# *Exposure Factors Sourcebook for European Populations (with Focus on UK Data)*

Technical Report No. 79

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## EXECUTIVE SUMMARY

Risk assessment includes elements of exposure, hazard, and dose-response. The exposure component is calculated using variables that represent the concentration in a given media (i.e., soil, water, air, food) and human contact with the media. Exposure factors are the variables used to estimate the human contact portion of the exposure calculation. Exposure factors include variables related to human activities (e.g., time indoors vs. outdoors, weekly work hours) and physiological parameters (e.g., inhalation rates, body weight).

This document summarises available exposure factor data for use in risk-based decision making. It updates and builds upon other available compendia of exposure factor data - the AIHC Exposure Factors Sourcebook (EFS) and the USEPA Exposure Factors Handbook (EFH). Whereas the EFS and EFH have focused on US data, this document focuses on data specific to Europe, in particular the UK. The exposure factors selected for inclusion were those most relevant to risk-based decision making for contaminated land sites. The factors and data presented, however, are applicable to exposure assessment and risk-based decision making in general. The information summarized in this document includes:

- Physiological Parameters
  (Adult Body Weight, Child Body Weight, Total Skin Surface Area, Surface Area of Specific Body Parts, Life Expectancy);

- Time-Activity Patterns
  (Weekly Work Hours, Daily Hours at Home/Away, Time Indoors/Outdoors, Daily School Hours, School Time Indoors/Outdoors, Outdoor Recreation, Shower Duration, Employer Tenure, Residential Tenure, School Tenure);

- Receptor Contact Rates
  (Soil Ingestion Rates, Soil Adherence to Skin, Inhalation - Short-term Rate, Inhalation - Long-term Rate, Food Consumption Rates, Home Grown Vegetable and Fruit Consumption Rate, Fish and Shellfish Consumption Rate, Meat and Beef Consumption Rate, Drinking Water Consumption Rate, Breast Milk Consumption Rate).

Exposure scenarios can differ widely and therefore the averages and distributions presented in this document may not be the best representation for all possible exposure scenarios. Best judgement should be used in selecting the values most appropriate for a given scenario. A section on good exposure assessment practices is also included in the document. The cited references may also serve as useful sources of additional information on exposure factors and exposure assessment.

Data gaps have been identified and whilst this document includes data for European countries in general, its primary focus is the UK. Future expansion of additional data for other countries would be useful for improving the accuracy of exposure assessments for other European populations.

# INTRODUCTION

This document summarises available exposure factor data for use in risk-based decision making. It updates and builds upon other available compendia of exposure factor data - the AIHC Exposure Factors Sourcebook (EFS) (AIHC, 1994) and the USEPA Exposure Factors Handbook (EFH) (USEPA, 1997). Whereas the EFS and EFH have focused on US data, this document focuses on data specific to Europe, in particular the UK. The exposure factors selected for inclusion were those most relevant to risk-based decision making for contaminated land sites. The factors and data presented, however, are applicable to exposure assessment and risk-based decision making in general.

Risk-based decision making, or risk management, includes the identification of an acceptable level of risk and, if needed, the actions that should be taken to reduce an unacceptable level of risk from occurring (Jackson and Edulgee, 1996). One piece of the overall risk management process is risk assessment. Risk assessment is the evaluation of the level of risk associated with a selected exposure scenario. Risk assessment information is considered in the context of political, social and economic aspects of a selected exposure scenario to develop a risk management plan.

Risk assessment includes elements of both exposure, hazard and dose-response (Quint *et al*, 1996). The exposure component is calculated using variables that represent the concentration in given media (i.e., soil, water, air, food) and human contact with the media. Exposure factors are the variables used to estimate the human contact portion of the exposure calculation. These include variables related to human activities (e.g., time indoors vs. outdoors, weekly hours at work) and physiological parameters (e.g., inhalation rates, body weight, skin surface area). Exposure represents only the amount of material that a person comes into contact with. To estimate dose (i.e., the portion of contacted material that is actually absorbed into the body), absorption factors are needed. Absorption factors vary depending upon the route of exposure and the physical-chemical properties of the compound of interest. Exposure represents the greatest potential dose that could occur given 100% absorption.

