals working on the second floor of the building complained of being bothered by dust from the street. The results of

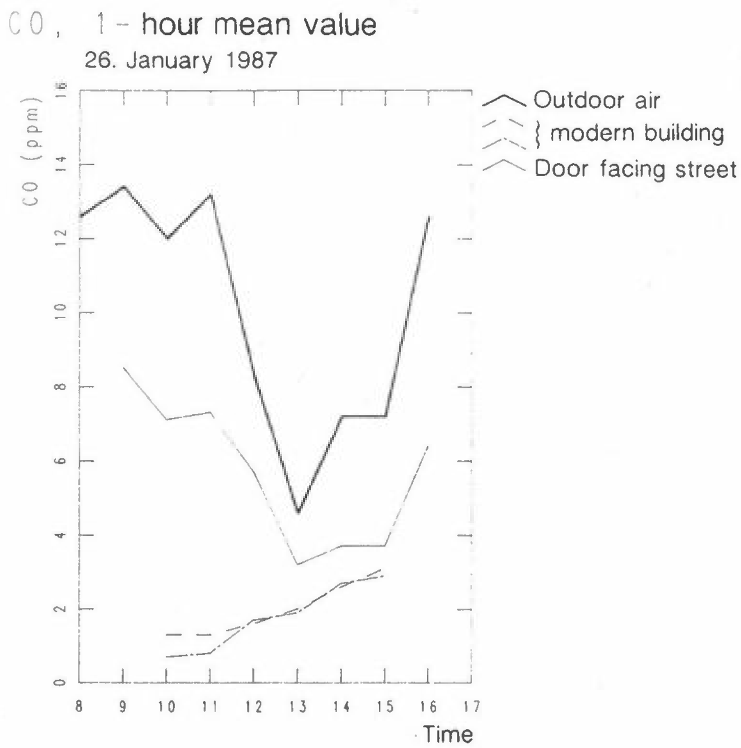



Figure 8: Comparison of concentration of CO measured in a modern building with those in an old building.

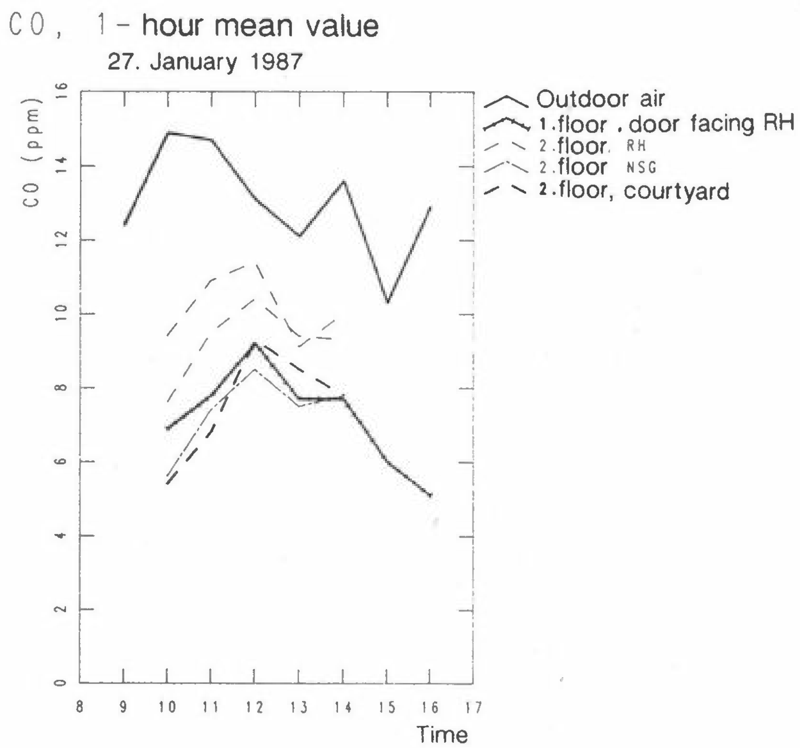



Figure 9: Concentrations of CO measured in various office in an older building.

measurements show that these offices had higher CO concentrations than offices in the same building facing either a side street or the courtyard. The office in the second floor had higher concentrations than in the shop under them with an entrance door facing Rådhusgata.

## 5.3 INDIVIDUAL CARBON MONOXIDE EXPOSURE

Information from the individuals diaries (as described in section 4.3) was coupled with the measurements of CO made indoors and outdoors. Table 1 summarizes each individual´s calculated average exposure for CO during the last 4 or 6 hours as well as the maximum single exposure that person was exposed to. A full hour by hour list of exposure for each participant is given in Appendix 2. As can be seen in Table 1, the highest concentration, an individual was exposed to 19.6 ppm. As can be seen in Table 2 the average exposure for each day for all the participants varied from 2 ppm to 8.6 ppm. The maximum hourly values the participants were exposed to varied from 3 to 11.9 ppm. Figures 10 and 11 show average and maximum exposure respectively for all subjects as a function of day of the week of the experiment. A maximum exposure for all subjects is shown in Figure 12 as a function of smoking habits. Even though monitors were placed in areas where smokers sat, smoking contributes very little to CO concentrations in ambient air. This was also observed in the Drammen study where CO concentrations were increased by only 1 or 2 ppm in rooms where people smoked. The principle source of CO in ambient air in Rådhusgata shops is therefore car traffic.

Table 1: Average 4 and 6 hour exposure as well as maximum hourly exposure to CO for each individual.

| Date | S.No. | 4 hour* average | 4 hour* max | 6 hour average | 6 hour max |
|---|---|---|---|---|---|
| 16.1.87 | 1 | 5.1 | 9.7 | 99.9 | 9.7 |
| 16.1.87 | 2 | 4.4 | 6.6 | 99.9 | 6.6 |
| 16.1.87 | 3 | 4.9 | 9.5 | 4.9 | 9.5 |
| 16.1.87 | 4 | 7.4 | 9.7 | 7.1 | 9.7 |
| 16.1.87 | 5 | 6.5 | 8.9 | 6.5 | 8.9 |
| 16.1.87 | 6 | 6.8 | 9.5 | 6.7 | 9.5 |
| 16.1.87 | 7 | 6.8 | 9.5 | 6.6 | 9.5 |
| 16.1.87 | 8 | 7.0 | 8.9 | 6.9 | 8.9 |
| 16.1.87 | 9 | 6.4 | 8.4 | 6.2 | 8.4 |
| 16.1.87 | 10 | 6.3 | 8.5 | 6.0 | 8.5 |
| 16.1.87 | 11 | 7.0 | 8.9 | 6.9 | 8.9 |
| 16.1.87 | 12 | 6.6 | 8.9 | 6.6 | 8.9 |
| 16.1.87 | 13 | 7.1 | 9.7 | 6.9 | 9.7 |
| 16.1.87 | 14 | 6.2 | 8.5 | 5.9 | 8.5 |
| 16.1.87 | 15 | 6.6 | 9.5 | 99.9 | 9.5 |
| 16.1.87 | 16 | 6.9 | 8.9 | 99.9 | 8.9 |
| 16.1.87 | 17 | 6.8 | 10.0 | 6.6 | 10.0 |
| 16.1.87 | 18 | 6.3 | 9.8 | 6.1 | 9.8 |
| 16.1.87 | 19 | 6.5 | 8.4 | 99.9 | 8.4 |
| 16.1.87 | 20 | 7.1 | 9.7 | 99.9 | 9.7 |
| 16.1.87 | 21 | 7.2 | 9.7 | 99.9 | 9.7 |
| 16.1.87 | 22 | 6.1 | 8.2 | 99.9 | 8.2 |
| 16.1.87 | 23 | 5.6 | 8.3 | 99.9 | 8.3 |
| 16.1.87 | 24 | 5.9 | 8.5 | 99.9 | 8.5 |
| 16.1.87 | 25 | 6.1 | 8.5 | 99.9 | 8.5 |
| 16.1.87 | 26 | 5.2 | 8.4 | 99.9 | 8.4 |
| 16.1.87 | 27 | 8.2 | 11.7 | 99.9 | 11.7 |
| 16.1.87 | 28 | 8.1 | 11.7 | 99.9 | 11.7 |
| 19.1.87 | 29 | 5.2 | 8.4 | 99.9 | 8.4 |
| 19.1.87 | 30 | 6.5 | 9.1 | 99.9 | 9.1 |
| 19.1.87 | 31 | 3.9 | 4.4 | 99.9 | 4.4 |
| 19.1.87 | 32 | 7.4 | 9.1 | 99.9 | 9.1 |
| 19.1.87 | 33 | 3.9 | 4.4 | 99.9 | 4.4 |
| 19.1.87 | 34 | 7.0 | 9.1 | 99.9 | 9.1 |
| 19.1.87 | 35 | 6.8 | 9.1 | 99.9 | 9.1 |
| 19.1.87 | 36 | 4.6 | 9.1 | 99.9 | 9.1 |
| 19.1.87 | 37 | 5.8 | 6.3 | 99.9 | 6.3 |
| 19.1.87 | 38 | 5.4 | 6.3 | 99.9 | 6.3 |
| 19.1.87 | 40 | 2.5 | 2.8 | 99.9 | 2.8 |
| 21.1.87 | 41 | 99.9 | 9.1 | 99.9 | 9.1 |
| 21.1.87 | 42 | 2.0 | 3.6 | 99.9 | 4.0 |
| 21.1.87 | 43 | 3.3 | 3.8 | 3.4 | 8.2 |
| 21.1.87 | 44 | 5.1 | 9.0 | 4.6 | 9.0 |
| 21.1.87 | 45 | 3.2 | 3.3 | 3.3 | 3.7 |
| 21.1.87 | 46 | 4.0 | 4.6 | 3.9 | 4.8 |
| 21.1.87 | 47 | 4.7 | 9.0 | 4.2 | 9.0 |
| 21.1.87 | 48 | 4.5 | 8.4 | 4.4 | 8.4 |
| 21.1.87 | 49 | 99.9 | 4.0 | 99.9 | 4.0 |
| 21.1.87 | 50 | 3.4 | 3.6 | 3.7 | 4.8 |
| 21.1.87 | 51 | 3.3 | 3.8 | 3.2 | 3.8 |
| 21.1.87 | 52 | 3.3 | 4.5 | 3.4 | 4.5 |
| 21.1.87 | 53 | 3.9 | 4.6 | 3.9 | 4.8 |
| 21.1.87 | 54 | 5.1 | 8.9 | 4.5 | 8.9 |
| 21.1.87 | 55 | 2.0 | 3.0 | 99.9 | 3.0 |
| 21.1.87 | 56 | 2.0 | 2.9 | 99.9 | 3.6 |
| 26.1.87 | 57 | 4.4 | 8.4 | 99.9 | 8.4 |
| 26.1.87 | 58 | 5.8 | 9.5 | 4.6 | 9.5 |
| 26.1.87 | 59 | 5.3 | 11.5 | 5.8 | 11.5 |
| 26.1.87 | 60 | 2.4 | 8.3 | 3.3 | 13.2 |
| 26.1.87 | 61 | 2.7 | 3.6 | 2.8 | 3.6 |
| 26.1.87 | 62 | 2.5 | 3.6 | 2.7 | 3.6 |
| 26.1.87 | 63 | 2.8 | 4.6 | 2.9 | 4.6 |
| 26.1.87 | 64 | 2.5 | 3.6 | 3.0 | 12.0 |
| 26.1.87 | 65 | 1.4 | 2.1 | 99.9 | 2.1 |
| 26.1.87 | 66 | 2.1 | 2.9 | 1.9 | 2.9 |

* 99.9 are missing data.

Table 1: cont.

