



## **Impacts of Earthquake Aftermath on Indoor Carbon Monoxide Levels in Turkish Coffeehouses Environment in Duzce, Turkey**

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### **Abstract**

**Background:** In 1999, Duzce suffered two consecutive devastating earthquakes above magnitude 7 in August and November. In the present study, we aimed to evaluate the indoor air quality of coffeehouses by determining carbon monoxide (CO) levels and their contributing factors in coffeehouses built before and after the earthquake.

**Methods:** We conducted our study in 76 Turkish coffeehouses in Duzce in winter (November 2007–March 2008) during rush hours (18:00-23:00). The Turkish coffeehouses included in the study were evaluated under four categories based on smoking status and construction date. The characteristics of the coffeehouses, such as their CO levels and temperatures both indoors and outdoors, were all measured. These analyses were carried out with the SPSS 15.0 program.

**Results:** The CO levels in Turkish coffeehouses were above the values indicated as being safe by the WHO. While stoves and cooking equipment were determined to contribute to indoor CO levels, cigarettes were found to be the main source. Indoor CO levels at second hour were very strongly correlated ( $r: 0.84, P<0.001$ ) ( $r: 0.91, P<0.001$ ) with indoor CO levels at initial and first hour as well as with smoking status ( $r: 0.69, P<0.001$ ); they were also moderately correlated with the room volume ( $r: 0.34, P<0.001$ ) and construction materials ( $r: 0.31, P<0.001$ ) of the coffeehouse.

**Conclusion:** Elevated CO levels in Turkish coffeehouses indicate the possible presence of other pollutants, particularly when the main source is smoking. In such cases, both individuals and the whole of society are affected negatively in many ways. Therefore, smoking should be prohibited by law in Turkish coffeehouses and national awareness programs should be developed based on peoples' lifestyles. Moreover, the standards for construction and management of Turkish coffeehouses should be improved as well.

**Keywords:** Turkish coffeehouse, Earthquake, Carbon Monoxide, Smoking

### **Introduction**

Duzce experienced two consecutive devastating earthquakes above magnitude 7 in August and November of 1999. Both earthquakes collapsed or damaged most of the houses, offices, stores, Turkish coffeehouses, and industrial facilities in the city. Reconstruction of the buildings in the aftermath of the earthquake was conducted with new construction materials. During the

reconstruction process, attention was paid to heat, sound, and air insulation, and for this purpose, materials uncommon to the region such as plastic panel doors and windows were used. Thus, the insulation of indoor air from outdoors was improved. In Duzce, buildings constructed with old building materials had wooden doors and windows and inadequate heat, sound, and

air insulation, whereas in some buildings air circulation was achieved through spaces left for air flow under the doors and above the windows. Therefore, Duzce offers the opportunity to examine both old buildings built with old construction materials and new buildings built with new construction materials.

Turkish coffeehouses (Kahvehane in Turkish), also found in other Middle Eastern countries, differ from their Western counterparts. They are points of social gathering for men above age 18 where smoking is allowed. In other words, Turkish coffeehouses are venues where men come together and interact with each other socially, economically, and culturally. In winter, the periods of time spent in Turkish coffeehouses are longer, especially during the evenings. In Duzce, Turkish coffeehouses have an attendance capacity of 10-100 people and comprise an indoor area (and sometimes a garden as well) that is either part of a larger building or a detached; they can be managed only by legal permission.

Duzce is a province situated on a wide and forestful geographical area in the northwestern part of Turkey in the Black Sea region. Among its wide area it has a small population. As it is localized on the water supplies of Istanbul (biggest city of Turkey) industrialization in Duzce is strictly limited and controlled. Since the central district of Duzce is surrounded by mountains, winds are blocked owing to its geotopography, which may sometimes lead to minimal environmental air pollution (1). But because of the limitation of the industry and air cleaning effects of the forests the outdoor carbon monoxide (CO) levels is always measured at minimal levels in Duzce.

The houses and offices of Duzce are heated with stoves; sources of energy are generally coal (53%), wood and hazelnut shell (41%), electricity (6%), liquid petroleum gas (LPG) and others (2). Turkish coffeehouses in Duzce also use stoves for heating, and wood, coal, hazelnut shell, and kerosene as energy sources during the

winter. Tea and coffee cookers are fueled with LPG.

