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Carbon Monoxide Contamination in Dwellings in Poor Rural Areas of Guatemala

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The detrimental effects of environmental carbon monoxide (CO) contamination have been well documented in both humans and experimental animals. In human adults, an increased incidence of cardiovascular and nervous disorders has been associated with CO contamination levels (ARONOW 1974, ASTRUP 1972, GRUT et al. 1970, HELIÖVAARA et al. 1978, LONGO 1977, STEWART et al. 1970, STONESIFER 1978). Exposure to CO contaminated air during pregnancy has been shown to have a detrimental effect on fetal growth (WILLIAMS et al. 1977). A similar effect is observed in pregnant women who are heavy smokers (LONGO 1977).

The most frequent causes of CO contamination in urban areas are related to incomplete combustion in motor vehicles and to cigarette smoke. In Guatemala, inhabitants of rural areas are isolated from the pollution of big cities, and cigarette smoking, especially among women in these areas, is not widespread. Therefore, these population groups are not affected by the urban types of contamination. Nevertheless, due to cooking procedures and housing structure, poor rural populations, particularly women, are exposed to high concentrations of carbon monoxide. In this article these characteristics are described as found in two rural Guatemalan communities.

MATERIALS AND METHODS

Two communities living at different altitudes were studied in rural Guatemala. Their general characteristics are shown in Table 1.

A house-to-house survey was conducted in each village in 200 houses selected at random. Information was gathered regarding materials used for cooking, cooking schedules and the degree of ventilation provided in the kitchen.

Specifically, the following data were collected: material used for walls (brick, cane poles or wood); their compactness, i.e., air filtration through walls; the number

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TABLE 1. Characteristics of populations studied.

	Village at low altitude (250-300 m above sea level)	Village at high altitude (1350-1400 m above sea level)
Village name	San Agustín Acasaguastlán	Joyabaj
Department	El Progreso	El Quiché
Temperature range	20–35°C	12-25°C
Annual precipitation	500–600 mm	2000–3000 mm
o/o Indian population	0.22o/o	37.54o/o
Principal sources of income	Corn, beans and fruit production	Corn, beans, and sugar-cane production
No. of inhabitants	3215	1987
No. of houses	1000	800
Material used for cooking:		
firewood	89o/o (n=178)	99o/o (n=198)
kerosene	7o/o (n=14)	1o/o (n=2)
propane	4o/o (n–8)	
Kitchen ventilation:		
good	71o/o (n=142)	30o/o (n=60)
poor	29o/o (n=58)	70o/o (n=140)

and size of openings (doors and windows); the presence or absence of chimneys and the interviewer's impression of air circulation in the kitchen. Based on this information the kitchens were classified as well– or poorly–ventilated.

After that information was gathered, a random sample of 180 houses was selected from the homes where wood fires were used for cooking and air samples were taken at different times during the day. The samples were taken at a point 1 meter away from the fire and at a height of 1 meter.

Room air was injected into 20 ml evacuated test tubes containing grains of barium hydroxide (Baralyme, Chemetron Corp., St. Louis, Mo., U.S.A.) to absorb CO_2 and anhydrous calcium sulfate (Drierite) to eliminate water vapor.

A finger prick blood sample of 0.5 ml was taken from 208 non-smoking women at the hour of greatest smoke exposure. Disodium EDTA at a concentration of 1 mg/ml was used as an anti-coagulant. The samples were kept in a portable ice chest at 4°C and then transported to the laboratory where they were analyzed 24 hours later.

The concentration of CO in the air was determined by means of gas-solid chromatography. The instrument used was a Varian Model 2732 equipped with helium detectors and stainless steel columns, 6' x 1/8" filled with molecular sieve 5A, 90/100 mesh. Analysis was performed at 110°C with a He flow of 25 ml/min. The detector temperature was 130°C. For injection of air samples, a gas sampling valve was used. As a standard, pure carbon monoxide at a concentration of 96.9 ppm in 99.999o/o helium was used.

The hemoglobin concentration was measured in the blood samples by means of a Royco Cell Crit apparatus (Royco Instrument, Inc., Menlo Park, Ca. 94025). Carboxyhemoglobin was determined spectrometrically using Amenta's technique (AMENTA 1963). A Varian Techtron Model 634 spectrophotometer was used.

