11. Exposure Duration

11.1 Introduction

Currently an assumption of lifetime exposure duration (70 years) for the calculation of cancer risk is incorporated into the cancer unit risk factor and oral cancer potency factors. Thus, when risk is calculated by multiplying modeled or measured concentrations in air by the unit risk factor, the risk is generally considered a "lifetime" risk. A cancer risk of 5×10^{-5} means that in a population exposed for 70 years, 50 people per million exposed would theoretically develop cancer over that 70-year period.

The point estimate risk assessment approach (Tier 1 and 2) can be used with more than one estimate of chronic exposure duration to give multiple point estimates of cancer risk. For stochastic risk assessment (Tier 3 and 4), there are two possible approaches to incorporating duration of exposure. The first would express the variability in exposure duration as a distribution of residency times and equate residency time to exposure duration. The variance in residency times would be propagated through the model and contribute to the variance in the cancer risk. The second approach would be to calculate separate cancer risk distributions for each fixed chronic exposure duration.

In site-specific risk assessment, the risk manager wants an estimate of risk from a specific facility. Estimates of lifetime risk are often criticized as overly protective since most individuals will not be exposed to that facility's emissions for 70 years; there is interest in assessing risks from shorter durations of exposure. In order to accommodate adjustment for less-than-70 year exposure scenarios, the lifetime average daily dose is calculated and used to represent the daily dose over 70 years.

11.2 Dose Algorithm and Duration of Exposure

The following equation for inhalation dose can accommodate different exposure durations:

$$DOSE = (Cair \times BR \times ED \times EF \times 1 \times 10^{-6}) / [AT]$$

Where:

DOSE =	Inhalation dose [(mg/kg body weight)/day]
Cair =	Average annual air concentration of contaminant ($\mu g/m^3$)
BR =	Average daily breathing rate (L/day*kg body weight)
EF =	Exposure frequency, days/year
ED =	Exposure duration, in years
1×10^{-6} =	Conversion factor ($\mu g/m^3$) to (mg/L)
AT =	Averaging time (period over which exposure is averaged, in years); for carcinogenic effects the averaging time is 70 years = 25,500 days

Adjustment for exposure less than 365 days/year (e.g., 350 out of 365 days a year or worker exposures of eight hours per day, 5 d/week) can be factored into the equation using the EF term.

11.3 Available Studies for Evaluating Residency Time

Israeli and Nelson (1992) used information from the American Housing Survey (AHS) for the United States for 1985 and 1987 (Bureau of the Census, 1987; 1989) to develop a distribution of average total residence time for all U.S. residents. Finley et al. (1994) calculated more of the percentiles for the data presented by Israeli and Nelson (1992). The mean of the distribution presented by Israeli and Nelson (1992) is 4.6 years. In addition distributions are presented for subpopulations such as renters and owners, and for regions of the country. The study clearly shows that home owners have a much greater average residency time than renters and therefore may be a more at risk population from exposure to emissions of a nearby facility. The average residency time for the Western region was lower than for the entire U.S. population. The authors note that with the methodology they used, there could be repeated sampling or over-sampling of a population of frequent movers. This methodology would also tend to overemphasize the more frequent short duration residency periods that have been found to occur from approximately age twenty to thirty by the Bureau of Census (1988). The Israeli and Nelson (1992) study has information on various categories such as renters, home owners, farm, urban and rural populations, and large geographic regions such as the West. However, no attempt was made in this study to examine the effect of socio-economic status. Many facilities in the Air Toxics “Hot Spots” program are located in areas surrounded by low socioeconomic status populations. OEHHA staff did not consider the Israeli and Nelson (1992) study to be appropriate for determining an appropriate residency time to use in less-than-lifetime exposure scenarios in the Air Toxics “Hot Spots” program.