The most important factors affecting CO levels in the indoor areas of buildings are as follows: 1) CO source, a) smoking, b) stoves with inadequate ventilation (wood, coal, and gas stoves, c) CO emitted by humans, 2) Characteristics of the indoor area, a) construction materials of the building, and b) ventilation system of the building (3). CO has long been known to be one of the factors polluting indoor air. The health effects of exposure to CO are generally described relative to carboxyhaemoglobin (COHb) levels (4). The most important impact of CO on health is its strong binding with hemoglobin, which leads to reduced oxygen capacity of blood. In non-smoking individuals unexposed to environmental CO, blood COHb levels are usually around 0.5% (5).

Various symptoms of neuropsychological impairment have been associated with acute low-level exposures. Subjects exposed to CO from residential stoves for up to 2.5 h showed declines in their learning and planning abilities, as well as drops in their attention and concentration spans (6). Chronic exposure to 30% COHb often produces symptoms that are easily misdiagnosed or overlooked, such as headache, fatigue, dizziness, and nausea (7). There is evidence from animal studies that some fetal damage may occur as a result of maternal exposure to CO at these levels (8). Carbon monoxide poisoning has its most acute toxic effects on the organs with the highest oxygen requirements: the heart and the brain. Thus, individuals with ischemic heart disease are at particularly high risk (9). According to the WHO guidelines determined in 1996, the acceptable maximum CO exposure levels are 100 mg/mm<sup>3</sup> (90 ppm) for 15 minutes, 60 mg/mm<sup>3</sup> for 30 minutes, 30 mg/mm<sup>3</sup> for 1-3 hours, and 10 mg/mm<sup>3</sup> for 3-8 hours (10).

In the present study, we aimed to 1) determine CO levels and their differences between Turkish coffeehouses built before and after the earth-

quake, and 2) outline the factors affecting CO levels in a Turkish coffeehouse environment.

## **Materials and Methods**

### ***Study design and population***

Duzce's population is 323,328. Due to the legal age and gender limitation, only men above age 18 (107,882) can attend Turkish coffeehouses. The male population of the central districts is 53,743, whereas that of the rural districts is 54,139 (11). There are 734 Turkish coffeehouses in Duzce, 326 of which are in the central districts and 418 are in villages. Of these coffeehouses, 279 were built after the earthquake (12). The present study was conducted during the winter (November 2007 – March 2008). Informed consent was obtained from the managers of the Turkish coffeehouses.

Information on the coffeehouses and the studied measurements were recorded on the forms developed for the study. Prior to the main study, a number of pilot experiments were performed to confirm the suitability of the sampling and analytical procedures proposed for the main study. The same research team and equipment were used throughout the course of the study. Each measurement was repeated at least twice and a third measurement was performed when differing results are obtained; mean values of the measurements were recognized as the final result. Calibration of the equipments was checked daily. The study was conducted in 76 Turkish coffeehouses in Duzce during the rush hours of the day (18:00-23:00).

The Turkish coffeehouses included in the study were categorized into four groups based on the construction materials they were built with and their smoking status: Group A) built with classical construction materials and smoking is not allowed, Group B) built with classical construction materials and smoking is allowed, Group C) built with new construction materials and smoking is not allowed, Group D) built with new construction materials and smoking is allowed. During the selection of the coffeehouses, the ru-

ral/urban ratios of those groups were also considered.

Each Turkish coffeehouse had a capacity of 20-160 people and their total capacity was 6231 people. Data forms included height, width, length, construction materials, capacity, fuel type, indoor temperature, ventilation, heater, and cooker information of the Turkish coffeehouses. Environmental CO level measurement was performed at seven points (four corners of the coffeehouse and three corners of an equilateral triangle with side length of 2 m) 1.5 m above ground by keeping a distance of at least 100 cm from people. The mean value of the measurement results obtained from those seven points were calculated and recognized as the final result. Measurements were performed three times as follows: initial, first hour, and second hour. Outdoor CO levels of study coffeehouses were also measured and because no value above 0-1 ppm was found, outdoor CO levels were not taken into consideration.