RESULTS

The majority of women in these communities use wood fires for cooking (Table 1). Ventilation in the kitchens was classified as good in 71o/o of the houses in the town at the lower altitude which also showed a higher mean enviromental temperature. In the high altitude village the mean temperature was lower and only 30o/o of the kitchens were classified as well-ventilated (Table 1).

Cooking schedules in the 2 towns were similar, with peaks at 7:00, 12:00 and 18:00 hours (Figure 1A). Sixty per cent of the women from the low altitude town spent less than 3 hours a day in the kitchen, while the same percentage of women in the high altitude community dedicated from 3 to 4 hours daily to kitchen activities. Figure 1B shows the environmental CO values found during the day in well– or poorly–ventilated kitchens in the two towns. In both villages, a greater CO concentration was noted in the poorly-ventilated kitchens when compared to the well–ventilated ones. A two-way analysis of variance of the data showed the effect of ventilation on CO concentration to be significant at the time of the day of maximum cooking frequency, i.e., 6:00 – 8:00 hours ($F = 5.83$, $p < 0.05$); 10:00 – 13:00 hours ($F = 16.58$, $p < 0.001$); and 16:00 – 19:00 hours ($F = 15.52$, $p < 0.001$). There was no significant difference between the villages studied.

The results obtained from the determination of blood HbCO concentration can be seen in Figure 2. On analyzing all age groups, it was observed that in both towns the inhabitants of houses with poorly-ventilated kitchens showed higher levels of HbCO. In the high altitude community greater HbCO values for people in both types of kitchen were seen. When all ages were grouped together, the two-way analysis of variance showed significant effects of ventilation ($F = 18.76$, $p < 0.001$) and type of town ($F = 6.96$, $p < 0.05$). When women were classified by age groups, the greatest effect of environmental pollution was observed for women between 21 and 49. The effects were highly significant for kitchen type ($F = 22.7$, $p < 0.00001$) and for village ($F = 19.5$, $p < 0.0001$). The women in the age range 13-20 years showed a significant effect due to kitchen type ($F = 6.21$, $p < 0.05$) but no influence by town type ($F = 0.32$, $p < 0.05$). In the age groups above 50 years, neither kitchen type nor town showed any significant effect (Figure 2).

The blood Hb levels of the women who were studied are shown in Table 2 . When all ages were grouped together, a highly significant town effect was observed ($F = 59.92$, $p < 0.00001$) as well as a lesser effect due to kitchen type ($F = 10.13$, $p < 0.05$). The town effect can of course be explained by the differences in altitude. When the data were analyzed by age groups as shown in Table 2, there was no ventilation effect on the 21-49 year group. All other effects were significant.

DISCUSSION

In the poor, rural Guatemalan villages which were studied, the use of wood fires for cooking was almost ubiquitous. This, as well as the lack of chimneys, accounts for the high level of smoke exposure to which these populations are subjected. The same exposure pattern can be observed throughout the entire rural area of Guatemala and it can be estimated that between 620,000 and 650,000 house-

