# Low Level Carbon Monoxide and Mortality of Persons Aged 65 or Older in Tokyo, Japan, 1976–1990

**Yasushi Honda,*[,a] Hiroshi Nitta,[b] and Masaji Ono[b]**

*[a]Institute of Health and Sport Sciences, University of Tsukuba , 1–1–1 Tennodai, Tsukuba 305–8574, Japan and [b]the National Institute for Environmental Studies, 16–2 Onogawa, Tsukuba 305–8506, Japan*

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Ambient carbon monoxide (CO) levels in most of the cities in Japan have not exceeded the National Air Quality Standard. We investigated whether or not this low level of CO pollution has been positively related to the mortality rate. We used computerized data for Tokyo, 1976–1990, obtained from governmental agencies. Subjects were restricted to those 65+ years old, because air-pollution influences this group the most. Although the CO level was higher in earlier years and was correlated with the sulfur dioxide level, the Poisson regression analysis that included chronological year and sulfur dioxide level as covariates showed a positive association between CO level and all-cause mortality rate: The mortality rate ratios for the CO levels 1.1–1.6, 1.6–2.2, 2.2+ ppm compared with the CO level < 1.1 ppm were 1.017 [95% confidence interval (CI) 1.009–1.026], 1.031 (95% CI 1.020–1.041) and 1.051 (95% CI 1.039–1.063), respectively. Although it is possible that the higher CO levels only displace deaths several days earlier, the results warrant further study as to whether or not further reduction of CO level would improve the mortality rate of the elderly.

**Key words** —— epidemiological study, carbon monoxide, daily mortality rate, temperature, sulfur dioxide

## INTRODUCTION

Effects of air pollution, including carbon monoxide (CO), on mortality/morbidity have been investigated intensively using time-series analyses in various countries.[1,2] Although these studies showed that CO has an effect on mortality, Moolgavkar reported that there was considerable area difference in air pollution effect.[1] Also in Japan, no evaluation has been done on the question of whether or not ambient CO has a short-term effect on mortality. Hence, we decided to investigate the CO effect on mortality in Japan.

To evaluate the short-term effect of ambient CO levels lower than the Japanese air quality standard (daily average concentration not exceeding 10 ppm) on mortality, we investigated the relation between the daily CO level and mortality rate in Tokyo.

*To whom correspondence should be addressed: Institute of Health and Sport Sciences, University of Tsukuba, 1–1–1 Tennodai, Tsukuba 305–8574, Japan. Tel. & Fax: +81-29-853-2627; E-mail: honda@taiiku. tsukuba.ac.jp

## MATERIALS AND METHODS

We used computerized data for Tokyo, 1976–1990 from the following sources: The Environment Agency (ambient CO, NO, $NO_2$, oxidant and $SO_2$ concentrations), the Meteorological Agency (daily maximum temperatures), the Ministry of Health and Welfare (selected items of death certificates, with the permission of the Prime Minister's Office) and the General Administrative Agency of the Cabinet (annual age-group- and sex- populations). The names of the agencies and the ministry are those in use as of the data acquisitions.

Tokyo has 37 points that continually monitor air pollution [$SO_2$, $NO_X$, NO, $NO_2$, oxidant, CO, suspended particulate matter (SPM)]. These data were available from the Air Continual Monitoring Database. We used the data at Chiyoda Ward monitoring point, which is located in the center of Tokyo. Among 37 monitoring points, CO has been measured in the 34 points. The correlation coefficients of the CO measurements for these points were very high. The source of air pollution in Tokyo is mobile emission sources such as automobiles, and the daily fluctuation of the concentrations of the pollutants are related to the extent of the traffic volume, *i.e.*, CO and $NO_X$ concentrations have bimodal pattern with two peaks being at around noon and early evening. The concentrations at night are usually very low.

Unfortunately, the method for SPM measurement was changed during the study period, and we decided not to use the SPM concentration data in the analyses.

Persons aged 65 or older, only, were included because they are the group most vulnerable to air pollutants, as observed in various air pollution episodes.[3] We used all-cause mortality to evaluate overall effect. This endpoint is a good index for the first attempt of evaluating the short-term effect, because of the following reasons: There are various types of diseases that are influenced by air pollution, and some of the deaths can be misclassified as "senility" or, in cases of sudden deaths, "unknown."