### ***Indoor CO measurement***

Indoor CO level was measured with a CO meter device (Fluke, CO 220). The detector mechanism of the device works with an electrochemical sensor and shows the result as a ppm value. It can perform measurements with 1 ppm resolution and  $\pm 2$  ppm accuracy within a 0-200 ppm range at 0-50 °C (13).

### ***Temperature measurement***

Temperature measurements were carried out with a digital Celsius thermometer. Measurement range was 0-1000 °C with  $\pm (0.3\% + 1^\circ\text{C})$  accuracy and  $\pm 0.1^\circ\text{C}$  reliability (14).

### ***Statistical analysis***

Descriptive analysis was applied to the obtained data. Parametric one-way ANOVA was used to compare more than two groups, the Hosdok Multiple Comparisons Sida ANOVA test was used to evaluate the affecting group, and a parametric paired simple test was applied to compare repeated measurements. The relation-

ships of variants were evaluated with the nonparametric nepal correlation method. The curve estimation logistic model and the regression analysis method were used in the modeling performed to determine the affecting factor. These analyses were carried out with the SPSS 15.0 program.

## Results

Among all the measurements performed in the Turkish coffeehouses, minimal and maximal CO levels were 2 ppm and 24 ppm, respectively. Indoor CO levels of coffeehouses classified in four groups according to their building characteristics and smoking status were presented as mean values obtained initially, at first hour, and at second hour. Initial mean CO levels measured in the coffeehouses were  $2.95 \pm 1.37$  in Group A,  $12.59 \pm 2.01$  in Group B,  $6.75 \pm 2.29$  in Group C, and  $15.39 \pm 5.54$  in Group D; these values were significantly different between groups ( $F=610.45$ ,  $P<0.0001$ ) (Table 1).

The hosdok multiple comparisons sidak ANOVA analysis used to determine differences between the groups demonstrated that all groups differed significantly from one another at each time of measurement ( $P<0.001$ ). The analysis of the difference between initial and second hour measurements of indoor CO levels demonstrated the following results and exhibited significant differences in all four groups: Group A ( $1.39 \pm 1.05$ ) ( $t=15.10$   $P<0.001$ ), Group B ( $1.45 \pm 1.66$ ) ( $t=10.17$   $P<0.001$ ), Group C ( $2.51 \pm 1.41$ ) ( $t=17.81$   $P<0.001$ ) and Group D ( $1.93 \pm 2.59$ ) ( $t= 9.04$   $P<0.001$ ) (Table 2).

The evaluation of indoor CO levels relative to the coffeehouse type revealed that Group D had

the highest mean value, whereas Group A exhibited the lowest mean value (Fig. 1).

Indoor CO levels at second hour were very strongly correlated ( $r: 0.84$ ,  $P<0.001$ ) ( $r: 0.91$ ,  $P<0.001$ ) with indoor CO levels at initial and first hour as well as with smoking (+) status ( $r: 0.69$ ,  $P<0.001$ ); they were also moderately correlated with the room volume ( $r: 0.34$ ,  $P<0.001$ ) and construction materials ( $r: 0.31$ ,  $P<0.001$ ) of the coffeehouse (Table 3).

Principle factors influencing the indoor CO level at second hour in the coffeehouses were as follows (in order of importance of influence): smoking status ( $MR=0.81$ ,  $P<0.001$ ), room volume ( $MR=0.52$ ,  $P<0.001$ ), construction materials ( $MR=0.38$ ,  $P<0.001$ ), temperature ( $MR=0.23$ ,  $P<0.001$ ) and ventilation of the coffeehouse ( $MR=0.17$ ,  $P<0.001$ ), and capacity ( $MR=0.12$ ,  $P=0.005$ ) (Table 4).