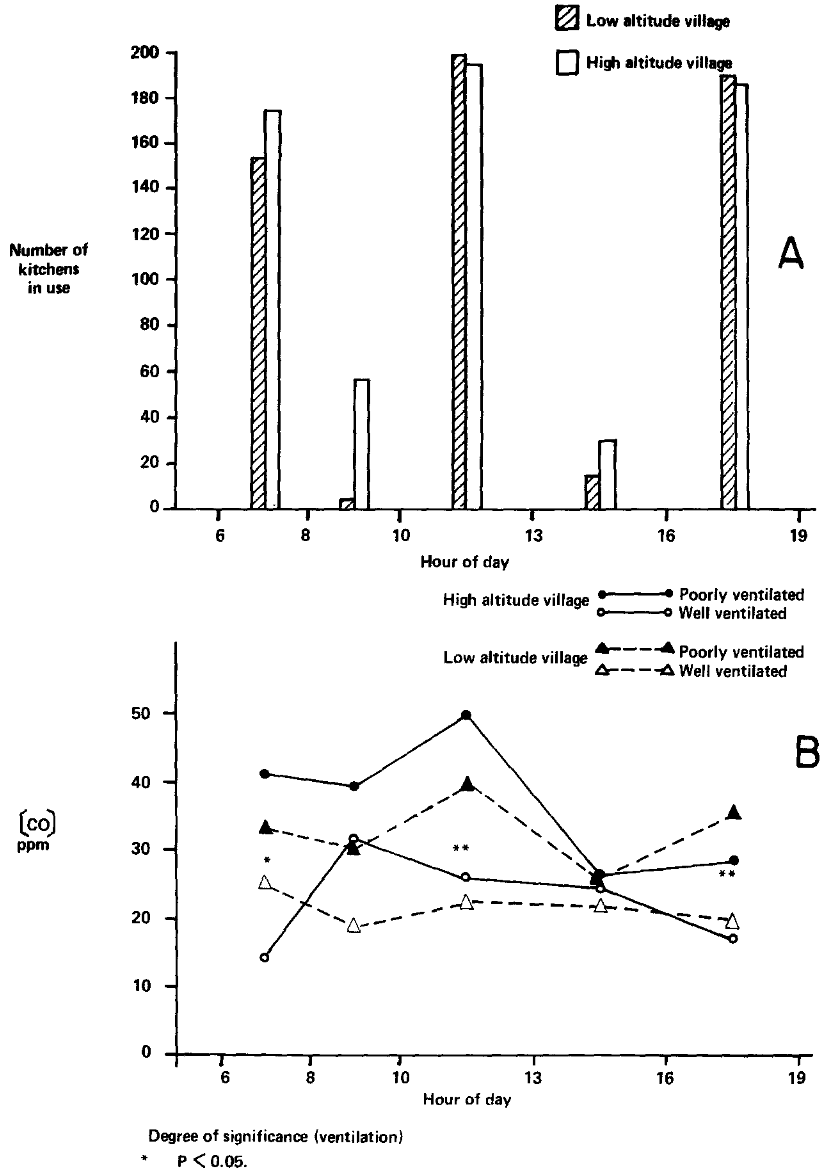

Figure 1. The times in the day of peak kitchen use were from 6:00–8:00, 10:00–13:00 and 16:00–19:00 hours. (Figure 1A).
In the lower half (B) it can be observed that the peak cooking times are significantly related to high CO concentration in the poorly-ventilated kitchens. Village type did not affect CO concentration levels.

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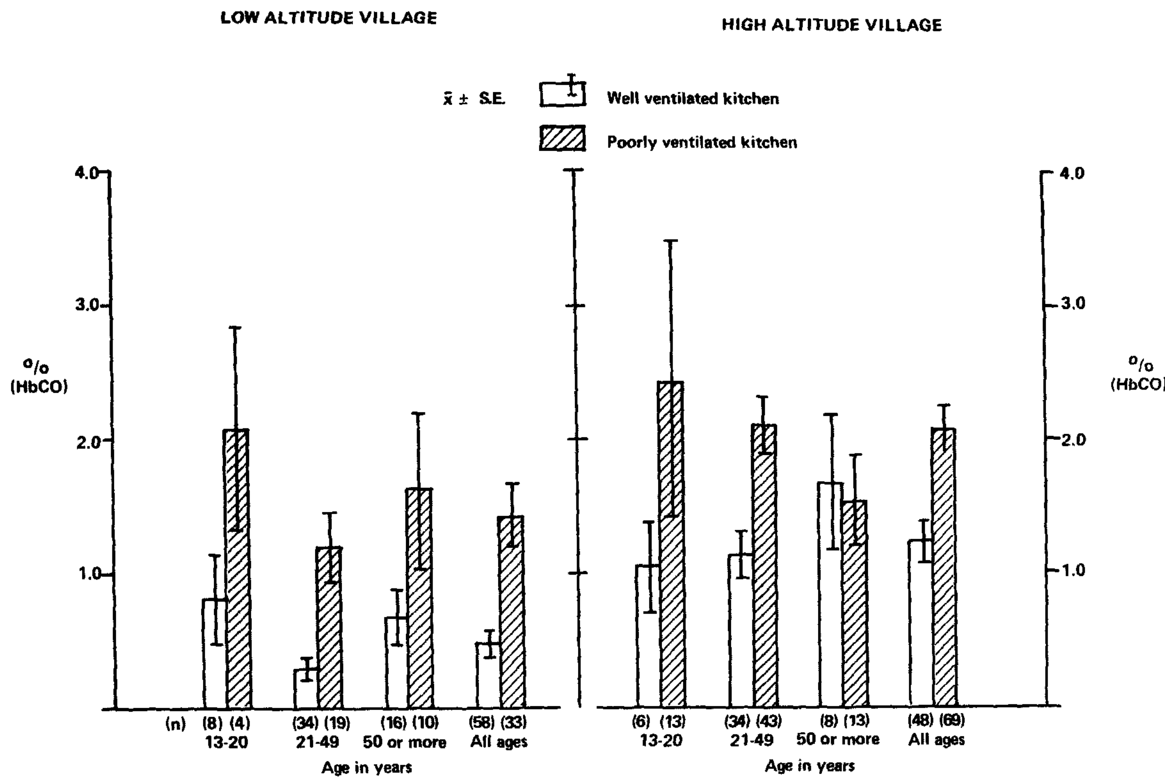

