industry and when gasoline- or propane-powered forklifts, chain-saws, or other machines are used in confined spaces, such as companies, tunnels, and mines. Low concentrations are produced in the atmosphere by the reactions of hydroxyl radicals with methane and other hydrocarbons as well as by the reactions of alkenes with ozone.

In addition to exogenous sources, humans are also exposed to small amounts of CO produced endogenously. In the process of natural degradation of hemoglobin to bile pigments, oxidation of the tetrapyrrol ring of heme leads to opening of the ring and formation of biliverdin and CO (WHO 1999a). The endogenous CO formation leads to a background COHb concentration in blood of about 0.5-0.8% (NIOSH 1972).

Increased destruction of red blood cells—for example, caused by hematomas, blood transfusion, or intravascular hemolysis—and accelerated breakdown of other heme proteins will lead to increased production of CO. In patients with hemolytic anemia, the CO production rate was 2-8 times higher and blood COHb was 2-3 times higher than in healthy individuals (Coburn et al. 1966).

Smokers are exposed to considerable CO concentrations leading to an average COHb of 4%, with a usual range of 3-8% (Radford and Drizd 1982).

Exposure to CO can also be caused indirectly by exposure to certain halomethanes, particularly dichloromethane (synonym, methylene chloride) because these solvents are at least partly metabolized oxidatively to CO by cytochrome P-450 (Gargas et al. 1986; see ATSDR 2000 for review).

Environmental exposure to CO can occur while traveling in motor vehicles, working, visiting urban locations associated with combustion sources, or cooking and heating with domestic gas, charcoal or wood fires, as well as by environmental tobacco smoke. WHO (1999a) summarized environmental concentrations as follows: CO concentrations in ambient air monitored from fixed-site stations are generally below 9 ppm (8 h average). However, short-term peak concentrations up to 50 ppm are reported on heavily traveled roads. The CO levels in homes are usually lower than 9 ppm; however, the peak value in homes could be up to 18 ppm with gas stoves, 30 ppm with wood combustion, and 7 ppm with kerosene heaters. The CO concentrations inside motor vehicles are generally 9-25 ppm and occasionally over 35 ppm. Similar exposure levels were reported by EPA (2000). The chemical and physical properties of CO are presented in Table 2-2.

2. HUMAN TOXICITY DATA

On the basis of older literature, the COHb in the blood has been correlated with symptoms in healthy adults, shown in the left half of Table 2-3 (WHO 1999a). Very similar tables or descriptions are found in different publications (e.g., Stewart 1975; Winter and Miller 1976; Holmes 1985; Roos 1994; AIHA 1999). However, with respect to both lethal and nonlethal effects of CO, suscep-