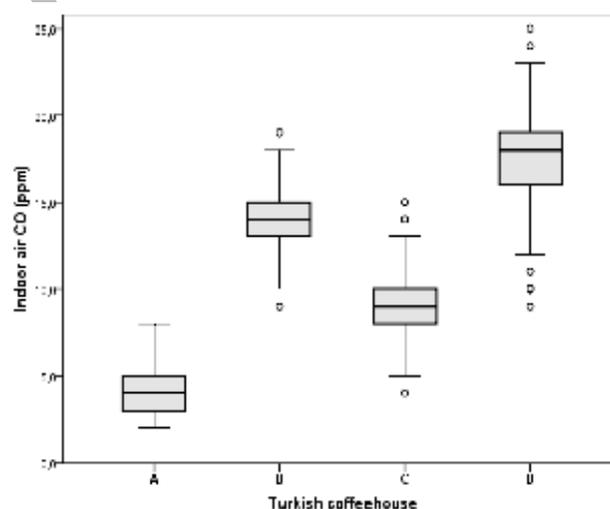


Fig. 1: Indoor CO level at second hour relative to the coffeehouse group

**Table 1:** Comparison of indoor CO levels based on coffeehouse type and measurement time (ppm)

|                | n  | Initial      |                      | 1 <sup>st</sup> hour |                      | 2 <sup>nd</sup> hour |                      |
|----------------|----|--------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|                |    | Mean ± SD    | Anova                | Mean ± SD            | Anova                | Mean ± SD            | Anova                |
| <b>Group A</b> | 19 | 2.95 ± 1.37  |                      | 3.55 ± 1.34          |                      | 4.34 ± 1.28          |                      |
| <b>Group B</b> | 19 | 12.59 ± 2.01 | F=610.45<br>P< 0.001 | 13.57 ± 2.08         | F=731.54<br>P< 0.001 | 14.04 ± 1.99         | F=781.80<br>P< 0.001 |
| <b>Group C</b> | 19 | 6.75 ± 2.29  |                      | 7.93 ± 2.19          |                      | 9.26 ± 2.22          |                      |
| <b>Group D</b> | 19 | 15.39 ± 5.54 |                      | 16.52 ± 3.64         |                      | 17.33 ± 3.34         |                      |

**Table 2:** Comparison of mean indoor CO levels between initial and second hour measurements within groups (ppm)

|                | n  | Mean ± SD   | Paired Differences<br>95% CI |       | t*    | P       |
|----------------|----|-------------|------------------------------|-------|-------|---------|
|                |    |             | Lower                        | Upper |       |         |
| <b>Group A</b> | 19 | 1.39 ± 1.05 | 1.21                         | 1.57  | 15.10 | < 0.001 |
| <b>Group B</b> | 19 | 1.45 ± 1.66 | 1.17                         | 1.47  | 10.17 | < 0.001 |
| <b>Group C</b> | 19 | 2.51 ± 1.41 | 2.23                         | 2.79  | 17.81 | < 0.001 |
| <b>Group D</b> | 19 | 1.93 ± 2.59 | 1.52                         | 2.36  | 9.04  | < 0.001 |

**Table 3:** Correlation between indoor CO level and coffeehouse characteristics

|                                | Initial indoor<br>CO level | Indoor CO level<br>at 1st hour | Indoor CO level<br>at 2nd hour | Construction<br>Type | Smoking | Capacity | Volume |
|--------------------------------|----------------------------|--------------------------------|--------------------------------|----------------------|---------|----------|--------|
| Indoor CO level at<br>1st hour | 0.90**                     |                                |                                |                      |         |          |        |
| Indoor CO level at<br>2nd hour | 0.84**                     | 0.91**                         |                                |                      |         |          |        |
| Smoking Status                 | 0.69**                     | 0.69**                         | 0.69**                         |                      |         |          |        |
| Construction type              | 0.26**                     | 0.28**                         | 0.31**                         |                      | 0.01    |          |        |
| Coffeehouse<br>capacity        | -0.06                      | -0.05                          | -0.08*                         | -0.20**              | -0.02   |          |        |
| Room Volume                    | -0.35**                    | -0.36**                        | -0.34**                        | 0.06                 | 0.55**  | 0.40**   |        |
| Coffeehouse<br>heating         | 0.14**                     | 0.14**                         | 0.12**                         | 0.31**               | 0.19**  | 0.23**   | 0.36** |
| Coffeehouse<br>Ventilation     | 0.12**                     | 0.12**                         | 0.13**                         | 0.20**               | 0.20**  | -0.48**  | -0.04  |

\* Correlation is significant at the 0.05 level; \*\* Correlation is significant at the 0.001 level