| Date | S.No. | 4 hour* average | max | 6 hour average | max |
|---|---|---|---|---|---|
| 26.1.87 | 67 | 1.6 | 2.9 | 99.9 | 2.9 |
| 26.1.87 | 68 | 2.0 | 2.9 | 1.6 | 2.9 |
| 26.1.87 | 69 | 2.3 | 7.2 | 2.0 | 7.2 |
| 26.1.87 | 70 | 1.5 | 2.1 | 1.5 | 2.1 |
| 27.1.87 | 71 | 1.6 | 3.1 | 1.5 | 3.1 |
| 27.1.87 | 73 | 6.5 | 12.9 | 6.6 | 12.9 |
| 27.1.87 | 74 | 7.9 | 9.3 | 99.9 | 9.3 |
| 27.1.87 | 75 | 7.2 | 12.9 | 7.0 | 12.9 |
| 27.1.87 | 76 | 10.3 | 11.4 | 99.9 | 11.4 |
| 27.1.87 | 77 | 7.7 | 8.5 | 99.9 | 8.5 |
| 27.1.87 | 78 | 10.4 | 12.1 | 99.9 | 12.1 |
| 27.1.87 | 79 | 9.7 | 10.4 | 99.9 | 10.4 |
| 27.1.87 | 81 | 5.0 | 6.1 | 5.3 | 6.9 |
| 27.1.87 | 82 | 7.1 | 9.2 | 7.4 | 9.2 |
| 27.1.87 | 83 | 5.3 | 6.3 | 99.9 | 6.3 |
| 27.1.87 | 84 | 5.2 | 6.9 | 99.9 | 6.9 |
| 27.1.87 | 85 | 6.8 | 13.6 | 99.9 | 13.6 |
| 27.1.87 | 86 | 5.2 | 6.3 | 99.9 | 6.3 |
| 27.1.87 | 87 | 99.9 | 13.1 | 99.9 | 13.1 |
| 27.1.87 | 88 | 5.2 | 6.3 | 99.9 | 6.3 |
| 29.1.87 | 89 | 5.1 | 6.3 | 99.9 | 6.3 |
| 29.1.87 | 91 | 8.7 | 9.4 | 99.9 | 9.4 |
| 29.1.87 | 92 | 9.3 | 9.5 | 99.9 | 12.3 |
| 29.1.87 | 93 | 9.3 | 9.5 | 99.9 | 9.5 |
| 29.1.87 | 94 | 9.3 | 9.5 | 99.9 | 9.5 |
| 29.1.87 | 95 | 10.8 | 13.6 | 99.9 | 13.9 |
| 29.1.87 | 96 | 11.5 | 19.6 | 99.9 | 19.6 |
| 29.1.87 | 97 | 4.7 | 7.2 | 99.9 | 7.2 |
| 29.1.87 | 98 | 4.7 | 7.2 | 99.9 | 7.2 |
| 29.1.87 | 99 | 99.9 | 7.2 | 99.9 | 7.2 |
| 29.1.87 | 100 | 8.8 | 13.0 | 99.9 | 13.0 |
| 29.1.87 | 101 | 99.9 | 12.2 | 99.9 | 12.2 |
| 3.2.87 | 102 | 99.9 | 12.2 | 99.9 | 12.2 |
| 3.2.87 | 103 | 1.7 | 2.0 | 99.9 | 2.0 |
| 3.2.87 | 104 | 1.7 | 2.0 | 99.9 | 2.0 |
| 3.2.87 | 105 | 1.9 | 3.0 | 99.9 | 3.0 |
| 3.2.87 | 106 | 3.3 | 5.5 | 99.9 | 5.5 |
| 3.2.87 | 107 | 2.2 | 5.5 | 2.3 | 5.5 |
| 3.2.87 | 108 | 1.5 | 3.0 | 1.5 | 3.0 |
| 3.2.87 | 109 | 2.6 | 3.0 | 99.9 | 3.0 |
| 3.2.87 | 110 | 2.9 | 5.5 | 99.9 | 5.5 |
| 3.2.87 | 111 | 2.5 | 4.7 | 99.9 | 4.7 |
| 3.2.87 | 112 | 1.4 | 1.6 | 1.5 | 1.7 |
| 3.2.87 | 113 | 1.9 | 5.5 | 99.9 | 5.5 |
| 3.2.87 | 114 | 1.4 | 3.0 | 99.9 | 3.0 |
| 3.2.87 | 115 | 1.2 | 1.4 | 99.9 | 2.0 |
| 3.2.87 | 116 | 1.8 | 2.0 | 99.9 | 5.2 |
| 3.2.87 | 117 | 2.2 | 2.5 | 99.9 | 2.5 |
| 3.2.87 | 118 | 1.8 | 2.0 | 1.8 | 2.0 |
| 3.2.87 | 119 | 2.5 | 6.8 | 2.4 | 6.8 |
| 3.2.87 | 120 | 2.1 | 5.2 | 99.9 | 5.2 |
| 3.2.87 | 121 | 1.6 | 2.1 | 99.9 | 2.1 |
| 3.2.87 | 122 | 1.2 | 1.4 | 99.9 | 2.0 |
| 3.2.87 | 123 | 3.0 | 4.7 | 99.9 | 4.7 |
| 3.2.87 | 124 | 1.4 | 1.6 | 99.9 | 2.3 |
| 3.2.87 | 126 | 1.1 | 3.0 | 99.9 | 3.0 |
| 3.2.87 | 127 | 2.7 | 2.9 | 99.9 | 2.9 |

* 99.9 are missing data

Table 2: Average values and average maximum hourly value of exposure to CO (ppm) for each field day.

| Date | Average CO exposure | Average maximum CO exposure | Numer of participants |
|---|---|---|---|
| 16.1.87 | 6.3 | 8.0 | 29 |
| 19.1.87 | 5.3 | 7.1 | 11 |
| 21.1.87 | 3.6 | 4.6 | 16 |
| 26.1.87 | 2.9 | 6.4 | 14 |
| 27.1.87 | 6.8 | 10.2 | 16 |
| 29.1.87 | 8.6 | 11.9 | 12 |
| 3.2.87 | 2.0 | 3.0 | 24 |

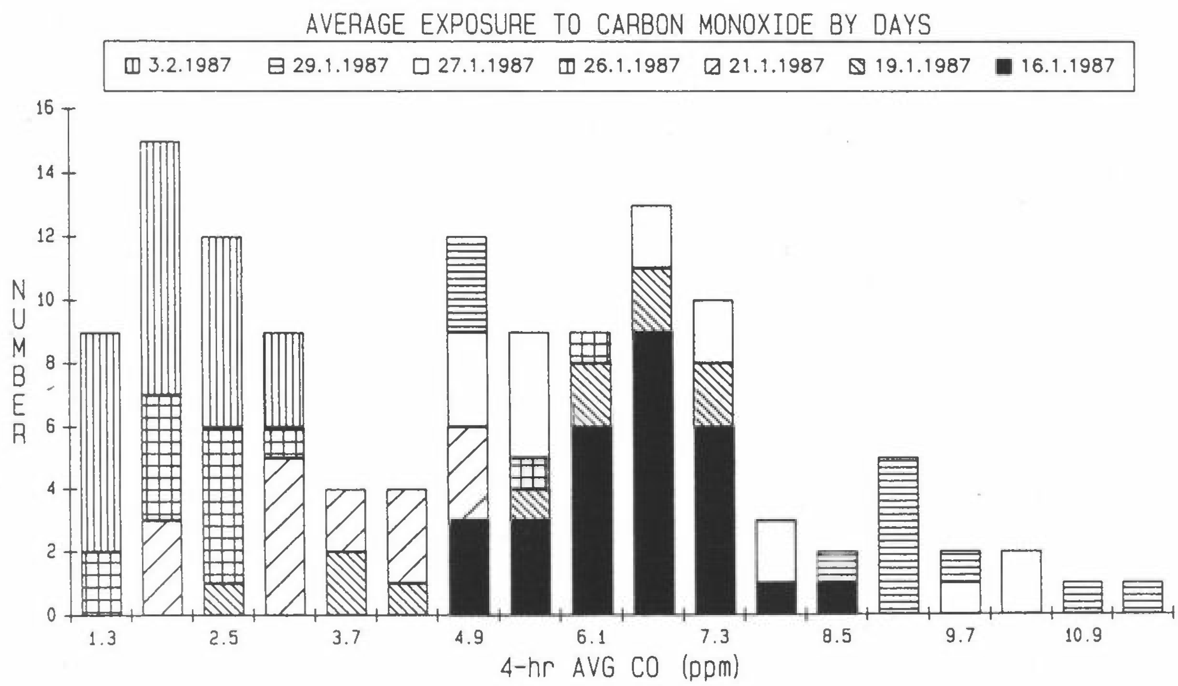



Figure 10: Average exposure to CO of participants in the study as a function of date.

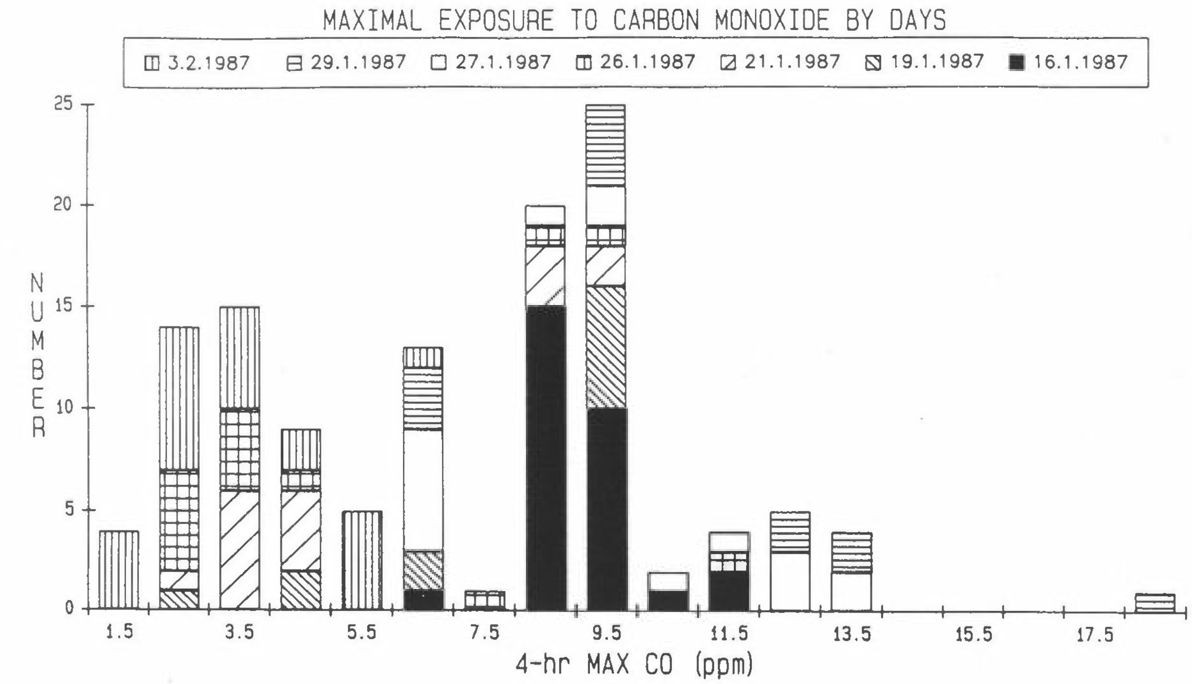



**Figure 11:** Maximal hourly exposure to CO of the participants as a function of date.

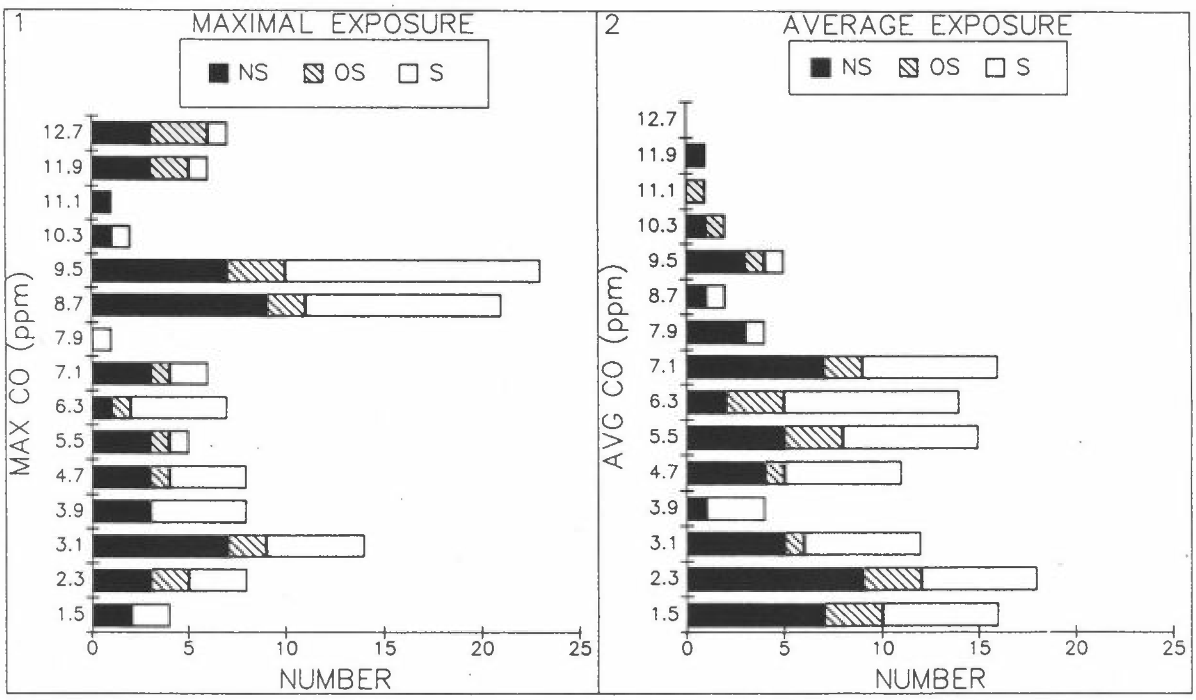



**Figure 12:** Frequency distribution of differences in HbCO between morning and afternoon samples (Delta HbCO) for smokers, occasional smokers and non-smokers.

## 5.4 CARBON MONOXIDE CONCENTRATIONS IN THE BLOOD IN THE MORNING AND AFTER A FULL WORKING DAY

The single most important factor that determines concentrations of CO in blood is smoking. Even though smoking does not contribute much CO to ambient air, a smoker inhales enormous amounts of CO. Therefore, it is usual to have values over 3% HbCO in smokers. Non-smokers on the other hand usually have values of HbCO under 1%. Therefore, when looking for a relationship between HbCO or changes in HbCO over the working day (delta HbCO) with exposure, the three smoking groups must be treated separately.

Average and maximum hourly exposure to CO and mean values of HbCO as measured in smokers, non-smokers and occasionaly smokers are given in Table 3. Since concentrations of ambient CO differ markedly between field days, the results are given for each day separately.

Differences between morning and afternoon HbCO values are visible only in smokers (see Table 4). In non-smokers no change is observed. The group of occasional smokers shows a large variability due to its non-homogeneity in smoking - it includes both those who smoked during the study day and those who did not. The amounts the individual participants smoked may vary substantially. Cumulative distribution of delta HbCO is given Figure 13, where the difference between non-smokers (no change) and smokers (positive values) is clearly visible.

An analysis of variance of delta HbCO was done by sex and smoking while controlling for age and weight to height ratio. Smoking was the only parameter to show a significant relationship with delta HbCO.