In the analysis, we included daily maximum temperature level as one of the covariates, because it is an important confounding factor in evaluating short-term effects of air pollution.[1]

Categorization of the CO levels was based on the 2-digit significant figures closest to the quartile cutoff points, *i.e.*, 1.1, 1.6, and 2.2 ppm. $SO_2$ levels were categorized in the same manner with the cutoff points being 1.0, 1.4, and 1.9 ppm.

Daily maximum temperature- and CO level-specific mortality rate was computed with an approximation of the person-time method[4]: The numerator is the total number of deaths which occurred on the days during the study period with a certain combination of the daily maximum temperature category and the CO concentration category, and the denominator is the number of days with the same combination of the categories multiplied by the population size; this calculation of denominator is the approximation of the actual person-days. For example, if the study period is 1977–1978, there were 20 days in 1977 and 12 days in 1978 on which the daily maximum temperature level was 33+°C and CO concentration level was less than 1.2 ppm, the total number of deaths during these 32 days was 200, and the population size was 100000 in 1977 and 105000 in 1978, then the mortality rate is calculated as

200/(20*100000 + 12*105000).

We used the mortality rate from all causes instead of cardio-vascular diseases only, because there may have been substantial number of deaths due to cardiovascular diseases that had been diagnosed as being due to other causes.[5]

In this study, we conducted the following three analyses: First, we evaluated the CO effect using the whole study period. Next, we evaluated the effect of other pollutants through their correlation coefficients with CO level; if the correlation coefficients are not very high, the obtained CO effect cannot be explained by other pollutants. In calculating the correlation coefficients, we did not include suspended particles as one of the air pollutants, because the method of measuring particles was changed in the middle of our observation period and our preliminary evaluation showed that the two types of measurements resulted in different correlation coefficients with CO. Third, we introduced Poisson regression models to evaluate the precision of the CO-mortality relation and the sulfur dioxide ($SO_2$) effect on the CO-mortality relation; the $SO_2$ level is correlated with the CO level as shown in the results section. Because the CO and $SO_2$ levels have been decreasing along with the annual mortality rates for the subjects, we incorporated year as a covariate in the models. Other variables included in the models were sex, daily maximum temperature and $SO_2$ level. Since we cannot assume that the effects of the covariates are linear, we treated these covariates as categorical variables.

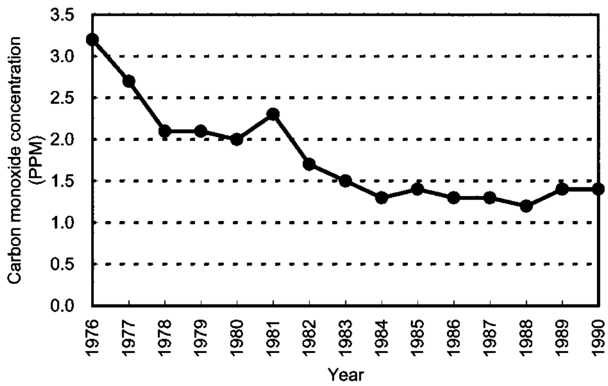


**Fig. 1.** Chronological Trend of the Daily Average Carbon Monoxide Concentration* (Tokyo, Japan)
*Annual average of the daily average concentration.

## RESULTS

The daily average CO level ranged from 0 to 6.8 ppm (median = 1.6 ppm). As shown in Fig. 1, the CO level has been decreasing during these 15 years.

Figure 2 shows that the mortality rate was lower when the CO level was lower for most of the categories of daily maximum temperature. The only exception was the line for males, 33+°C.

Table 1 shows the correlation coefficients of the daily average concentrations of other pollutants with that of CO. The $SO_2$ level has a moderately high correlation coefficient, but the correlations were not very high for the levels of nitrogen oxides or oxidant.

Table 2 shows the number of deaths by CO level and daily maximum temperature level. The maximum temperature category 33+°C has low numbers of deaths, especially in the lowest CO level category.