Johnson and Capel (1992) used a Monte Carlo approach for determining residency occupancy periods. Their methodology can incorporate population information about location, gender, age, and race to develop a mobility table based on US Census data. The mobility table contains the probability that a person with the demographic characteristics considered would not move. A mortality table is also used which determines the probability that a person with the demographic characteristics considered would die. Some of the results from this study are presented in Table 11.1. Although the published methodology can be used to determine mobility for different income groups, the published tables are for the entire U.S. population. Also, as is pointed out in the study, the Monte Carlo methodology employed in the study uses the same probability of moving for persons who have resided in their current residence for extended periods as for those who have recently moved in. The data collected by the U.S. Census does not indicate where the individuals queried move to other than broad descriptions such as “in county”, “out of county”, “within metropolitan area”, and so forth. This problem is common to all of the studies discussed. As a result, it is difficult to define residence time within a zone of impact for those who do not move very far (e.g., within the same apartment complex, neighborhood, or town). The conclusions of this study are similar to the results that the U.S. EPA (1997) reached using the AHS study (Bureau of the Census, 1993) (Table 11.1).

The U.S. EPA (1997) has reviewed the studies presented above. In addition, the U.S. EPA (1997) reviewed the results of the 1991 AHS (Bureau of the Census, 1993). The U.S. Bureau of the Census (1993) conducted a survey using 55,000 interviews which covered home owners and renters. Black, white and Hispanic ethnic groups were represented in this study. The U.S. EPA used the information available in this study to determine a distribution of the percent of households who have lived at their current address for several ranges of years. The median and 90th percentiles of this distribution are 9.1 and 32.7 years, respectively. The methodology used to derive the distribution was not specified in the report (U.S. EPA, 1995). Based on the studies by Israeli and Nelson (1992), Johnson and Capel (1992), and their analysis of the U.S. Bureau of the Census (1993), U.S. EPA recommends a central tendency estimate of 9 years, and a high-end estimate of 30 years for residency time.

Table 11.1 Summary of Studies of United States Residency Times

Israeli and Nelson (1992)	1.4, 23.1 (50th and 95th %tile)
Johnson and Capel (1992)	2.0, 9.0, 33 (5th, 50th and 95th %tile)
U.S. EPA (1997); evaluation of BOC (1993) data	9.1, 32.7 (50th, 90th %tile)

Table 11.2 Summary of Regulatory Recommendations for Residency Times

Reference	***Recommendation***
CAPCOA, 1993	70 years (point estimate)
U.S. EPA, 1997	9 years for central tendency; 30 years for high-end
U.S. EPA, 1989	9 years for average, 30 years for high-end

11.4 Discussion

Exposure duration is a variate in the Air Toxics "Hot Spots" program stochastic risk assessment guidelines for which consideration of the purposes that the information will be used is important. Public notification provisions of the Air Toxics "Hot Spots" program require that a facility notify the surrounding community if the risks from exposure to emissions is deemed significant by the district. Thus, one of the important uses for the risk assessment information is for public notification. The individual or household that receives a notification letter has little uncertainty as to the length of time that they have lived at their current address. If a range of risks is calculated for fixed lengths of residency, an individual would have a better idea of what his or her individual range of risks might be as they could compare the 9-, 30-, and 70-year risks with the length of time they have resided at their residence.

The other important user of the risk assessment information is the risk manager. The risk manager may wish to compare a range of risks for fixed reference periods of time when prioritizing or comparing facilities.

11.4.1 Problems with Less-than-Lifetime Risk Estimates

An assumption which appears to be implicit in the use of less than a lifetime exposure duration is that, when people move away from the source of exposure, they escape risk. This assumption may be erroneous for several reasons. In some cases they may be moving to another location within the zone of impact of the facility being evaluated. The person may also be moving out of the zone of impact of one facility and into the zone of impact of another facility. The U.S. Census data do not provide adequate information to determine whether a surveyed individual has moved next door or to another property removed from the zone of impact of a specific facility. The U.S. Census Bureau statistics on socioeconomic status and mobility show that homeowners in low income areas are likely to have less mobility than those with more resources (Bureau of the Census, 1993). Low income, inner city homeowners may constitute a sensitive subpopulation which has much longer residency times than predicted by Israeli and Nelson (1992), Johnson and Capel (1992), and U.S. EPA’s analysis of the Bureau of the Census data.