Even though differences between afternoon and morning samples were only slight for non-smokers, it was possible to examine by regression analysis the relationship of body burden of CO with ambient CO exposure. The results are summarized in Table 6. There is no improvement in the relationship to express it as a function of maximum hourly exposure to CO for the four hours prior to afternoon blood sampling as

Table 3: HbCO in the morning and afternoon in non-smokers, occasional smokers and daily smokers as a function for date of the study.

| Table: Mean / Std.dev. / Number | Date 3.2.87 | 16.1.87 | 19.1.87 | 21.1.87 | 26.1.87 |
|---|---|---|---|---|---|
| NON-SMOKERS | | | | | |
| 4-hr avg CO pers. | | | | | |
| exp. (ppm) | 1.91 | 6.78 | 5.56 | 3.62 | 1.75 |
| | 0.62 | 1.06 | 2.01 | 1.16 | 0.35 |
| | 13 | 8 | 5 | 9 | 2 |
| 4-hr max CO pers. | | | | | |
| exp. (ppm) | 3.62 | 9.48 | 7.84 | 5.50 | 2.50 |
| | 1.73 | 1.43 | 2.82 | 2.51 | 0.57 |
| | 13 | 8 | 5 | 9 | 2 |
| HbCO - morning (%) | 0.35 | 0.76 | 0.34 | 0.40 | 0.50 |
| | 0.09 | 0.56 | 0.13 | 0.23 | 0.28 |
| | 13 | 7 | 5 | 9 | 2 |
| HbCO - afternoon (%) | 0.40 | 0.68 | 0.46 | 0.44 | 0.30 |
| | 0.08 | 0.20 | 0.11 | 0.31 | |
| | 11 | 5 | 5 | 8 | 1 |
| Delta HbCO (%) | 0.05 | -0.14 | 0.12 | 0.10 | |
| | 0.12 | 0.57 | 0.20 | 0.28 | |
| | 11 | 5 | 5 | 8 | 1 |
| OCCASIONAL SMOKERS | | | | | |
| 4-hr avg CO pers. | | | | | |
| exp. (ppm) | 2.17 | 6.15 | 6.00 | | 2.00 |
| | 0.59 | 0.79 | | | 0.36 |
| | 4 | 4 | 1 | | 3 |
| 4-hr max CO pers. | | | | | |
| exp. (ppm) | 3.55 | 9.23 | 9.10 | | 4.40 |
| | 1.82 | 0.63 | | | 2.43 |
| | 4 | 4 | 1 | | 3 |
| HbCO - morning (%) | 0.56 | 0.72 | 1.90 | | 1.10 |
| | 0.27 | 0.48 | | | 0.89 |
| | 5 | 4 | 1 | | 3 |
| HbCO - afternoon (%) | 0.40 | 1.17 | 2.80 | | 1.00 |
| | 0.16 | 0.68 | | | 1.47 |
| | 4 | 3 | 1 | | 3 |
| Delta HbCO (%) | -0.23 | 0.67 | 0.90 | | -0.10 |
| | 0.39 | 0.67 | | | 0.66 |
| | 4 | 3 | 1 | | 3 |
| SMOKERS | | | | | |
| 4-hr avg CO pers. | | | | | |
| exp. (ppm) | 2.01 | 6.32 | 5.20 | 3.56 | 3.00 |
| | 0.70 | 0.83 | 1.32 | 0.90 | 1.53 |
| | 7 | 17 | 5 | 7 | 9 |
| 4-hr max CO pers. | | | | | |
| exp. (ppm) | 2.67 | 8.95 | 6.10 | 5.13 | 5.52 |
| | 1.38 | 0.85 | 1.93 | 2.50 | 3.35 |
| | 7 | 17 | 5 | 7 | 9 |
| HbCO - morning (%) | 2.74 | 2.70 | 2.35 | 1.73 | 3.04 |
| | 1.53 | 1.66 | 1.57 | 1.23 | 2.35 |
| | 7 | 16 | 4 | 7 | 8 |
| HbCO - afternoon (%) | 4.03 | 3.41 | 4.02 | 3.34 | 2.81 |
| | 2.33 | 2.05 | 2.40 | 1.88 | 1.43 |
| | 6 | 15 | 5 | 7 | 7 |
| Delta HbCO (%) | 1.18 | 0.55 | 1.02 | 1.61 | -0.30 |
| | 2.53 | 1.03 | 0.68 | 0.93 | 1.68 |
| | 6 | 14 | 4 | 7 | 7 |

Table 4: Mean values of differences in HbCO between afternoon and morning samples and CO in end-expired breath samples (CO-EEB) as a function of smoking.

| | Non-smokers | Occas. smokers | Daily smokers |
|---|---|---|---|
| Delta HbCO (%) | | | |
| Mean | 0.13 | 0.19 | 0.73 |
| Std.dev. | 0.44 | 0.74 | 1.46 |
| N | 44 | 16 | 49 |
| Delta CO-EEB (ppm) | | | |
| Mean | 1.08 | 1.56 | 5.57 |
| Std.dev. | 1.14 | 3.57 | 7.68 |
| N | 50 | 18 | 49 |

Table 5: Results of analysis of variance of differences in HbCO between morning and afternoon blood samples as a function of smoking, sex, age and weight index.

| Source of Variation | Sum of squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|
| Covariates | 1.495 | 2 | 0.747 | 0.663 | 0.518 |
| AGE | 0.534 | 1 | 0.534 | 0.474 | 0.493 |
| Weight/height index | 0.842 | 1 | 0.842 | 0.747 | 0.390 |
| Main Effects | 10.032 | 3 | 3.344 | 2.966 | 0.036 |
| SMOKING | 10.018 | 2 | 5.009 | 4.443 | 0.014 |
| SEX | 1.142 | 1 | 1.142 | 1.013 | 0.317 |
| 2-way Interactions | 2.128 | 2 | 1.064 | 0.944 | 0.393 |
| SMOKE SEX | 2.128 | 2 | 1.064 | 0.944 | 0.393 |
| Explained | 13.654 | 7 | 1.951 | 1.730 | 0.112 |
| Residual | 100.330 | 89 | 1.127 | | |
| Total | 113.985 | 96 | 1.187 | | |

| Covariate | Raw Regression Coefficient |
|---|---|
| AGE | - 0.006 |
| Weight/height | -1.649 |

134 Cases were processed.
37 Cases (27.6 PCT) were missing

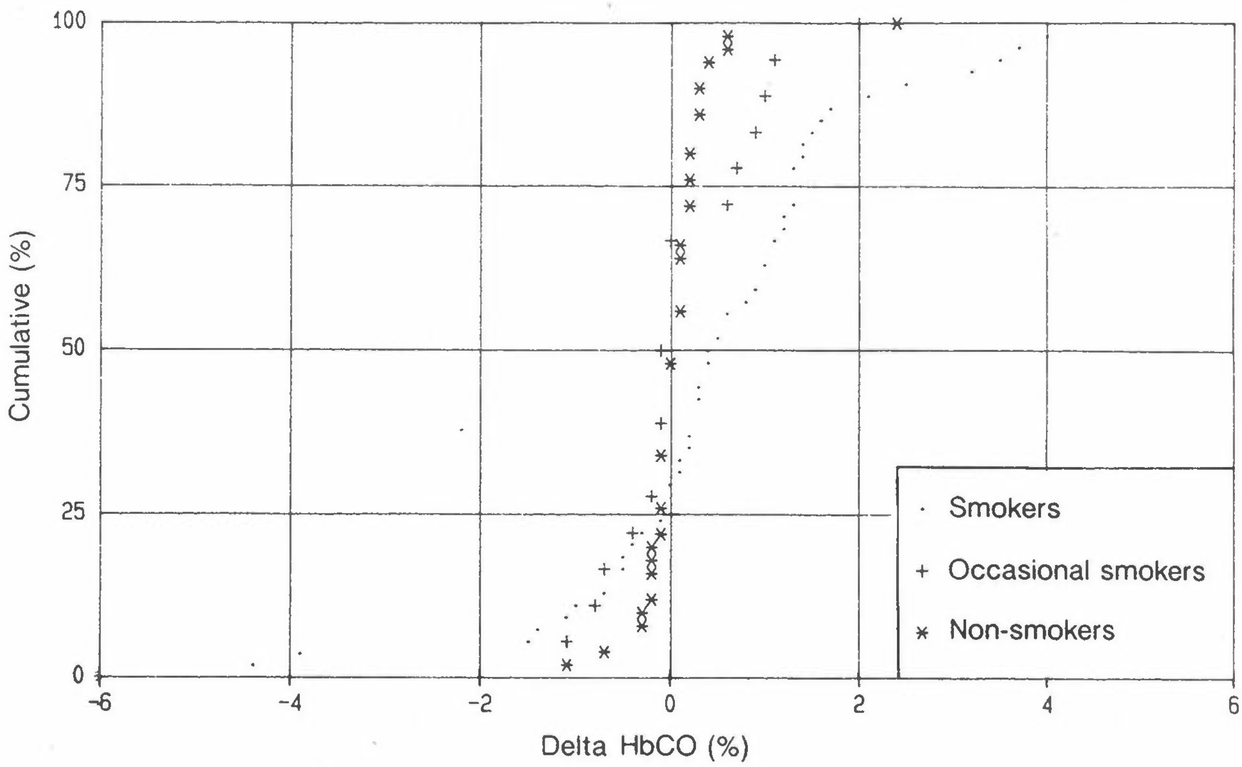



Figure 13: Cumulative distribution of HbCO in morning and afternoon samples.

opposed to the average value for the 4 hours preceeding blood sampling. Therefore, we present only the relationships with average CO exposure (Figures 14-15)

Delta HbCO seems only slightly related to ambient exposure if at all (Figures 15, Table 6). There are no significant relationships between body burden of CO and ambient exposure in smokers. In occasional smokers there is a significant relationship between HbCO and CO in end-expired breath samples measured in the afternoon and ambient exposure. However, as previously discussed, this group is difficult to interpret due to non-homogeneity. The significant relationship between HbCO in the afternoon samples and ambient exposure are more interesting. The regression coefficients imply that with an average four hour exposure to 10 ppm CO, HbCO will increase by 0.7% 10 ppm is over the eight hour air quality guideline, whereas 0.7% HbCO is well under the limit of 1.5% HbCO by the health authorities.

Table 6: Results of regression analysis between HbCO, CO-EEB, delta HbCO and delta CO-EEB and average and maximal exposure.

| Summary of regression results: equation $Y = a_0 + a_1 X$ | | | | | |
|---|---|---|---|---|---|
| X Independent | Y dependent | Statistics | Non-smokers (39)[a] | Occasional smokers (18)[a] | Smokers (47)[a] |
| AVERAGE EXPOSURE | HbCO | $R^2$ | 0.23 | 0.27 | 0 |
| | | $a_0$(s.d.) | 0.23+ (0.12) | 0.22 (0.50) | 3.23* (0.65) |
| | | $a_1$(s.d.) | 0.07* (0.02) | 0.18* (0.08) | 0.03 (0.13) |
| | CO-EEB | $R^2$ | 0.73 | 0.40 | 0 |
| | | $a_0$(s.d.) | 3.68* (0.31) | 3.58 (2.70) | 23.69 (4.03) |
| | | $a_1$(s.d.) | 0.54* (0.06) | 1.36* (0.46) | 0.14 (0.79) |
| | delta HbCO (afternoon -morning) | $R^2$ | 0.08 | 0.19 | 0.02 |
| | | $a_0$(s.d.) | -0.04 (0.14) | -0.34 (0.33) | 0.36 (0.55) |
| | | $a_1$(s.d.) | 0.04+ (0.02) | 0.10 (0.06) | 0.09 (0.11) |
| | delta CO-EEB (afternoon -morning) | $R^2$ | 0.19 | 0.23 | 0 |
| | | $a_0$(s.d.) | 0.17 (0.35) | -0.54 (1.57) | 4.35 (2.88) |
| | | $a_1$(s.d.) | 0.18* (0.06) | 0.53+ (0.27) | 0.23 (0.56) |
| MAXIMAL EXPOSURE | HbCO | $R^2$ | 0.14 | 0.26 | 0 |
| | | $a_0$(s.d.) | 0.29* (0.13) | 0.15+ (0.07) | 25.6 (4.04) |
| | | $a_1$(s.d.) | 0.04* (0.02) | 0.05 (0.58) | -0.20 (0.58) |
| | CO-EEB | $R^2$ | 0.59 | 0.41 | 0.01 |
| | | $a_0$(s.d.) | 3.82* (0.40) | 2.08 (3.12) | 3.64* (0.64) |
| | | $a_1$(s.d.) | 0.35* (0.05) | 1.18* (0.39) | -0.04 (0.09) |
| | delta HbCO (afternoon -morning) | $R^2$ | 0.02 | 0.17 | 0 |
| | | $a_0$(s.d.) | 0.06 | -0.41 (0.39) | 0.75 (0.55) |
| | | $a_1$(s.d.) | 0.02 (0.02) | 0.08 (0.05) | 0 (0.08) |
| | delta CO-EEB (afternoon -morning) | $R^2$ | 0.09 | 0.24 | 0 |
| | | $a_0$(s.d.) | 0.39 (0.40) | -1.17 (1.80) | 5.57+ (2.90) |
| | | $a_1$(s.d.) | 0.09+ (0.05) | 0.46+ (0.23) | -0.03 (0.41) |

* 95% significance level
\+ 90% significance level
a) number of cases in the regression

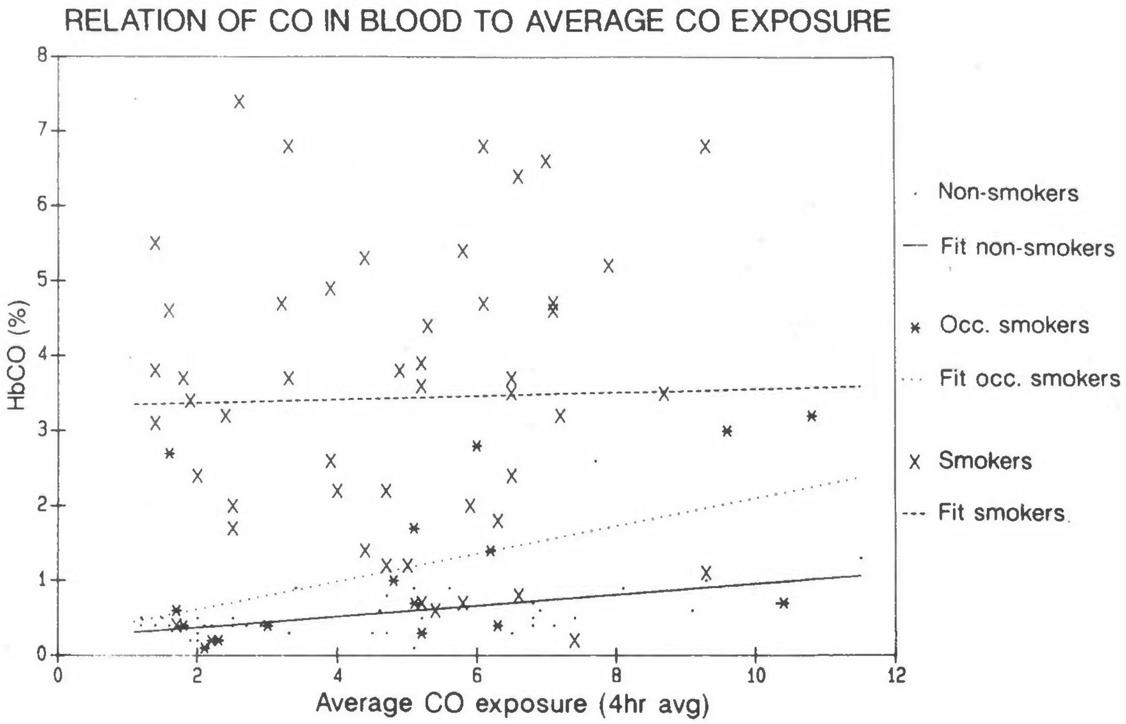



Figure 14: Relationship of HbCO measured in the afternoon to average exposure to ambient CO.