Table 3 shows the rate ratio estimates and 95% confidence intervals of the covariates. The higher

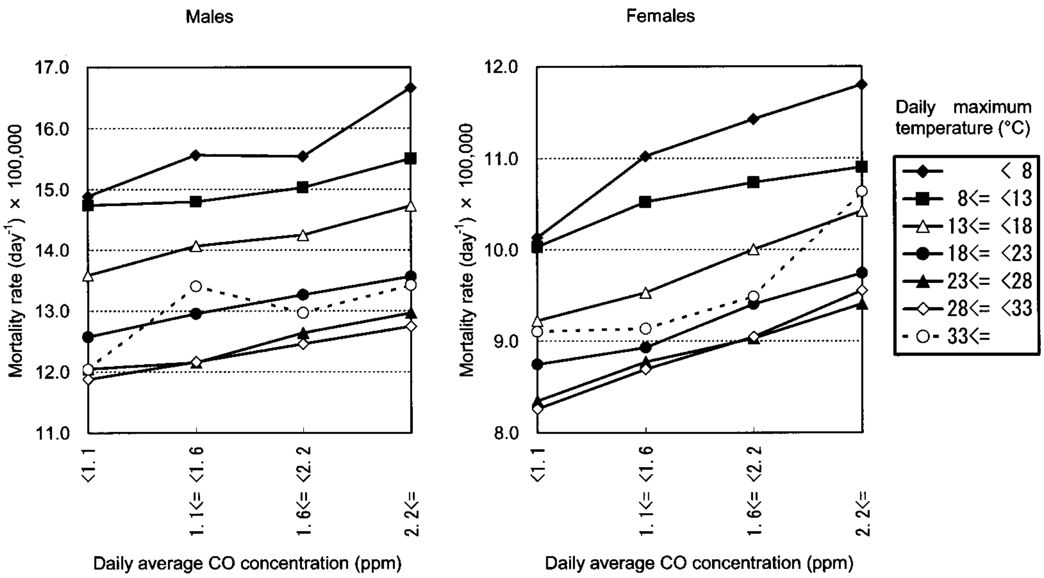


**Fig. 2.** Mortality Rate from All Causes by Daily Average Carbon Monoxide Concentration Level and by Daily Maximum Temperature Level (Tokyo, 65+ year-old Males and Females, April 1976–December 1990)

**Table 1.** Correlation Coefficients between the Average Daily Carbon Monoxide Concentration and the Average Daily Concentrations of the Other Pollutants

| | CO | NO | $NO_2$ | Oxidant | $SO_2$ |
|---|---|---|---|---|---|
| CO | 1.000 | 0.403 | 0.415 | 0.396 | 0.675 |
| | — | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | 4823 | 4725 | 4726 | 4652 | 4644 |
| NO | 0.403 | 1.000 | 0.564 | −0.037 | 0.429 |
| | 0.0001 | — | 0.0001 | 0.0095 | 0.0001 |
| | 4725 | 5204 | 5198 | 5015 | 5003 |
| $NO_2$ | 0.415 | 0.564 | 1.000 | 0.126 | 0.584 |
| | 0.0001 | 0.0001 | — | 0.0001 | 0.0001 |
| | 4726 | 5198 | 5200 | 5012 | 5000 |
| Oxidant | 0.396 | −0.037 | 0.126 | 1.000 | 0.428 |
| | 0.0001 | 0.0095 | 0.0001 | — | 0.0001 |
| | 4652 | 5015 | 5012 | 5123 | 4920 |
| $SO_2$ | 0.675 | 0.429 | 0.584 | 0.428 | 1.000 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | — |
| | 4644 | 5003 | 5000 | 4920 | 5104 |

The set of values for each cell represents correlation coefficient, $p$-value, and number of observations.