**Table 4:** Regression analysis of factors affecting the indoor CO levels of coffeehouses at 2<sup>nd</sup> hour with curve estimation logistic model

|                        | Indoor CO at 2nd |                | hour | (Constant) | F       | P      |
|------------------------|------------------|----------------|------|------------|---------|--------|
|                        | MR               | R <sup>2</sup> |      |            |         |        |
| Smoking status         | 0.81             | 0.65           | 0.95 | 1.25       | 1005.50 | <0.001 |
| Room volume            | 0.52             | 0.27           | 0.96 | 0.01       | 204.97  | <0.001 |
| Construction materials | 0.38             | 0.15           | 0.98 | 0.31       | 93.11   | <0.001 |
| Indoor temperature     | 0.23             | 0.05           | 0.10 | 0.05       | 29.01   | <0.001 |
| Ventilation            | 0.17             | 0.03           | 0.99 | 0.98       | 16.27   | <0.001 |
| Capacity               | 0.12             | 0.01           | 1.00 | 0.02       | 7.83    | 0.005  |

## Discussion

In measurements performed in the Turkish coffeehouses, minimal CO level was 2 ppm and the maximum CO level was 24 ppm. In a study conducted in Hanoi, Vietnam, whereas the mean CO value was 15.7 ppm, it was 18.6 ppm on motorbikes, 18.5 ppm in cars, 11.5 ppm in buses, and 8.5 ppm while walking. (According to WHO guidelines, acceptable mean CO level is 10 ppm at 8 hours and 50 ppm at 30 minutes) (15). A study performed in Korea revealed that indoor CO levels were as high as 90 ppm in five restaurants and 41 ppm in one restaurant (16). In the current study, CO level in the measured air was found to be similar. The health of people exposed to CO for a long time is known to be affected negatively in the following ways: headaches, reduction in activity capacity, elevation in coronary artery disease risk, and loss of work efficiency (17, 18).

According to initial measurements of indoor air in coffeehouses, mean CO levels were highest in Group D followed by Group B, C, and A, respectively. A statistically significant difference was found between all four groups ( $F=610.45$ ,  $P<0.001$ ). The mean values of indoor CO levels were the same at first and second hours and fell in the same order according to group, maintaining the statistically significant difference ( $F=731.54$ ,  $P<0.001$ ), ( $F=781.80$ ,  $P<0.001$ ) (Table 2). These results suggest that CO levels in Groups A and C where smoking was prohibited were lower than the levels in Groups B and D where smoking was allowed.

However, Group A, which comprised older buildings, showed lower indoor CO levels than Group C, which included new buildings recognized. Group B with old buildings exhibited again lower indoor CO levels compared with those in Group D with new buildings. These results suggest that CO concentrations are reduced by the natural air flow into and out of the room in Turkish coffeehouses with inadequate air insulation.

During the course of the study, indoor CO levels were observed to be increasing. This change was found to be statistically significant in each group ( $P<0.001$ ); however, it was more significant in Group C (mean= $2.51 \pm 1.41$  ppm) and Group D (mean= $1.93 \pm 2.59$  ppm) (Table 3). These results can be explained by a reduction of air permeability with the introduction of new building materials such as windows and doors, and the inadequacy or inactivation of ventilation systems. Indoor CO levels at the second hour were highest in Group D and lowest in Group A (Fig. 1). Indoor CO levels at the second hour were very strongly correlated with indoor CO levels at the initial stage (initial;  $r=0.84$ ,  $P<0.001$ , 1 h;  $r=0.91$ ,  $P<0.001$ ), which suggested that indoor CO levels in Turkish coffeehouses were constant to a certain degree.

A strong relationship was found between the smoking status of coffeehouses and the indoor CO level at second hour ( $r=0.69$ ,  $P<0.001$ ). This result was concluded to be an outcome of reduced ventilation rates during winter, while smoking remains to be the main pollutant. This conclusion was consistent with other similar studies (19, 20). Nonsmokers in Turkish coffeehouses that allow smoking are recognized as secondhand smokers and known to be under higher risk for the development of health problems (e.g., cancer) (21).