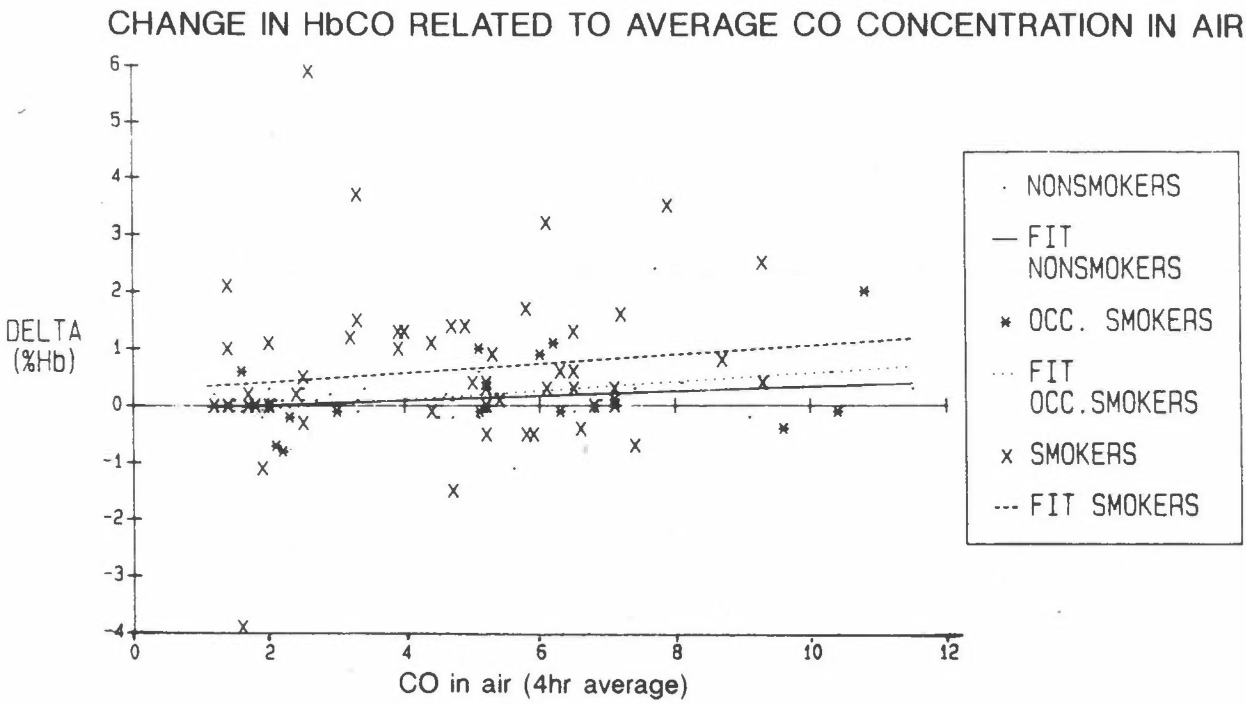



Figure 15: Change in HbCO between afternoon and morning as a function of average ambient exposure to CO the last 4 hours prior to blood sampling.

Ambient concentrations of CO are dependent both on traffic conditions and on climate. Pollution levels, including CO, tend to be high both during the morning and afternoon rush hour traffic of the same day.

The possibility existed that blood concentrations of CO did not rise particularly during the day because they were already high in the morning. This could be due to high concentrations of pollutions that day and/or to travel into the city. Thus it was decided to study the levels of CO in the morning blood samples as a function of the method of transportation. An analysis of variance confirmed that both mode of transportation and smoking had a significant effect on HbCO (Table 7). Transportation time did not significantly affect the HbCO values.

Table 7: Concentrations of HbCO in the morning as a function of mode of transport.

| Source of Variation | Sum of squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|
| Covariates | 0.837 | 1 | 0.837 | 0.789 | 0.377 |
| TRANSPORT TIME | 0.837 | 1 | 0.837 | 0.789 | 0.377 |
| Main Effects | 120.920 | 4 | 30.230 | 28.513 | 0.000 |
| MODE OF TRANSPORT | 12.813 | 2 | 6.407 | 6.043 | 0.003 |
| SMOKING | 99.939 | 2 | 49.970 | 47.132 | 0.000 |
| 2-way Interactions | 14.245 | 4 | 3.561 | 3.359 | 0.013 |
| MODE TR. SMOKE | 14.245 | 4 | 3.561 | 3.359 | 0.013 |
| Explained | 136.002 | 9 | 15.111 | 14.253 | 0.000 |
| Residual | 103.900 | 98 | 1.060 | | |
| Total | 239.902 | 107 | 2.242 | | |

Covariate Raw Regression Coefficient
TRANSPORT TIME -0.005

134 Cases were processed.
26 Cases (19.4 PCT) were missing.

These findings are presented in the form of two way tables. Transportation time was similar for all participants in this study regardless of means of transportation used (Table 8). Values of HbCO were higher in non-smokers using a car to get to work than either bus or train (Table 9). This difference is less than a half a per cent HbCO, and therefore cannot be considered of major importance to health.

Table 8: Mean transportation time to workplace in or near Rådhusgata, Oslo depending on main means of transportation.

| | Bus | Car | Train |
|---|---|---|---|
| Non-smokers | | | |
| Transport. time (mins) | 45 | 30 | 34 |
| Std.dev. | 26 | 8 | 17 |
| N | 7 | 12 | 35 |
| Occas. smokers | | | |
| Transport. time (mins) | 36 | 35 | 31 |
| Std.dev. | 14 | 28 | 17 |
| N | 6 | 4 | 9 |
| Daily smokers | | | |
| Transport. time (mins) | 35 | 33 | 36 |
| Std.dev. | 14 | 19 | 20 |
| N | 10 | 13 | 32 |

Table 9: Mean CO concentration in blood (% Hb) in the morning depending on main means of transportation to workplace in or near Rådhusgata, Oslo.

| | Bus | Car | Train |
|---|---|---|---|
| Non-smokers | | | |
| HbCO - morning (%) | 0.37 | 0.60 | 0.48 |
| Std.dev. | 0.17 | 0.21 | 0.35 |
| N | 7 | 10 | 33 |
| Occas. smokers | | | |
| HbCO - morning (%) | 0.62 | 1.45 | 1.06 |
| Std.dev. | 0.31 | 1.34 | 0.68 |
| N | 5 | 4 | 9 |
| Daily smokers | | | |
| HbCO - morning (%) | 3.32 | 3.18 | 2.05 |
| Std.dev. | 2.24 | 1.06 | 1.44 |
| N | 10 | 13 | 29 |

Further, it was of interest to see whether those individuals who had higher HbCO in the morning dependent on their mode of transport had relatively less of an increase during the day, confirming the hypothesis mentioned earlier that levels were already high when we measured them in the morning. Examining non-smokers in Table 10 does not indicate this. There are slightly lower values of delta HbCO in those individuals using the car than in those using other methods of transportation, but again the differences are minimal. The non-significance of this result can possibly be ascribed to a low number of participants in the respective groups.

Table 10: Mean values of differences in HbCO and CO in end-expired breath samples (CO-EEB) as a function of smoking and mode of transportation.

| | Non-smokers | | Occas. smokers | | Daily smokers | |
|---|---|---|---|---|---|---|
| | Car | Other | Car | Other | Car | Other |
| Delta HbCO (%) | | | | | | |
| Mean | 0.08 | 0.14 | 0.33 | 0.15 | 0.98 | 0.66 |
| Median | 0.10 | 0.10 | -0.15 | | 0.90 | 0.45 |
| Std.dev. | 0.20 | 0.49 | 1.12 | 0.62 | 1.69 | 1.41 |
| N | 9 | 35 | 4 | 12 | 11 | 38 |
| Delta CO-EEB (ppm) | | | | | | |
| Mean | 1.11 | 1.07 | 3.50 | 1.00 | 9.50 | 4.56 |
| Median | 1.00 | 1.00 | 2.00 | 0.50 | 11.50 | 4.00 |
| Std.dev. | 1.27 | 1.13 | 5.26 | 2.96 | 8.96 | 7.10 |
| N | 9 | 41 | 4 | 14 | 10 | 39 |

## 5.5 CONCENTRATION OF CARBON MONOXIDE IN END-EXPIRED BREATH SAMPLES

Analyses similar to those described in the previous section for HbCO were performed for CO in end-expired breath samples (CO-EEB). Analogous to delta HbCO, differences in CO in breath samples were calculated (delta CO-EEB). The results are analogous to those obtained for HbCO and delta HbCO. Measuring CO-EEB as an alternative to taking blood samples for determining the body burden of CO was described in our first study (Clench-Aas et al., 1988). The relationship between HbCO and CO-EEB is described in section 5.6.

In an analysis of variance smoking was again the only parameter to significantly affect delta CO-EEB. Sex, age or weight to height ratio did not seem to influence delta CO-EEB (see Table 11). Mean values of CO-EEB in the morning and afternoon in the different smoking categories, together with the average and maximal personal exposure are given in Table 12.

Table 11: Analysis of variance of the difference between samples of end-expired breath measured in the afternoon and morning as a function of age, weight, smoking and sex.

| Source of Variation | Sum of squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|
| Covariates | 50.810 | 2 | 25.405 | 0.853 | 0.429 |
| AGE | 10.493 | 1 | 10.493 | 0.352 | 0.554 |
| WEIGHT/HEIGHT INDEX | 36.801 | 1 | 36.801 | 1.236 | 0.269 |
| Main Effects | 442.434 | 3 | 147.478 | 4.953 | 0.003 |
| SMOKING | 442.352 | 2 | 221.176 | 7.428 | 0.001 |
| SEX | 45.485 | 1 | 45.485 | 1.528 | 0.220 |
| 2-way Interactions | 36.549 | 2 | 18.274 | 0.614 | 0.544 |
| SMOKE SEX | 36.549 | 2 | 18.274 | 0.614 | 0.544 |
| Explained | 529.792 | 7 | 75.685 | 2.542 | 0.020 |
| Residual | 2649.960 | 89 | 29.775 | | |
| Total | 3179.753 | 96 | 33.122 | | |

| Covariate | Raw Regression Coefficient |
|---|---|
| AGE | -0.027 |
| WEIGHT/HEIGHT INDEX | -10.899 |

134 Cases were processed.
37 Cases (27.6 PCT) were missing.

Table 12: Mean values of CO-EEB morning and afternoon for the different field days.

| Table: Mean / Std.dev. / Number | Date | | | | |
|---|---|---|---|---|---|
| | 3.2.87 | 16.1.87 | 19.1.87 | 21.1.87 | 26.1.87 |
| NON-SMOKERS | | | | | |
| 4-hr avg CO pers. exp. (ppm) | 1.91 | 6.78 | 5.56 | 3.62 | 1.75 |
| | 0.62 | 1.06 | 2.01 | 1.16 | 0.35 |
| | 13 | 8 | 5 | 9 | 2 |
| 4-hr max CO pers. exp. (ppm) | 3.62 | 9.48 | 7.84 | 5.50 | 2.50 |
| | 1.73 | 1.43 | 2.82 | 2.51 | 0.57 |
| | 13 | 8 | 5 | 9 | 2 |
| CO-EEB - morning (ppm) | 4.31 | 6.33 | 4.60 | 4.56 | 2.67 |
| | 0.63 | 1.03 | 0.55 | 1.33 | 0.58 |
| | 13 | 6 | 5 | 9 | 3 |
| CO-EEB - afternoon (ppm) | 4.69 | 7.67 | 6.80 | 5.75 | 3.00 |
| | 0.63 | 1.03 | 0.84 | 1.04 | |
| | 13 | 6 | 5 | 8 | 2 |
| Delta CO-EEB (ppm) | 0.38 | 1.33 | 2.20 | 1.00 | |
| | 0.65 | 1.03 | 1.30 | 0.93 | |
| | 13 | 6 | 5 | 8 | 2 |
| OCCASIONAL SMOKERS | | | | | |
| 4-hr avg CO pers. exp. (ppm) | 2.17 | 6.15 | 6.00 | | 2.00 |
| | 0.59 | 0.79 | | | 0.36 |
| | 4 | 4 | 1 | | 3 |
| 4-hr max CO pers. exp. (ppm) | 3.55 | 9.23 | 9.10 | | 4.40 |
| | 1.82 | 0.63 | | | 2.43 |
| | 4 | 4 | 1 | | 3 |
| CO-EEB - morning (ppm) | 5.60 | 9.00 | 15.00 | | 6.33 |
| | 1.34 | 2.65 | | | 4.16 |
| | 5 | 3 | 1 | | 3 |
| CO-EEB - afternoon (ppm) | 5.00 | 11.33 | 19.00 | | 9.00 |
| | 0.82 | 1.53 | | | 8.66 |
| | 4 | 3 | 1 | | 3 |
| Delta CO-EEB (ppm) | -0.75 | 2.33 | 4.00 | | 2.67 |
| | 0.96 | 1.53 | | | 4.73 |
| | 4 | 3 | 1 | | 3 |
| DAILY SMOKERS | | | | | |
| 4-hr avg CO pers. exp. (ppm) | 2.01 | 6.32 | 5.20 | 3.56 | 3.00 |
| | 0.70 | 0.83 | 1.32 | 0.90 | 1.53 |
| | 7 | 17 | 5 | 7 | 9 |
| 4-hr max CO pers. exp. (ppm) | 2.67 | 8.95 | 6.10 | 5.13 | 5.52 |
| | 1.38 | 0.85 | 1.93 | 2.50 | 3.35 |
| | 7 | 17 | 5 | 7 | 9 |
| CO-EEB - morning (ppm) | 21.14 | 22.45 | 18.40 | 15.00 | 18.11 |
| | 9.21 | 10.74 | 10.36 | 7.33 | 13.41 |
| | 7 | 11 | 5 | 7 | 9 |
| CO-EEB - afternoon (ppm) | 25.86 | 29.50 | 26.20 | 25.00 | 21.56 |
| | 14.14 | 13.84 | 12.70 | 12.06 | 9.07 |
| | 7 | 10 | 5 | 7 | 9 |
| Delta CO-EEB (ppm) | 4.71 | 6.40 | 7.80 | 10.00 | 3.44 |
| | 11.25 | 6.08 | 4.55 | 7.23 | 9.62 |
| | 7 | 10 | 5 | 7 | 9 |

Figure 16 gives the cumulative distribution of delta CO-EEB for the different smoking categories. No change is observed for non-smokers. Wheras smokers show a positive change, increased concentrations later in the day. Relations between CO-EEB and CO exposure are similar as those for HbCO and CO exposure; (Table 6, Figures 17 and 18) The regression coefficient indicates that with a 10 ppm increase in ambient levels of CO one can expect an increase of 5 ppm in samples of end-expired breath.