When the results of a cancer risk estimate based on a 70-year exposure duration is below a significant risk level, the risk manager can be assured that the facility does not likely pose cancer risks above the defined risk level to any individual residing in the zone of impact of the facility in question within the limits of present knowledge. Risk estimates based on exposure durations of 9 or 30 years do not provide the same level of assurance because they exclude those who reside in the zone of impact for longer periods of time.

Another aspect of cumulative risk is the additive risks from all facilities impacting a given area. At the present time, the risk assessment process itself does not address cumulative risk. Only considering short-term durations of exposure in evaluating risk would increase the impact of ignoring cumulative risks of simultaneous or sequential exposures to multiple facility emissions.

11.5 Recommendations

OEHHA is recommending that point estimate and stochastic risk estimates be conducted for 70-year exposure durations. This will ensure that a person residing in the vicinity of a facility for a lifetime will be included in the evaluation of risks posed by that facility. In addition, the assessor may want to present risk estimates for 9-year and 30-year exposure scenarios using the duration-appropriate point estimates and distributions recommended in the previous chapters. The 9-year scenario point estimates and distributions in the previous chapters reflect children’s exposures from age 0 to 9. The 9- and 30-year estimates are the figures that U.S. EPA (1989;

1997) has recommended for the central tendency and high-end estimates, respectively, of residency time. The U.S. EPA's estimates may not apply to all populations. However, the 9- and 30-year estimates appear to fall into a range of possible estimates that will provide useful information to the risk manager and the notified community.

11.6 References

Brown P (1995). Race, class, and environmental health: A review and systematization of the literature. Environ. Research 69:15-30.

Bureau of the Census (1988). U.S. Department of Commerce, Bureau of Census and U.S. Department of Housing and Urban Development, American Housing Survey for the United States 1985, Current Housing Reports (H-150-85, 28-29, 1988)

Bureau of the Census (1988). U.S. Department of Commerce, Bureau of the Census, 1980-1985. Mobility Patterns by Age.

Bureau of the Census (1989). U.S. Department of Commerce, Bureau of Census and U.S. Department of Housing and Urban Development, American Housing Survey for the United States 1987, Current Housing Reports (H-150-87, 52-53, 1989).

Bureau of the Census (1993). U.S. Department of Commerce, Bureau of Census and U.S. Department of Housing and Urban Development, American Housing Survey for the United States 1991, Current Housing Reports (H-150-93, 1993).

CAPCOA (1993). CAPCOA Air Toxics "Hot Spots" Program Revised 1992 Risk Assessment Guidelines, October 1993.

Cohen BL (1992). Percentage of lifetime spent in area of residence at time of death. Environ. Research. 57:208-211.

Clement (1988). Multi-pathway Health Risk Assessment Input Parameters Guidance Document. Prepared for: South Coast Air Quality Management District, Prepared by Clement Associates.

Finley B, Proctor D, Scott P, Harrington N, Paustenbach D, and Price P (1994). Recommended distributions for exposure factors frequently used in health risk assessment. Risk Analysis 14:533-553.

Israeli M, and Nelson C (1992). Distribution and expected time of residence of U.S. households. Risk Analysis 12:65-72.

Johnson T, and Capel JA (1992). Monte Carlo approach to simulating residential occupancy periods and its application to the general U.S. population. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality and Standards.

U.S. EPA (1989). U.S. Environmental Protection Agency. Risk Assessment Guidance for Superfund. Vol. 1. Human Health Evaluation Manual (Part A). Office of Solid Waste and Emergency Response. EPA/540/1-89/002. Washington, D.C., December 1989.

U.S. EPA (1997). Exposure Factors Handbook, August 1997. Volume III. Activity Factors. EPA/600/P-95/002Fc.