This document focuses on the development of representative exposure factor data for populations of the UK and/or Europe. For each exposure factor, a description of available data is provided. Based upon these data, a point value representative of the central tendency (i.e., mean or median) is given[1]. Upper and lower values are also presented when available. Because individual variation within a population can be significant, data distributions are a better portrayal of population data than a single point value. For exposure factors with sufficient data, appropriate data distributions are also provided. The information provided in this document can be used to develop more realistic estimates of exposure than those calculated using single point values based upon extreme exposure scenarios. The resulting exposure estimates can form the basis for better informed risk management decisions.

[1] Central tendency may be estimated by either a mean or median, but should be clearly specified as either one (USEPA, 1992a). The arithmetic mean and median (midpoint, 50th percentile) are the same for normally distributed data, but differ for other types of distributions. For non-normal data, the arithmetic mean may not be a good indicator of the midpoint (median) of a distribution. When available, both median and mean values are reported for an exposure factor. In many cases, however, only mean data are available.

Individual behaviour affects exposure. Appropriate exposure factors will vary depending upon cultural and geographical factors. For example, children playing outdoors will have higher potential skin surface area exposures in hot climates than in cool climates. Time spent outdoors in recreation may be greater for sunny vs. rainy regions. Consumption of home-caught fish will vary depending upon proximity to fishing areas.

Exposure scenarios can also differ widely. The averages and distributions presented in this document may not be the best representation for all possible exposure scenarios. Best judgement should be used in selecting the values most appropriate for a given scenario. While the focus of this document is on exposure factors specific to the UK and Europe, all identified data are discussed and cited. Cited references, in particular the EFH and EFS, are useful sources of additional information on exposure factors and exposure assessment.

The information presented in this document can be applied across sites to develop representative estimates of exposure to various environmental media. This information can be used in conjunction with site and media specific concentration data to estimate exposure levels for a compound of interest.

This document does not address concentration data for various environmental media nor the hazard or dose-response components of risk assessment. The political, economic, and social aspects of risk-based decision making are also not considered. Sources that can be consulted for further information on risk assessment and risk-based decision making include:

- European oil industry guideline for risk-based assessment of contaminated sites (CONCAWE, 1997);
- Environmental impact of chemicals: assessment and control (Quint *et al*, 1996);
- Risk assessment for contaminated sites in Europe (CARACAS, 1998);
- Guidelines on risk assessment of contaminated sites (Vik *et al*, 1999);
- Assessment factors in human health risk assessment (ECETOC, 1995);
- Risk assessment guidance for Superfund, Volume 1: Human health evaluation manual, Part A (USEPA, 1989);
- Standard provisional guide for risk-based corrective action (ASTM, 1998);
- Standard guide for risk-based corrective action applied at petroleum release sites (ASTM, 1995);
- Draft risk assessment guidance for Superfund, Volume 3, Part A: Process for conducting probabilistic risk assessment (USEPA, 2000 in draft).

## 1. PROBABILITY DISTRIBUTIONS

Values observed for a given exposure factor can vary widely within a population. The range, variability, and uncertainty associated with a given exposure factor is thus better represented by a distribution than a single point value. By using distributions for exposure factors, exposure distributions can be developed rather than single point estimates. Exposure distributions provide a more realistic estimate of population exposure than can be obtained from a single point estimate. Probabilistic exposure assessments use probability distributions to characterize variability or uncertainty, whereas deterministic exposure assessments are based upon point estimates of input variables.

The probability distributions presented in this document were either: 1) identifed from the scientific literature or 2) developed from available data. Distributions were developed using Crystal Ball®, an Excel™ add-in[2]. Distributions are described by statistical terms that indicate the distribution shape. Typical shapes include lognormal, normal, cumulative and uniform. The following parameters are used in describing distributions:

| | |
|---|---|
| Lognormal: | lognormal (arithmetic mean, standard deviation) |
| Normal: | normal (arithmetic mean, standard deviation) |
| Cumulative: | a list of discrete values or ranges and the probability associated with each value or range |
| Uniform: | uniform (minimum, maximum) |

The statistical tool of Monte Carlo analysis is the most widely used method to develop probabilistic estimates of exposure (USEPA, 1992a). In Monte Carlo analysis, probability density functions, such as the type described above, are specified for exposure parameters. Values from these distributions are then randomly selected and inserted into the exposure equation. Distributions generated by Monte Carlo analysis for this document were based upon simulations of 1,000 trials.