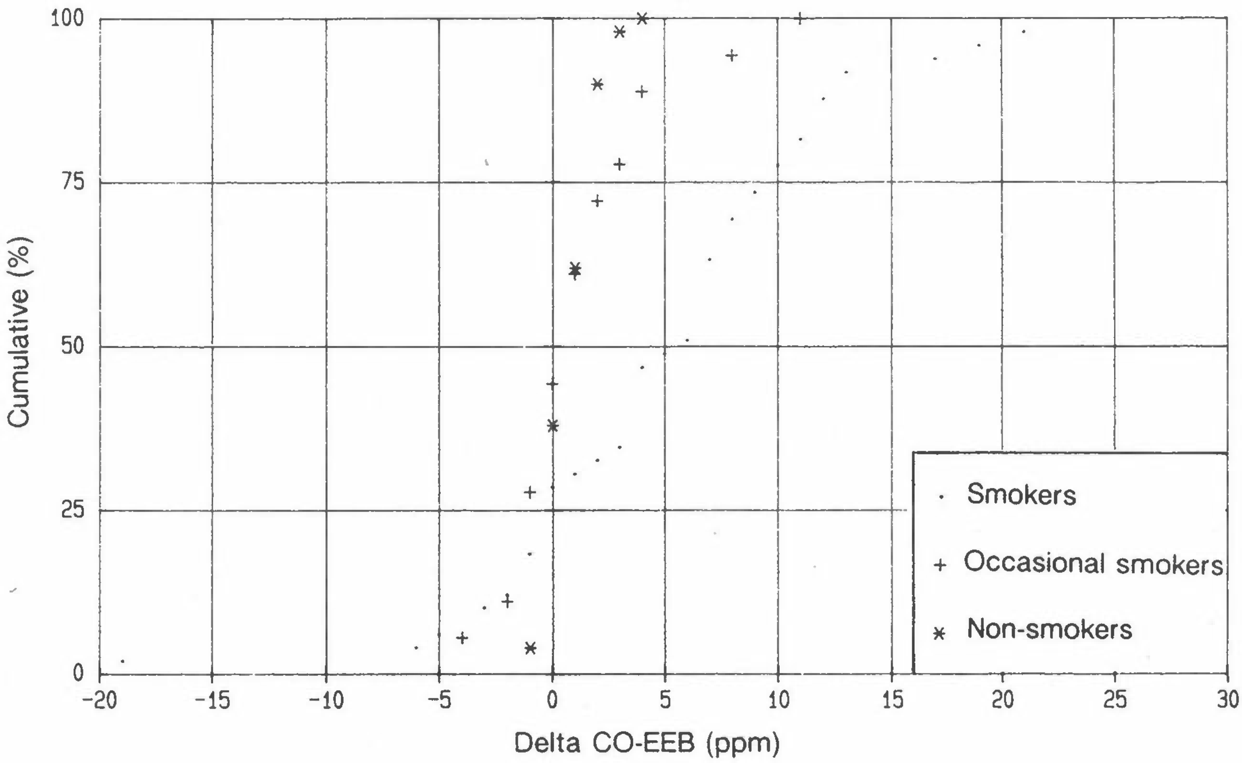



Figure 16: Cumulative distribution of differences between afternoon and morning samples of end-expired breath (delta CO-EEB) as a function of smoking category.

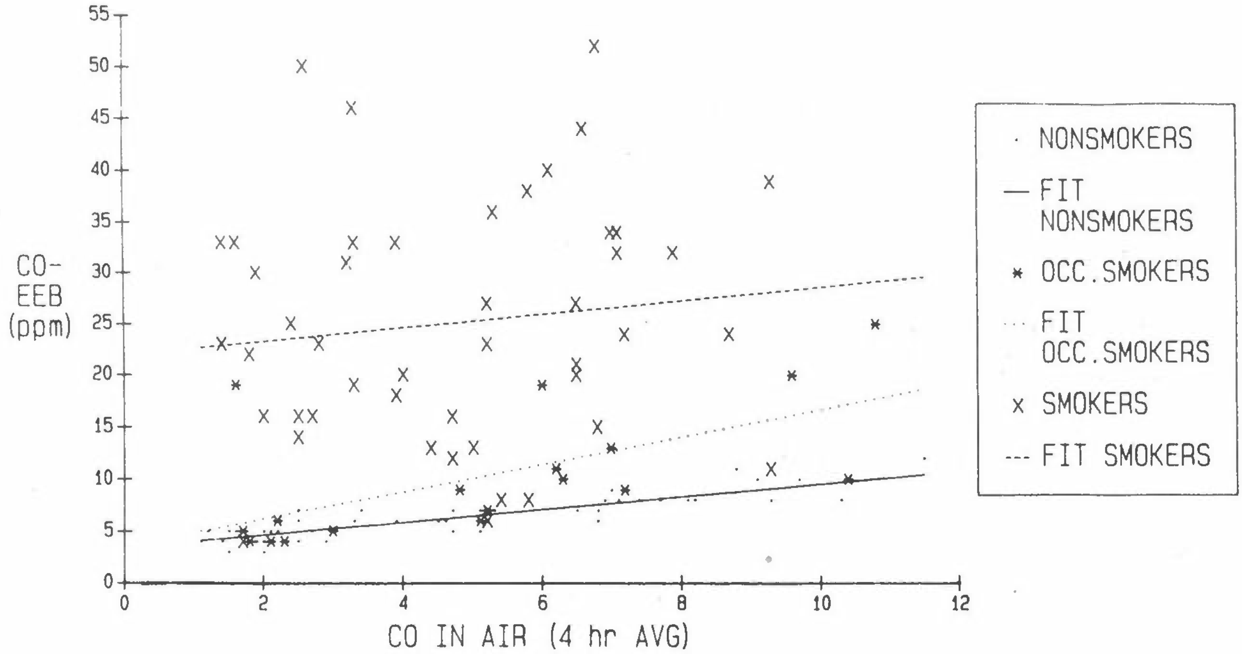



**Figure 17:** Relation of CO in samples of end-expired air to average ambient CO exposure.

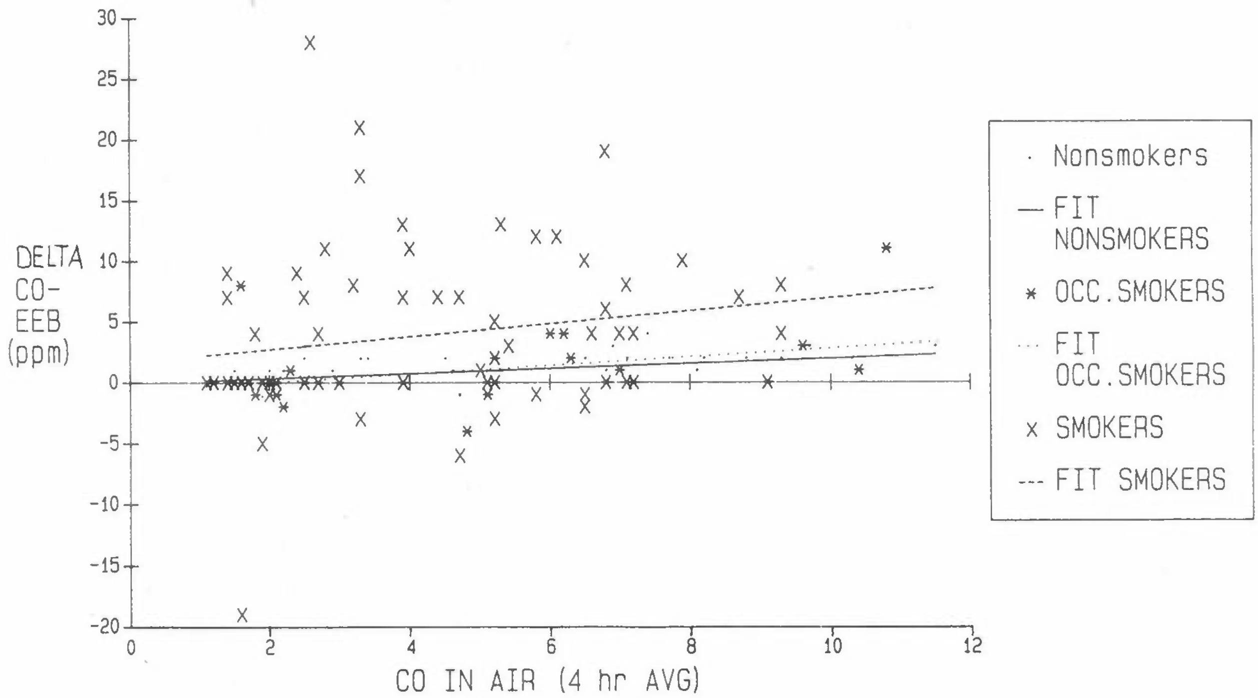



**Figure 18:** Change in CO-EEB between afternoon and morning as a function of average ambient exposure to CO the last 4-hours prior to breath sampling.

The findings reported in section 5.4 concerning the significant relationship between mode of transport and HbCO was also confirmed for CO-EEB (Tables 13-14). The effect of smoking was even more clear with CO-EEB.

Table 13: Analysis of variance of CO-EEB measured in the morning and transportation time, mode of transport and smoking.

| Source of Variation | Sum of squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|
| Covariates | 77.281 | 1 | 77.281 | 2.390 | 0.125 |
| TRANSPORTATION TIME | 77.281 | 1 | 77.281 | 2.390 | 0.125 |
| Main Effects | 5037.354 | 4 | 1259.338 | 38.950 | 0.000 |
| MODE OF TRANSPORT | 511.489 | 2 | 255.745 | 7.910 | 0.001 |
| SMOKING | 4203.200 | 2 | 2101.600 | 65.001 | 0.000 |
| 2-way Interactions | 549.604 | 4 | 137.401 | 4.250 | 0.003 |
| MODE TR. SMOKE | 549.604 | 4 | 137.401 | 4.250 | 0.003 |
| Explained | 5664.239 | 9 | 629.360 | 19.466 | 0.000 |
| Residual | 3168.530 | 98 | 32.332 | | |
| Total | 8832.769 | 107 | 82.549 | | |
| Covariate Raw Regression Coefficient | | | | | |
| TRANSPORTATION TIME | -0.048 | | | | |
| 134 Cases were processed. | | | | | |
| 26 Cases (19.4 PCT) were missing. | | | | | |

Table 14: Mean values of CO concentration in end-expired breath samples (ppm) depending on main means of transportation to workplace in or near Rådhusgata, Oslo.

| | Bus | Car | Train |
|---|---|---|---|
| Non-smokers | | | |
| CO-EEB - morning (ppm) | 4.88 | 6.50 | 5.00 |
| Std.dev. | 0.99 | 1.51 | 1.71 |
| N | 8 | 10 | 33 |
| Occas. smokers | | | |
| CO-EEB - morning (ppm) | 7.60 | 10.25 | 8.78 |
| Std.dev. | 3.29 | 6.40 | 3.49 |
| N | 5 | 4 | 9 |
| Daily smokers | | | |
| CO-EEB - morning (ppm) | 26.33 | 22.18 | 16.24 |
| Std.dev. | 11.10 | 6.46 | 9.18 |
| N | 9 | 11 | 29 |

Values of CO-EEB measured in Rådhusgata can be compared to those measured in Drammen, a generally less polluted area. Non-smokers in Drammen had an average CO-EEB value of 3.8 ppm whereas non-smokers working along Rådhusgata had 4.6 ppm in the morning and 5.7 ppm in the afternoon.

Thus the inhabitants of Oslo, and especially those working in Rådhusgata have a higher body burden of CO. This was not the case for smokers. Values measured in Drammen for smokers were 24.0 ppm as opposed to 19.3 and 25.7 ppm in samples from Rådhusgata. Thus CO-EEB values were the same for smokers in the two studies.

## 5.6 RELATIONSHIP OF CARBON MONOXIDE IN BLOOD AND END-EXPIRED BREATH SAMPLE

This research team has been trying to confirm the use of measurements of CO in end-expired breath samples as a substitute for blood measurements for several years. We reported the relationship in a study performed in Drammen (Clench-Aas et al., 1988). The indications were that the blood measurements in that study were too high. The comparison of CO in blood and in end-expired breath was therefore repeated in this study. The method of measuring HbCO was slightly changed between the two studies (see section 4.4), whereas the method of measuring CO-EEB remained identical. The method of measuring CO-EEB has previously been reported in the literature (Jones et al., 1958) and is now an accepted method.