Figure 2. Blood HbCO concentrations were significantly greater in those women using poorly–ventilated kitchens and in the high altitude village. These effects were not significant in the "50 or more" age group.

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TABLE 2

Effect of CO environmental pollution on hemoglobin levels of women in two different altitude towns.

(Hemoglobin, g/dl)

Age (years)	Low altitude village				High altitude village				Ventilation effect		Town effect	
	Well-ventilated kitchen		Poorly-ventilated kitchen		Well-ventilated kitchen		Poorly-ventilated kitcken					
	n	$\bar{x}$ ± S.E.	n	$\bar{x}$ ± S.E.	n	$\bar{x}$ ± S.E.	n	$\bar{x}$ ± S.E.				
13 – 20	8	11.9 ± 0.83	4	11.0 ± 0.59	6	13.4 ± 0.50	13	12.4 ± 1.41	$F=5.07$	$p < 0.05$	$F=12.03$	$p < 0.05$
21 – 49	34	11.9 ± 0.89	19	12.0 ± 0.75	34	12.6 ± 1.02	43	12.7 ± 1.24	$F=0.22$	N. S.	$F=15.08$	$p < 0.0005$
50 or more	16	11.9 ± 0.75	10	10.5 ± 1.71	8	13.7 ± 1.35	13	13.2 ± 1.25	$F=6.77$	$p < 0.05$	$F=36.37$	$p < 0.00001$
TOTAL	58	11.9 ± 0.83	33	11.4 ± 1.28	48	12.9 ± 1.11	69	12.7 ± 1.28	$F=10.13$	$p < 0.05$	$F=59.92$	$p < 0.00001$

holds in the country are subjected to similar levels of exposure. This implies that about 1.5 million Guatemalan women of reproductive age are living in the conditions described above and are subjected to high levels of CO contamination.

The contamination level in poorly-ventilated kitchens oscillates between 30 and 50 ppm at cooking times. In several countries the maximum safe levels of exposure to CO for periods up to one hour have been established as being between 32 and 40 ppm (GRUT et al. 1970, LONGO 1977 , WRIGHT et al. 1975). Thus, the populations described here are exposed to dangerous CO levels during the greater part of the day. Carboxyhemoglobin levels resulting from this exposure fluctuate between 1.5 and 2.5%. Levels of this magnitude have been associated with an increased incidence of cardiac disease (STEWART et al. 1970). Based on data accumulated from studies of cigarette smoking and pregnancy it can be speculated that chronic CO exposure in these communities may be a contributing factor in fetal underdevelopment. Furthermore, since it is customary for women in these communities to carry their newborn constantly on their backs, the small baby becomes yet another victim of continuous, direct contact with high CO levels. This may have serious repercussions on the health and well-being of the child, especially in terms of respiratory and eye diseases.

The greater HbCO concentrations found in women living at higher altitudes may be explained by an increased endogenous production of CO and a higher relative P_{CO} under the conditions described.

From the present study it can be seen that even in isolated rural Guatemalan communities, supposedly free of environmental pollution and where cigarette smoking is minimal, the danger of over-exposure to toxic levels of CO is high due to the particular cooking and living habits of their inhabitants. Simple low-cost measures (chimneys, improved ventilation, etc.), if implemented by public health authorities, could greatly reduce the dangers to which these poor, rural populations are exposed.

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