**Table 2.** Distribution of Deaths by Daily Maximum Temperature Level and Daily Average CO Level (Tokyo, 65+ years old Males, April 1976–December 1990)

| Daily maximum temperature (°C) | Daily CO concentration (ppm) < 1.1 | 1.1 <= < 1.6 | 1.6 <= < 2.2 | 2.2 <= | Missing |
|---|---|---|---|---|---|
| < 8 | 9690 | 5886 | 3262 | 1193 | 3283 |
| 8 <= < 13 | 19196 | 15607 | 11064 | 9962 | 7219 |
| 13 <= < 18 | 12682 | 12506 | 12211 | 13905 | 5607 |
| 18 <= < 23 | 14918 | 15721 | 11041 | 12146 | 5533 |
| 23 <= < 28 | 9694 | 17514 | 13105 | 12963 | 4998 |
| 28 <= < 33 | 4184 | 11495 | 11590 | 11114 | 3095 |
| 33 <= | 470 | 1741 | 2068 | 2531 | 770 |

**Table 3.** Mortality Rate Ratio for Daily Mortality Calculated with Poisson Regression Models

| Covariates | Rate ratio (95% confidence interval) | *p*-value |
|---|---|---|
| CO level | | |
| < 1.1 | 1 (reference category) | — |
| 1.1 <= < 1.6 | 1.017 (1.009–1.026) | < .0001 |
| 1.6 <= < 2.2 | 1.031 (1.020–1.041) | < .0001 |
| 2.2 <= | 1.051 (1.039–1.063) | < .0001 |
| Daily maximum temperature (°C) | | |
| < 8 | 1.179 (1.166–1.193) | < .0001 |
| 8 <= < 13 | 1.144 (1.134–1.153) | < .0001 |
| 13 <= < 18 | 1.070 (1.061–1.079) | < .0001 |
| 18 <= < 23 | 1 (reference category) | — |
| 23 <= < 28 | 0.958 (0.950–0.966) | < .0001 |
| 28 <= < 33 | 0.958 (0.950–0.967) | < .0001 |
| 33 <= | 1.014 (0.996–1.032) | 0.1215 |

Note: The other covariates included in the model were sex, chronological year, daily maximum temperature and $SO_2$ level, all of which were treated as categorical variables.

the CO level was, the higher the rate ratio was. Also, each CO level had a very small *p*-value. The rate ratios for CO levels were somewhat enhanced when $SO_2$ was not incorporated in the model (data not shown). Although not shown in Table 3, the males had 1.411 times higher mortality rate than the females, and the year effect (when 1990 mortality was set as a reference) ranged from 0.957 in 1987 to 1.034 in 1978, with no clear trend.

## DISCUSSION

As shown in Fig. 1, the CO level was constantly decreasing. In this case, it is possible that the observed relation between the CO concentration and mortality rate is attributable to chronological mortality change, since the mortality rate for persons 65+ years old has been decreasing in recent decades in Japan, according to the Vital Statistics in Japan.

However, Table 3 shows the same pattern of the mortality rate increasing as the CO level became higher even when the chronological year was controlled for. Hence the relation may not be due to chronological change.

Sulfur dioxide level had a moderately high correlation coefficient, but the relatively low correlation coefficient of CO with the nitrogen oxides, and the results in Table 3 in which $SO_2$ level was controlled for suggest that the relation between the mortality rate and CO concentration may not be attributed entirely to other pollutants.

The relation between daily average CO concentration and mortality rate shown in Fig. 2 was monotonous with the line for the 33+°C category among males being the only exception. This non-monotonous pattern may be due to a random error attributable to the small numbers of deaths in 33+°C category as shown in Table 2 and to the open-ended nature of the 33+°C category.

The limitations of the present study are as follows: (i) The CO effect on mortality may be only for several days (which is called mortality displacement); (ii) the effect may have been confounded by suspended fine particles. As for (i), some articles reported that the short-term effects of the pollutants may not be considered as mortality displacement,[6,7] although further studies are needed to confirm whether or not the reported results are applicable to CO pollution and to the Japanese population. As for (ii), the change of the SPM measurement method prohibited us from evaluating the possibility of SPM involvement. However, because both the CO and the particles are produced mainly by automobiles, it may be safe to say that the mortality rate is dependent on the combination of concentrations of some pollutants, represented by the CO level.

In conclusion, we found that high CO levels were related to increased mortality rates in persons aged 65 or older, even after controlling for some confounding factors and even when the CO levels were lower than the National Air Quality Standard in Japan.

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