In Figure 19 we can see cumulative distribution functions for HbCO and for CO-EEB in the three smoking categories in the morning and in the afternoon. The cumulative distributions are very similar in their shape indicating a good correlation between the two.

Using physiological principles the relationship between the two can be stated as follows (McIlvaine et al., 1969):

$$\mathrm{HbCO} = 0.18\ \mathrm{CO\text{-}EEB}$$

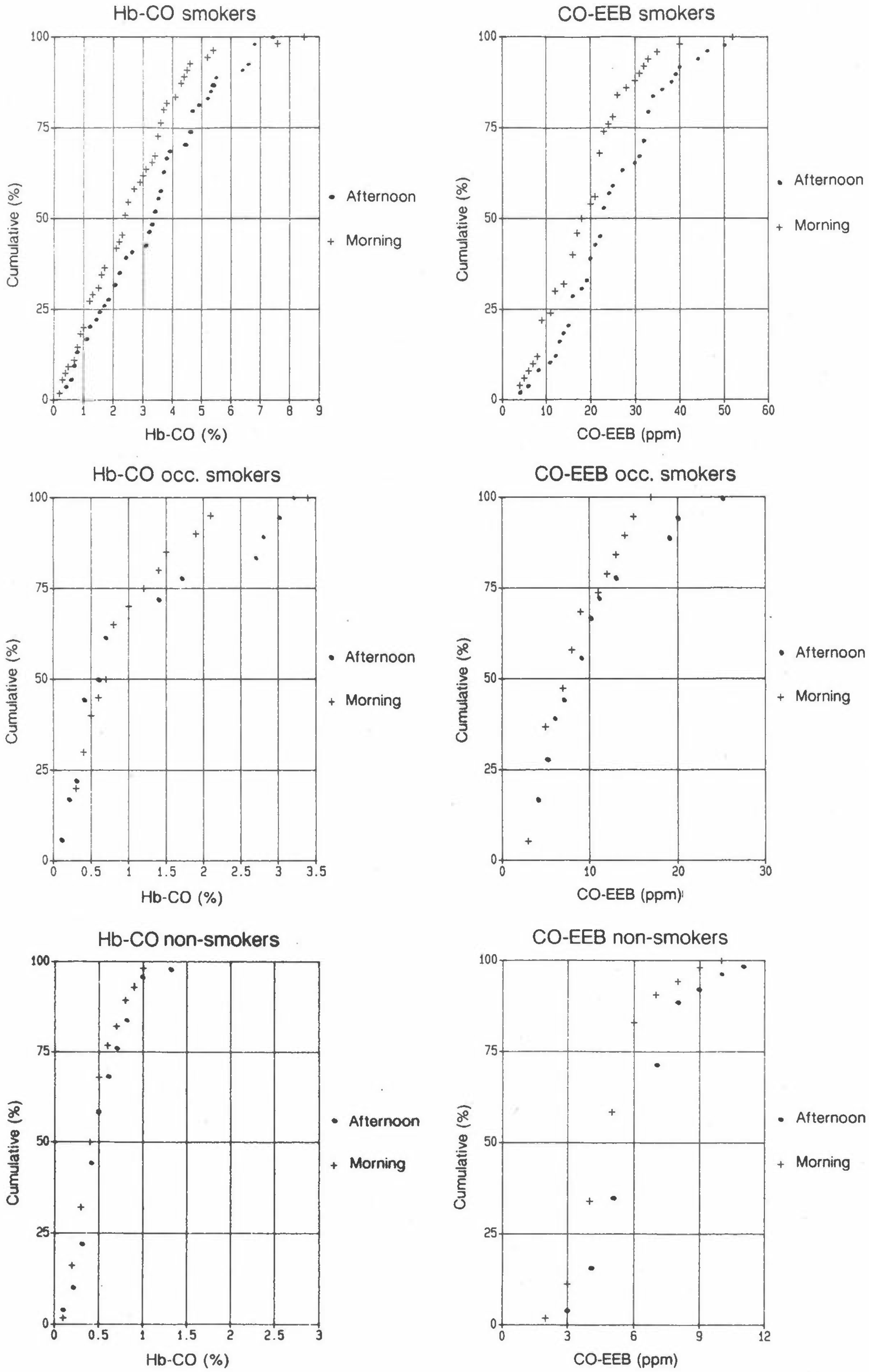



Figure 19: Cumulative distribution for HbCO and CO-EEB in morning and afternoon samples for all three smoking categories.

We ran the comparison separately for morning and afternoon samples and found the relationship to be (Figures 20 and 21):

morning - HbCO = -0.36 + 0.16 x CO-EEB
afternoon - HbCO = -0.42 + 0.16 x CO-EEB

This study confirmed that the method of measuring CO-EEB is a satisfactory replacement for measuring HbCO. Using the regression found in this study the Norwegian suggested limit of a value of HbCO of 1.5% suggested in Norway is equivalent to a CO-EEB of approximately 12 ppm.

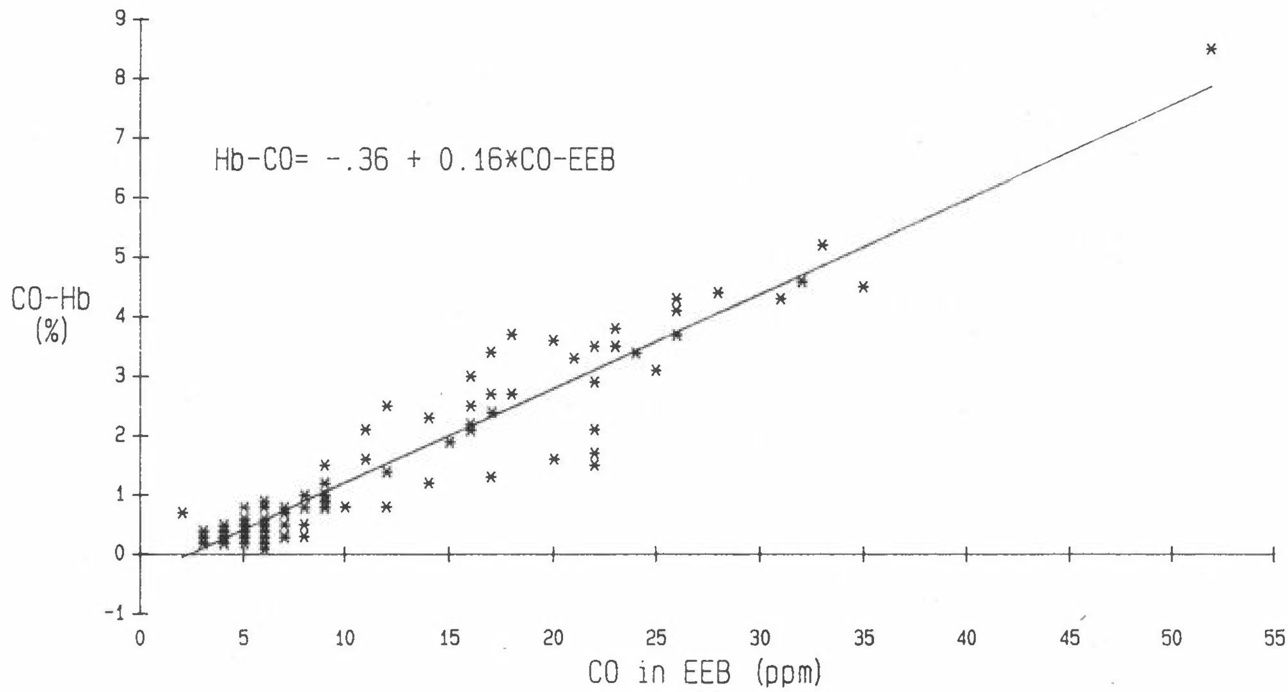



Figure 20: Relation of carbon monoxide in end-expired breath samples to carbon monoxide in hemoglobin - morning measurements.

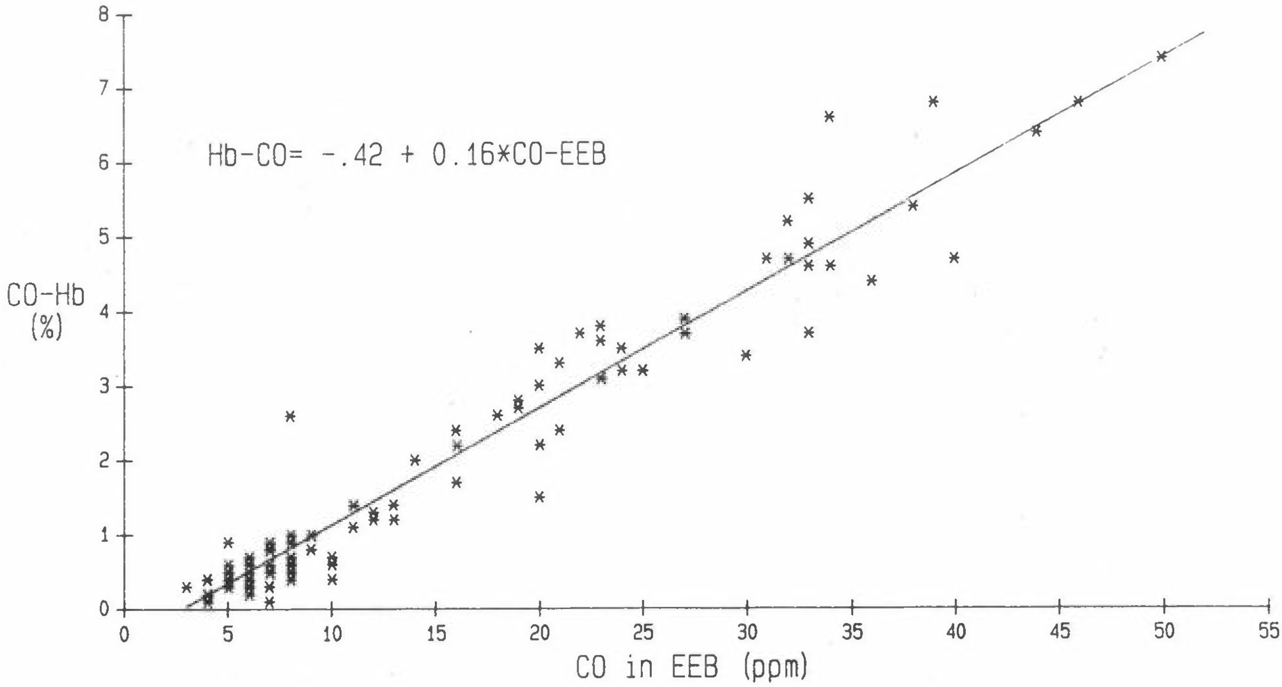



Figure 21: Relation of carbon monoxide in end-expired breath samples to carbon monoxide in hemoglobin - afternoon measurements.

These are so similar to the relationship reported by McIlvaine (1969) based on physiological principles, that the results are considered satisfactory. However, other relationships have also been reported in the literature. Differences between studies are more likely associated with variability in methods of measuring HbCO, than to variability in methods of determining CO-EEB. This entire subject is reviewed by Lambert et al. (1988).

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# APPENDIX 1

Concentration of CO indoors in each business establishment.

# CO CONCENTRATIONS (ppm)

Date: 16.1.1987

| Business Establishment | 16 | 16 | 16 | 16 | 16 | 16 | 11 | 25 | Outdoor air |
|---|---|---|---|---|---|---|---|---|---|
| Floor | 1 | 2 | 2 | 2 | 3 | 3 | 1 | 2 | |
| Facing street | RH | RH | RH | corner RH/KG | RH | KG | RH | court-yard | |
| Time | | | | | | | | | |
| 0800 | | | | | | | | | |
| 0900 | 6.0 | 4.7 | 4.7 | 5.7 | 5.2 | 5.9 | | | 7.6 |
| 1000 | 6.1 | 5.4 | 5.2 | 6.4 | 6.4 | 6.5 | | 5.1 | 6.2 |
| 1100 | 5.9 | 5.9 | 5.3 | 6.3 | 6.7 | 6.9 | 7.0 | 4.6 | 6.2 |
| 1200 | 5.9 | 5.6 | 4.8 | 6.0 | 6.4 | 5.9 | 7.5 | 4.4 | 7.1 |
| 1300 | 5.5 | 5.6 | 4.9 | 6.1 | 6.6 | 5.9 | 7.8 | 4.1 | 7.0 |
| 1400 | 7.0 | 6.6 | 6.1 | 7.4 | 7.8 | 7.2 | 9.1 | 5.7 | 9.8 |
| 1500 | 8.4 | 8.2 | 8.3 | 9.5 | 9.7 | 8.9 | 11.7 | 8.4 | 13.0 |
| 1600 | 8.9 | 8.9 | 8.5 | 10.5 | 10.2 | 10.0 | | | 13.0 |
| 1700 | | | | | | | | | |

RH = Rådhusgt. KG = Kirkegt. DG = Dronningens gt. SK = Skippergt.

# CO CONCENTRATIONS (ppm)

Date: 19.1.1987

| Business Establishment | 10 | 2 | 13 | 26 | 8 | 18 | Outdoor air |
|---|---|---|---|---|---|---|---|
| Floor | 1 | 2 | 1 | 1 | 1 | 1 | |
| Facing street | courtyard | RH | courtyard | courtyard | corner RH | RH | |
| Time | | | | | | | |
| 0800 | | | | | | | |
| 0900 | | | | | | | 8.8 |
| 1000 | 3.7 | 5.2 | 4.2 | | 4.7 | 5.2 | 8.1 |
| 1100 | 3.9 | 5.9 | 4.0 | 3.9 | 5.3 | 6.1 | 7.4 |
| 1200 | 4.0 | 5.6 | 3.6 | 3.5 | 5.7 | 9.1 | 7.0 |
| 1300 | 4.1 | 5.5 | 3.8 | 3.5 | 5.6 | 7.7 | 8.6 |
| 1400 | 4.2 | 6.0 | 3.9 | 4.1 | 5.6 | 6.7 | 9.6 |
| 1500 | | 6.3 | 4.4 | 4.2 | 5.8 | 6.1 | 10.4 |
| 1600 | | 5.9 | | 4.3 | 5.8 | | 10.6 |
| 1700 | | | | | | | |

RH = Rådhusgt. KG = Kirkegt. DG = Dronningens gt. SK = Skippergt.