A moderate negative correlation was found between room volume and indoor CO level at the second hour ( $r=-0.34$ ,  $P<0.001$ ); in other words, CO level increased as the volume decreased. During the construction of a Turkish coffeehouse adequate space per individual should be considered. A moderate relationship was found between building materials used in the construction of the coffeehouse and the CO levels measured at the second hour ( $r=0.31$ ,  $P<0.001$ ). The air insulation provided by indoor structure building materials was found to be an important factor in CO exposure.

A weak correlation was found between the presence of a ventilation system and indoor CO levels at second hour. Inadequate ventilation systems or ineffective management of the ventilation are possible explanations for this relationship. Three factors may be mentioned as the underlying causes of ventilation problems: 1) absence of a standard legal structure requiring the implementation of an adequate ventilation system and its effective management, 2) managers' insensitive approach towards air pollution, and 3) lack of individual awareness for air pollution. Our results are consistent with those of a study performed on houses, offices, and restaurants in Korea (18) and results of another study performed on offices in Hong Kong (22). Raising individual awareness on this subject should be a priority and people should be educated to deem inadequately ventilated environments as uninhabitable. A study conducted in Norway found that further research was required to examine the informational, educational, and clinical interventions that should accompany these major shifts in national lifestyle in order to best take advantage of the rich opportunities for achieving tobacco control objectives. The results of the present study support the same conclusions (23).

The regression analysis of factors affecting the indoor CO levels at second hour in Turkish coffeehouses was performed with curve estimation logistic model; the following main factors were determined to have an influence over the indoor CO levels: smoking status (MR=0.81  $P<0.001$ ), room volume (MR=0.52,  $P<0.001$ ), building material characteristics (MR=0.38  $P<0.001$ ), temperature (MR=0.23  $P<0.001$ ), ventilation (MR=0.17  $P<0.001$ ), and capacity of the coffeehouse (MR=0.12,  $P=0.005$ ).

Therefore, it can be said that indoor CO level in a coffeehouse is affected by smoking, room volume, building materials used in the construction, and ventilation system. A study conducted in South Korea shows that indoor activities that generate pollutants include the use of gas or kerosene stoves for heating and cooking, clean-

ing, and the use of a variety of consumer products including cigarettes. The density of human occupancy, with people tending to spend more time indoors in the winter compared with the summer, combined with inadequate ventilation, can also play important roles in determining air quality during winter (16). In the current study, although the main cause of air pollution was smoking, factors such as ineffective use of ventilation systems and spending more time indoors during winter were also contributing factors, as was found in the study conducted in South Korea.

The examination of the building materials of Turkish coffeehouses revealed that because classic building materials used in construction would leave 4-5 cm spaces under doors or 3-4 cm spaces above windows, fresh air circulation could be provided to a certain degree even without any ventilation system. However, since usage of new building materials provides complete indoor heat and air isolation, an inadequate ventilation system or its ineffective management leads to elevated indoor CO levels. Jo W. K. and Lee J. Y. reported that outdoor CO levels affect indoor CO levels by elevating them (20, 24). In the current study, because the outdoor CO level was very low or zero, we believe it had no influence on the level of indoor CO levels and therefore advocate providing air flow from outside in. Since the main pollutant in the coffeehouses is known to be cigarette smoke, it is evident that CO will be present in the indoor air along with other air pollutants; many studies have found significant correlations between levels of CO and other pollutants (17, 25). It should be noted that such conditions indirectly affect human health and may lead to serious diseases such as cancer (26).

In conclusion, indoor CO levels in the Turkish coffeehouses of Duzce province are influenced by indoor smoking and building materials used during construction. Indoor CO levels in Turkish coffeehouses built before the earthquake were found to be lower than those built after the earthquake; old buildings provided natural air

ventilation through the spaces left below doors and above windows. However, new buildings built with newer construction materials were found to have higher CO levels when appropriate ventilation systems were not installed or managed properly.

Since other air pollutants are present along with CO in public places such as coffeehouses, smoking should be prohibited by law, buildings should be built according to regional requirements, and ventilation systems should be installed and managed according to prearranged regulations. Smoking should be avoided in indoor environments such as Turkish coffeehouses within a framework of a national awareness campaign based on the education of people.

### Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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The authors declare that there is no conflict of interests.

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