6. POTENTIAL FOR HUMAN EXPOSURE

A large number of workers are potentially exposed to styrene. NIOSH estimates that approximately 300,000 workers at 22,000 facilities may be exposed to styrene (NIOSH 1990); about 30,000 of these on a full-time basis (NIOSH 1983) and about 86,000 are females. The highest potential exposure occurs in the reinforced-plastics industry, where workers may be exposed to high air concentrations and also have dermal exposure to liquid styrene or resins (Dalton et al. 2007; Fustinoni et al. 2008; Lemasters et al. 1985; NIOSH 1983; Rihs et al. 2008; Sato et al. 2009; Triebig et al. 2008; Van Rooij et al. 2008).

Hemminki and Vianio (1984) estimated that heavily exposed workers in this industry in Finland might be exposed to up to 3 g of styrene per day. Van Rooij et al. (2008) estimated that styrene levels ranged from 30 to 222 mg/m³ in the breathing zone of European open-mold process workers in 2003. Table 6-4 lists levels of styrene measured in the blood, urine, and surrounding air of reinforced plastic workers. Urinary levels of styrene metabolites are also included. Significant occupational exposures may also occur in other industrial settings, including styrene polymerization, rubber manufacturing, and styrene-polyester resin facilities (Engstrom et al. 1978b; NIOSH 1983; Rappaport and Fraser 1977) as well as in photocopy centers or facilities (Leovic et al. 1996, 1998; Stefaniak et al. 2000). Fustinoni et al. (2008) found that concentrations of styrene and its metabolites measured in the urine of 13 varnish workers were comparable to those measured in fiberglass reinforced plastic workers.

6.6 EXPOSURES OF CHILDREN

This section focuses on exposures from conception to maturity at 18 years in humans. Differences from adults in susceptibility to hazardous substances are discussed in Section 3.7, Children’s Susceptibility.

**Children are not small adults.** A child’s exposure may differ from an adult’s exposure in many ways. Children drink more fluids, eat more food, breathe more air per kilogram of body weight, and have a larger skin surface in proportion to their body volume. A child’s diet often differs from that of adults. The developing human’s source of nutrition changes with age: from placental nourishment to breast milk or formula to the diet of older children who eat more of certain types of foods than adults. A child’s behavior and lifestyle also influence exposure. Children crawl on the floor, put things in their mouths, sometimes eat inappropriate things (such as dirt or paint chips), and spend more time outdoors. Children also are closer to the ground, and they do not use the judgment of adults to avoid hazards (NRC 1993).

Children can be exposed to styrene at home by inhalation of contaminated air and by food consumption. Inhalation-based exposures may occur in both urban and rural home environments, both of which may be contaminated by vehicular and industrial emissions. In addition, exposure to tobacco smoke may provide
another route of styrene exposure, especially in homes where one or both parents, any siblings, or other relatives smoke. Children may be also be exposed to higher levels of styrene indoors at home during painting of indoor rooms, especially during winter months (such as over winter school vacations) when the child stays indoors more and during which time, windows may not be opened.

From a food-based exposure perspective, infants may be exposed to styrene from consuming food items such as those listed in Table 6-3. In addition, it is possible that exposure may also result from consumption of infant formula or from nursing practices. In the 5-year FDA study on volatile organic compounds in foods (Fleming-Jones and Smith 2003), soy- and milk-based infant formula was included in the study; however, the results for styrene were not reported. Baby foods and infant formula are often stored in polystyrene containers and the migration of low levels of non polymerized styrene into food items from polystyrene containers has been demonstrated (EPA 1985a; Tang et al. 2000). In a study on chemicals in mother’s milk, styrene was identified, but not quantified, in 8 out of 12 samples of mother’s milk samples collected from mothers living in four U.S. urban areas (Pellizzari et al. 1982). Duffy and Gibney (2007) estimated the styrene exposure of Irish children between the ages of 5 and 12 years as a result of the migration of styrene from food packaging. The calculated mean styrene intake was 0.122 µg/kg body weight-day when using 90th percentile migration values and 0.169 µg/kg when using maximum migration values. The authors note that these values are well below the provisional maximum tolerable daily intake of 40 µg/kg body weight-day established by the Joint FAO/WHO Expert Committee on Food Additives. Although children are exposed to styrene from the oral routes mentioned above, it has been estimated that >90% of human exposure to styrene arises due to inhalation routes (Fleming-Jones and Smith 2003; Tang et al. 2000).

Aside from food-related intake, children’s exposure to styrene may differ from exposures to adults, especially during school, home, or play activities that may expose the children to styrene sources. For example, for elementary aged children (grades 2, 3, 4, and 5) attending inner city schools in Minneapolis, it was found that the lowest exposure to styrene occurred either outdoors or in school, and the highest exposure occurred at home. The latter can be substantially influenced (increased) if smoking occurs in the home. Exposures to styrene while outside, in either winter or spring, were very low (winter: 0.0 µg/m³; spring: 0.1 µg/m³), whereas exposures were much higher at school (winter: 31.3 µg/m³; spring: 39.7 µg/m³), but were almost three times higher at home (winter: 91.9 µg/m³; spring: 91.9 µg/m³) (Adgate et al. 2004). These exposures led to blood level concentrations of styrene that were generally twice as high as the general population (Sexton et al. 2005).