# CO CONCENTRATIONS (ppm)

Date: 21.1.1987

| Business Establish-ment | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | |
|---|---|---|---|---|---|---|---|---|---|
| Floor | 3 | 11 | 6 | 3 | 2 | 1 | 8 | 4 | Outdoor air |
| Facing street | RH | court-yard | court-yard | court-yard | court-yard | court-yard | court-yard | court-yard | |
| Time | | | | | | | | | |
| 0800 | | | | | | | | | |
| 0900 | | | | | | | | | 13.1 |
| 1000 | | 3.6 | 4.0 | 4.8 | | | 2.1 | 3.7 | 10.6 |
| 1100 | 5.0 | 3.2 | 3.4 | 4.1 | 3.6 | 3.6 | 1.8 | 3.5 | 10.3 |
| 1200 | 4.4 | 2.9 | 3.2 | 3.5 | 3.2 | 3.6 | 1.6 | 3.2 | 8.2 |
| 1300 | 4.5 | 3.0 | 3.5 | 3.6 | 3.7 | 3.2 | 1.8 | 3.0 | 9.0 |
| 1400 | 5.1 | 3.4 | 3.5 | 4.1 | 4.0 | 3.5 | 2.0 | 3.2 | 8.9 |
| 1500 | 4.9 | 3.2 | 3.2 | 4.1 | 3.7 | 3.4 | 1.8 | 3.3 | 8.4 |
| 1600 | | 3.8 | | 4.6 | 3.9 | 3.5 | | | 9.8 |
| 1700 | | | | | | | | | |

RH = Rådhusgt. KG = Kirkegt. DG = Dronningens gt. SK = Skippergt.

# CO CONCENTRATIONS (ppm)

Date: 26.1.1987

| Building Establishment | 9 | 9 | 7 | Outdoor air |
|---|---|---|---|---|
| Floor | 1 | 1 | 1 | |
| Facing street | Kongens gt.- entrance | RH | RH | |
| Time | | | | |
| 0800 | | | | 12.6 |
| 0900 | | | 8.5 | 13.4 |
| 1000 | 1.3 | 0.7 | 7.1 | 12.0 |
| 1100 | 1.3 | 0.8 | 7.3 | 13.2 |
| 1200 | 1.6 | 1.7 | 5.7 | 8.3 |
| 1300 | 2.0 | 1.9 | 3.2 | 4.6 |
| 1400 | 2.6 | 2.7 | 3.7 | 7.2 |
| 1500 | 3.1 | 2.9 | 3.7 | 7.2 |
| 1600 | | | 6.4 | 12.6 |
| 1700 | | | | |

RH = Rådhusgt. KG = Kirkegt. DG = Dronningens gt. SK = Skippergt.

CO CONCENTRATIONS (ppm)

Date: 27.1.1987

| Business Establish-ment | 17 | 15 | 15 | 22 | 19 | 21 | 21 | 21 | Outdoor air |
|---|---|---|---|---|---|---|---|---|---|
| Floor | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | |
| Facing street | RH | RH | court-yard | court-yard | RH | court-yard | Nedre Slottsgt | RH | |
| Time | | | | | | | | | |
| 0800 | | | | | | | | | |
| 0900 | | | | | | | | | 12.4 |
| 1000 | 7.6 | | | | 6.9 | 5.6 | 5.4 | 9.4 | 14.9 |
| 1100 | 9.5 | 5.0 | 6.2 | 6.3 | 7.8 | 7.4 | 6.8 | 10.9 | 14.7 |
| 1200 | 10.4 | 6.3 | 5.4 | 6.9 | 9.2 | 8.5 | 9.3 | 11.4 | 13.1 |
| 1300 | 9.4 | 6.0 | 3.9 | 5.2 | 7.7 | 7.5 | 8.5 | 9.1 | 12.1 |
| 1400 | 9.3 | 5.0 | 3.4 | 4.7 | 7.7 | 7.8 | 7.8 | 10.0 | 13.6 |
| 1500 | | 2.8 | 3.3 | 3.9 | 6.0 | | | | 10.3 |
| 1600 | | | | | 5.1 | | | | 12.9 |
| 1700 | | | | | | | | | |

RH = Rådhusgt. KG = Kirkegt. DG = Dronningens gt. SK = Skippergt.

## CO CONCENTRATIONS (ppm)

Date: 29.1.1987

| Business Establishment | 7 | 5 | 1 | 3 | Outdoor air |
|---|---|---|---|---|---|
| Floor | 1 | 1 | 1 | 2 | |
| Facing street | RH | RH | RH | RH | |
| Time | | | | | |
| 0800 | | | | | |
| 0900 | | | | | 8.1 |
| 1000 | | | | | 11.5 |
| 1100 | 13.9 | | | 6.8 | 12.3 |
| 1200 | 13.1 | | 8.7 | 8.4 | 12.3 |
| 1300 | 11.4 | 12.2 | 9.5 | 9.5 | 13.6 |
| 1400 | 9.7 | 9.3 | 8.7 | 9.5 | 9.6 |
| 1500 | 9.4 | 8.0 | 7.9 | 9.3 | 10.4 |
| 1600 | 11.5 | 9.9 | 8.0 | 9.5 | 13.0 |
| 1700 | | | | | 8.8 |

RH = Rådhusgt. KG = Kirkegt. DG = Dronningens gt. SK = Skippergt.

# CO CONCENTRATIONS (ppm)

Date: 3.2.1987

| Business Establishment | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | Outdoor air |
|---|---|---|---|---|---|---|---|---|---|
| Floor | 5 | 2 | 3 | 7 | 2 | 3 | 7 | 5 | |
| Facing street | RH | DG | court-yard | SK | RH | RH | SK | SK | |
| Time | | | | | | | | | |
| 0800 | | | | | | | | | |
| 0900 | | | | | | | | | 9.1 |
| 1000 | | | | | | | | | 5.8 |
| 1100 | 2.8 | | | | 1.9 | 1.7 | 2.6 | 1.4 | 5.4 |
| 1200 | 2.8 | 2.5 | 2.2 | 1.4 | 1.9 | 1.6 | 2.9 | 1.4 | 5.2 |
| 1300 | 2.5 | 2.1 | 2.4 | 1.2 | 1.8 | 1.3 | 2.4 | 1.3 | 5.5 |
| 1400 | 2.4 | 1.4 | 2.5 | 0.9 | 1.6 | 1.2 | 2.5 | 1.2 | 4.7 |
| 1500 | 2.7 | 1.6 | 2.4 | 0.8 | 1.8 | 1.4 | 2.9 | 1.1 | 4.2 |
| 1600 | | 1.6 | 2.3 | | 2.0 | 1.5 | 2.9 | 0.9 | 6.8 |
| 1700 | | | | | | | | | |

RH = Rådhusgt. KG = Kirkegt. DG = Dronningens gt. SK = Skippergt.

# APPENDIX 2

Derived CO exposure for each individual.

Table 2-1: Hourly values for exposure to CO for each individual in the study.

| VALUES OF CO EXPOSURE | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | ID number | Hour 0700 | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 |
| 16. 1.87 | 1: | | 5.2 | 6.4 | 3.4 | 3.2 | 3.3 | 6.5 | 9.7 | | | |
| 16. 1.87 | 2: | | 4.7 | 5.4 | 3.3 | 3.2 | 3.9 | 4.8 | 6.6 | | | |
| 16. 1.87 | 3: | | 5.7 | 6.4 | 3.2 | 3.0 | 3.0 | 5.2 | 9.5 | | | |
| 16. 1.87 | 4: | | 5.2 | 6.4 | 6.7 | 6.4 | 6.6 | 7.8 | 9.7 | | | |
| 16. 1.87 | 5: | | 2.8 | 6.5 | 6.9 | 4.4 | 5.9 | 7.2 | 8.9 | | | |
| 16. 1.87 | 6: | | 5.7 | 6.4 | 6.3 | 4.4 | 6.1 | 7.4 | 9.5 | | | |
| 16. 1.87 | 7: | | 5.7 | 6.4 | 6.3 | 4.6 | 6.1 | 7.4 | 9.5 | | | |
| 16. 1.87 | 8: | | 5.9 | 6.5 | 6.9 | 5.9 | 5.9 | 7.2 | 8.9 | | | |
| 16. 1.87 | 9: | | 6.0 | 6.1 | 5.9 | 5.9 | 5.2 | 6.0 | 8.4 | | | |
| 16. 1.87 | 10: | | 4.7 | 5.2 | 5.3 | 4.8 | 5.9 | 6.1 | 8.3 | 8.5 | | |
| 16. 1.87 | 11: | | 5.9 | 6.5 | 6.9 | 5.9 | 5.9 | 7.2 | 8.9 | | | |
| 16. 1.87 | 12: | | 5.9 | 6.5 | 6.9 | 4.6 | 5.9 | 7.2 | 8.9 | | | |
| 16. 1.87 | 13: | | 5.2 | 6.4 | 6.7 | 4.5 | 6.6 | 7.8 | 8.9 | 8.5 | | |
| 16. 1.87 | 14: | | | 5.2 | 5.7 | 5.0 | 4.9 | 6.1 | 8.3 | 8.5 | | |
| 16. 1.87 | 15: | | | 6.4 | 6.3 | 6.0 | 5.4 | 6.2 | 9.5 | | | |
| 16. 1.87 | 16: | | | 6.5 | 6.9 | 5.9 | 5.9 | 7.2 | 8.9 | | | |
| 16. 1.87 | 17: | | | 6.5 | 6.0 | 4.8 | 5.9 | 7.2 | 8.9 | 10.0 | | |
| 16. 1.87 | 18: | | | 6.1 | 5.9 | 3.2 | 4.9 | 7.5 | 8.4 | 8.4 | | |
| 16. 1.87 | 19: | | | 6.1 | 5.9 | 5.9 | 5.5 | 7.0 | 8.4 | | | |
| 16. 1.87 | 20: | | | 5.2 | 6.7 | 6.4 | 4.9 | 7.8 | 9.7 | | | |
| 16. 1.87 | 21: | | | 6.4 | 6.7 | 5.1 | 6.6 | 7.8 | 9.7 | | | |
| 16. 1.87 | 22: | | | 5.4 | 5.9 | 5.6 | 5.2 | 5.9 | 8.2 | | | |
| 16. 1.87 | 23: | | | 5.2 | 5.3 | 4.8 | 3.3 | 5.9 | 8.3 | | | |
| 16. 1.87 | 24: | | | 5.2 | 5.3 | 4.0 | 4.9 | 6.1 | 8.3 | 8.5 | | |
| 16. 1.87 | 25: | | | 5.5 | 5.3 | 4.8 | 4.9 | 6.1 | 8.3 | 8.5 | | |
| 16. 1.87 | 26: | | | 5.1 | 4.6 | 4.4 | 4.1 | 5.7 | 8.4 | | | |
| 16. 1.87 | 27: | | | 6.5 | 7.0 | 7.5 | 7.8 | 9.1 | 11.7 | | | |
| 16. 1.87 | 28: | | | 6.5 | 6.7 | 7.3 | 7.6 | 9.1 | 11.7 | | | |
| 19. 1.87 | 29: | | | 5.1 | 4.6 | 4.4 | 4.1 | 5.7 | 8.4 | | | |
| 19. 1.87 | 30: | | | 4.9 | 4.8 | 8.8 | 6.4 | 5.4 | 5.3 | | | |
| 19. 1.87 | 31: | | | 4.2 | 4.0 | 3.6 | 3.8 | 3.9 | 4.4 | | | |
| 19. 1.87 | 32: | | | 5.2 | 6.1 | 9.1 | 7.7 | 6.7 | 6.1 | | | |
| 19. 1.87 | 33: | | | 4.2 | 4.0 | 3.6 | 3.8 | 3.9 | 4.4 | | | |

Table 2-1, cont.

| VALUES OF CO EXPOSURE | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | ID number | Hour 0700 | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 |
| 19. 1.87 | 34: | | | 5.2 | 6.1 | 7.6 | 7.7 | 6.7 | 6.1 | | | |
| 19. 1.87 | 35: | | | 5.2 | 6.1 | 8.4 | 7.0 | 6.1 | 5.2 | | | |
| 19. 1.87 | 36: | | | 3.7 | 3.9 | 5.3 | 5.0 | 4.2 | | | | |
| 19. 1.87 | 37: | | | 5.2 | 5.9 | 5.6 | 5.5 | 6.0 | 6.3 | | | |
| 19. 1.87 | 38: | | | | 5.9 | 5.6 | 5.0 | 5.2 | 6.3 | | | |
| 19. 1.87 | 40: | | | | 2.6 | 2.3 | 2.3 | 2.7 | 2.7 | 2.8 | | |
| 21. 1.87 | 41: | | | | 5.3 | 7.4 | 5.8 | 5.6 | 5.8 | | | |
| 21. 1.87 | 42: | | 4.0 | 2.1 | | 1.6 | 2.7 | 2.0 | 1.8 | | | |
| 21. 1.87 | 43: | | 4.0 | 3.6 | 3.2 | 3.6 | 3.0 | 3.2 | 3.6 | 3.8 | | |
| 21. 1.87 | 44: | | 4.0 | 3.7 | 3.5 | 6.0 | 8.0 | 3.2 | 3.3 | | | |
| 21. 1.87 | 45: | | 4.0 | 3.7 | 3.5 | 3.2 | 3.0 | 3.2 | 3.3 | 3.3 | | |
| 21. 1.87 | 46: | | 4.0 | 4.8 | 3.5 | 3.5 | 3.6 | 4.1 | 4.1 | 4.6 | | |
| 21. 1.87 | 47: | | 4.0 | 3.4 | 3.3 | 5.7 | 4.8 | 3.9 | 3.9 | 4.5 | | |
| 21. 1.87 | 48: | | 4.0 | 4.4 | 4.1 | 3.5 | 3.6 | 4.1 | 6.3 | 4.6 | | |
| 21. 1.87 | 49: | | 4.0 | 3.6 | 3.3 | 2.9 | 3.0 | | | | | |
| 21. 1.87 | 50: | | 4.0 | 4.8 | 4.1 | 3.5 | 3.3 | 3.5 | 3.4 | 3.5 | | |
| 21. 1.87 | 51: | | | 3.8 | 3.2 | 2.9 | 3.0 | 3.4 | 3.2 | 3.8 | | |
| 21. 1.87 | 52: | | | 4.0 | 3.4 | 3.3 | 3.5 | 3.1 | 3.2 | 4.5 | | |
| 21. 1.87 | 53: | | | 4.8 | 3.7 | 3.5 | 3.6 | 4.1 | 4.1 | 4.6 | | |
| 21. 1.87 | 54: | | | 3.6 | 3.2 | 3.2 | 3.4 | 7.7 | 6.1 | 3.9 | | |
| 21. 1.87 | 55: | | | 2.1 | 1.8 | 1.9 | 2.2 | 2.0 | 1.8 | | | |
| 21. 1.87 | 56: | | | 2.1 | 2.1 | 2.2 | 1.8 | 2.0 | 1.8 | | | |
| 26. 1.87 | 57: | | | 4.8 | 3.7 | 3.5 | 3.6 | 4.1 | 5.9 | 4.6 | | |
| 26. 1.87 | 58: | 11.5 | 11.5 | 9.0 | 8.4 | 2.7 | 1.4 | 1.9 | 2.9 | 8.4 | 9.5 | 9.5 |
| 26. 1.87 | 59: | 8.5 | 8.3 | 7.1 | 7.3 | 5.7 | 3.2 | 3.7 | 6.4 | 9.3 | | |
| 26. 1.87 | 60: | | 2.0 | 2.8 | 5.8 | 5.1 | 1.5 | 2.7 | 2.4 | 2.0 | | |
| 26. 1.87 | 61: | | 2.0 | 2.8 | 3.3 | 2.7 | 2.8 | 2.7 | 2.4 | | | |
| 26. 1.87 | 62: | | 2.0 | 2.8 | 3.3 | 2.7 | 2.8 | 2.7 | 2.4 | 2.0 | | |
| 26. 1.87 | 63: | | 2.0 | 2.8 | 3.3 | 3.6 | 3.1 | 2.7 | 2.4 | 2.0 | | |
| 26. 1.87 | 64: | | 2.0 | 4.5 | 3.3 | 2.7 | 2.7 | 2.7 | 2.4 | 2.0 | | |
| 26. 1.87 | 65: | | 1.1 | | 1.2 | .7 | 1.2 | 1.7 | 2.1 | | | |
| 26. 1.87 | 66: | | 1.0 | 1.7 | 1.3 | 1.7 | 1.3 | 2.7 | 2.9 | | | |
| 26. 1.87 | 67: | | 1.0 | .7 | .8 | 1.7 | 1.6 | | 2.9 | | | |

Table 2-1, cont.

| VALUES OF CO EXPOSURE | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | ID number | Hour 0700 | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 |
| 26. 1.87 | 68: | | 1.0 | .7 | .8 | 1.2 | 1.9 | 2.7 | 2.9 | | | |
| 26. 1.87 | 69: | | 1.0 | 1.7 | 1.3 | 1.2 | 2.0 | 3.4 | 3.1 | | | |
| 26. 1.87 | 70: | | 1.2 | 1.7 | 1.3 | 1.2 | 1.2 | 1.7 | 2.1 | | | |
| 27. 1.87 | 71: | | 1.0 | 1.3 | 1.3 | 1.6 | .9 | 1.4 | 3.1 | | | |
| 27. 1.87 | 73: | | 4.3 | 5.6 | 7.4 | 8.5 | 10.0 | 1.0 | 5.3 | 12.9 | | |
| 27. 1.87 | 74: | | 4.3 | 5.6 | 7.4 | 8.9 | 8.5 | 6.8 | | | | |
| 27. 1.87 | 75: | | 4.8 | 5.4 | 6.8 | 9.3 | 12.1 | 1.0 | 5.6 | 12.9 | | |
| 27. 1.87 | 76: | | | 9.4 | 10.9 | 11.4 | 9.1 | 10.0 | | | | |
| 27. 1.87 | 77: | | | 5.6 | 7.4 | 8.5 | 7.5 | 7.8 | 5.8 | | | |
| 27. 1.87 | 78: | | | 9.4 | 10.9 | 11.4 | 9.6 | 10.0 | 9.6 | | | |
| 27. 1.87 | 79: | | | 7.6 | 9.5 | 10.4 | 9.4 | 9.3 | 9.8 | | | |
| 27. 1.87 | 81: | | | 6.9 | 5.2 | 6.1 | 5.2 | 5.2 | 4.0 | 5.1 | | |
| 27. 1.87 | 82: | | | 6.9 | 7.8 | 9.2 | 7.7 | 7.7 | 6.0 | 5.1 | | |
| 27. 1.87 | 83: | | | 5.0 | 6.0 | 6.3 | 6.0 | 5.0 | 2.8 | | | |
| 27. 1.87 | 84: | | | 5.1 | 6.3 | 6.9 | 5.2 | 4.7 | 3.9 | | | |
| 27. 1.87 | 85: | | | | 5.0 | 6.3 | 11.1 | 6.4 | 2.8 | | | |
| 27. 1.87 | 86: | | | | 5.0 | 6.3 | 6.0 | 5.0 | 2.8 | | | |
| 27. 1.87 | 87: | | | | 6.2 | 5.0 | | 3.4 | 5.9 | | | |
| 27. 1.87 | 88: | | | | 5.0 | 6.3 | 6.0 | 5.0 | 2.8 | | | |
| 29. 1.87 | 89: | | | | 5.0 | 6.3 | 6.0 | 5.0 | 2.8 | | | |
| 29. 1.87 | 91: | | | 7.8 | 8.6 | 8.8 | 9.4 | 8.6 | 8.0 | 8.3 | | |
| 29. 1.87 | 92: | | | | 9.5 | 9.7 | 9.3 | 9.5 | 9.3 | 9.5 | | |
| 29. 1.87 | 93: | | | | 6.8 | 8.4 | 9.5 | 9.5 | 9.3 | 9.5 | | |
| 29. 1.87 | 94: | | | | 6.8 | 8.4 | 9.5 | 9.5 | 9.3 | 9.5 | | |
| 29. 1.87 | 95: | | | | 13.9 | 13.1 | 11.6 | 9.7 | 9.6 | 11.5 | 13.2 | |
| 29. 1.87 | 96: | | | | 13.9 | 13.1 | 11.4 | 13.0 | 9.4 | 11.5 | 13.2 | |
| 29. 1.87 | 97: | | | | | 7.2 | 5.1 | 3.5 | 3.4 | 4.5 | | |
| 29. 1.87 | 98: | | | | | 7.2 | 5.1 | 3.5 | 3.4 | 4.5 | | |
| 29. 1.87 | 99: | | | | | 7.2 | 5.1 | 3.5 | 3.4 | 4.5 | | |
| 29. 1.87 | 100: | | | | | 8.7 | 9.5 | 8.7 | 7.9 | 9.2 | 8.5 | |
| 29. 1.87 | 101: | | | | | | 12.2 | 9.3 | 8.0 | 9.9 | | |
| 3. 2.87 | 102: | | | | | | 12.2 | 9.3 | 7.1 | 9.1 | | |

Table 2-1, cont.

| VALUES OF CO EXPOSURE | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | ID number | Hour 0700 | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 |
| 3. 2.87 | 103: | | | 1.8 | 1.9 | 1.7 | 1.8 | 1.6 | 1.8 | 2.0 | | |
| 3. 2.87 | 104: | | | 2.0 | 1.9 | 1.6 | 1.8 | 1.6 | 1.8 | 2.0 | | |
| 3. 2.87 | 105: | | | 2.0 | 2.7 | 2.5 | 2.1 | 1.4 | 1.6 | 3.0 | | |
| 3. 2.87 | 106: | | | 2.0 | 2.7 | 3.2 | 5.5 | 3.1 | 1.6 | 1.6 | | |
| 3. 2.87 | 107: | | | 2.0 | 1.7 | 5.2 | 2.3 | 1.2 | 1.4 | 1.3 | | |
| 3. 2.87 | 108: | | | 2.0 | 1.5 | 1.4 | 1.5 | 1.2 | 1.4 | 1.9 | | |
| 3. 2.87 | 109: | | | 2.8 | 2.8 | 2.8 | 2.5 | 2.4 | 2.7 | 3.0 | | |
| 3. 2.87 | 110: | | | 2.0 | 2.3 | 2.6 | 4.2 | 2.5 | 2.4 | 2.3 | | |
| 3. 2.87 | 111: | | | 2.0 | 2.2 | 1.9 | 2.1 | 3.6 | 2.4 | 2.3 | | |
| 3. 2.87 | 112: | | | 1.8 | 1.7 | 1.6 | 1.3 | 1.2 | 1.4 | 1.5 | | |
| 3. 2.87 | 113: | | | 2.0 | 1.4 | 3.3 | 2.0 | 1.2 | 1.1 | .9 | | |
| 3. 2.87 | 114: | | | 2.1 | 1.4 | 1.4 | 1.3 | 1.2 | 1.0 | 3.0 | | |
| 3. 2.87 | 115: | | | 2.0 | 1.4 | 1.4 | 1.3 | 1.2 | 1.1 | .9 | | |
| 3. 2.87 | 116: | | | 2.0 | 1.9 | 2.4 | 1.8 | 1.6 | 1.8 | 2.0 | | |
| 3. 2.87 | 117: | | | 2.0 | 2.2 | 1.8 | 2.2 | 2.5 | 2.4 | 2.3 | | |
| 3. 2.87 | 118: | | | 2.0 | 1.9 | 1.9 | 1.8 | 1.6 | 1.8 | 2.0 | | |
| 3. 2.87 | 119: | | | 2.0 | 1.7 | 2.8 | 1.3 | 1.2 | 2.8 | 4.4 | 3.0 | |
| 3. 2.87 | 120: | | | 2.0 | 1.9 | 4.4 | 1.8 | 1.6 | 1.8 | 2.0 | | |
| 3. 2.87 | 121: | | | 2.0 | 1.9 | 1.8 | 1.9 | 1.4 | 1.6 | 1.6 | | |
| 3. 2.87 | 122: | | | 2.0 | 1.4 | 1.4 | 1.3 | 1.2 | 1.1 | .9 | | |
| 3. 2.87 | 123: | | | 2.0 | 2.2 | 2.2 | 2.4 | 3.6 | 4.2 | 1.4 | | |
| 3. 2.87 | 124: | | | 2.0 | 2.2 | 1.7 | 1.3 | 1.4 | 1.4 | 1.5 | | |
| 3. 2.87 | 126: | | | 2.0 | 2.5 | 1.4 | 1.2 | .9 | .8 | 3.0 | | |
| 3. 2.87 | 127: | | | | 2.6 | 2.9 | 2.4 | 2.5 | 2.9 | 2.9 | | |

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NORWEGIAN INSTITUTE FOR AIR RESEARCH
POSTBOKS 64, N-2001 LILLESTRØM

| | | | |
|---|---|---|---|
| RAPPORTTYPE<br>OPPDRAGSRAPPORT | RAPPORTNR. OR 44/89 | ISBN-82-425-0052-5 | |
| DATO<br>AUGUST 1989 | ANSV. SIGN.<br>SLarland | ANT. SIDER<br>66 | PRIS<br>kr 105,- |
| TITTEL<br>Carbon monoxide exposure in individuals working along Rådhusgata, Oslo, Norway, 1987. | | PROSJEKTLEDER<br>J. Clench-Aas | |
| | | NILU PROSJEKT NR.<br>N-8626 | |
| FORFATTER(E)<br>J. Clench-Aas, K. Myhre, T. Krognes, A. Bartonova, M. Johnsrud, I.L. Neslein | | TILGJENGELIGHET<br>A | |
| | | OPPDRAGSGIVERS REF. | |
| OPPDRAGSGIVER (NAVN OG ADRESSE)<br>Norges Teknisk-Naturvitenskapelige Forskningsråd<br>Postboks 70 Tåsen<br>0801 Oslo 8 | | | |
| 3 STIKKORD (à maks. 20 anslag)<br>Karbonmonoksid | Blod | Utåndingsluft | |

REFERAT (maks. 300 anslag, 7 linjer)

Ved bruk av bærbare CO-målere ble eksponering for CO i luft målt og estimert hos 126 mennesker (både røykere og ikke-røykere) som jobbet langs Rådhusgata. Disse verdiene ble sammenlignet med målte verdier av CO i blod (HbCO) og CO i utåndingsluft (CO-EEB) om morgenen når de kom til jobb og igjen om ettermiddagen. Hos ikke-røykere var det en svak økning av HbCO og CO-EEB utover dagen. Morgenverdiene av HbCO og CO-EEB var høyere enn tilsvarende verdier målte i Drammen og høyest blant de som kjørte bil mot de som tok tog eller buss. Men ingen overskred 1.5% HbCO, som er øvre grensen satt av SFT. Verdier av CO i uteluft lå stort sett på eller over grenseverdien på 9 ppm (8 timers middel).

TITLE

ABSTRACT (max. 300 characters, 7 lines)

Using portable CO-monitors, exposure for CO was measured in 126 people, both smokers and non-smokers working along Rådhusgata, Oslo, Norway. These values were compared to values of CO measured in blood (HbCO) or end-expired breath (CO-EEB) both in the morning when they came to work and in the afternoon. In non-smokers, both HbCO and CO-EEB increased slightly during the day. The morning values were higher than those measured in a less polluted area, Drammen, and were highest in those individuals driving to work as opposed to taking the train or bus. No individuals had values of HbCO greater than 1.5%, the upper suggested limit in Norway. Values of CO in outdoor air were at or above the recommended 8-hour limit of 9 ppm.

| | | |
|---|---|---|
| * Kategorier: | Åpen - kan bestilles fra NILU | A |
| | Må bestilles gjennom oppdragsgiver | B |
| | Kan ikke utleveres | C |