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2 A statistical software package that can be used to estimate best-fit distributions for data sets, or to perform Monte Carlo simulation of specified distributions.

## 2. GOOD EXPOSURE ASSESSMENT PRACTICES

Exposure assessment can be performed directly, by measuring exposure, or indirectly, by estimating exposure based upon models or other algorithms. In order to be applied appropriately, exposure assessment results must be 1) reproducible and 2) performed at a sufficient level of accuracy and certainty to support their end-use. Documentation and transparency are essential in all cases; their importance is critical when the results are applied by a third party.

Guidance on good exposure assessment practices is available (Burmaster and Anderson, 1994; Hawkins *et al*, 1992; AIHC, 1994; USEPA, 1992a). A summary of this guidance is provided below. The implementation of guidance will depend upon the nature of the intended use of the exposure estimate. For example, screening level assessments may be based upon conservative assumptions that will result in exposure estimates greater than actual values. If this conservative estimate indicates that exposure is much lower than any level of concern, a detailed quantification of the certainty or accuracy of the assessment may not be warranted. In cases where a need for further information is indicated, however, direction of additional resources may be needed to refine the assessment and quantify better certainty and accuracy.

Hawkins *et al* (1992) proposed eight good exposure assessment practices (GEAP). These practices address elements of study protocol; organisation, personnel, and resources; study model(s); study design; quality assurance; overall uncertainty; archiving; and communication and confidentiality of results. The guidelines assist in ensuring that the conclusions of an assessment are scientifically supported by the methods and data used in the process lie within known and stated bounds of uncertainty.

1. A protocol should be written before the assessment is conducted, clearly defining the purpose, variables to be evaluated, level of detail needed, how uncertainty will be addressed, and how uncertainty may relate to the conclusions of the assessment. It should also describe adequately each of the next seven GEAP.

2. The upfront commitment of organisation, personnel and resources should be adequate to perform successfully the assessment as described in the protocol. This includes technical qualifications and experience of staff, dedication of funds and facilities, and pre-assessment commitment of outside resources. The sponsoring agency should commit to the protocol and draw only those conclusions supported by the study methods and data.

3. Study model(s) that will be used in the assessment should be identified. For each model, information should be provided on its basis (i.e., deterministic, empirical, or statistical), which parameters are measured, which parameters are assumed, and how uncertainty in parameters and the model itself will be evaluated and treated. Information on model validation and its underlying assumptions should also be included.

4. Study design should be stated clearly and demonstrated to be adequate to yield results sufficient for the purpose of the assessment (i.e., that will be adequate to support the possible conclusions to be drawn at the stated levels of confidence and power). Study design includes sampling statistics, data collection methods, analytical methods, and data analysis procedures.

5. Quality assurance procedures must be defined and their implementation documented to ensure that acceptable data quality is maintained in all aspects of data gathering and use, including sampling, transport, analysis, compilation, recording and storage. Quality audits should be performed periodically by an individual who is not part of the study team.

6. A statement of overall uncertainty, combining uncertainty related to sampling variability calculated from the data and nonsampling errors related to model and parameter assumptions, should be provided along with results. The statement should include random variability and bias. The statement should be presented at least as a range between specified percentiles.

7. The protocol, all of the raw data, and other assessment documents should be archived for a specified period.

8. Practices suggested for communication and confidentiality of results include: a) reporting results of personal exposure measurements to the individual on whom the data were collected; b) reporting less-direct exposure measurements to an exposed person if the data are substantially relevant to that person's exposure; and c) maintaining the confidentiality of the identity of study participants.

These eight GEAP apply to exposure assessment in general. As previously discussed, probabilistic exposure estimates can be more informative than deterministic estimates, providing additional information on the expected variability of exposure for the population of interest. The most common technique for performing probabilistic estimation is Monte Carlo Analysis (MCA). Principles have been developed specific to the use of Monte Carlo techniques in human health and ecological risk assessment that can be applied to probabilistic exposure assessment in general (Burmaster and Anderson, 1994). As for the eight GEAP, the MCA principles are meant to provide general guidance to be used as appropriate by the assessor. The fourteen principles of good practices for MCA proposed by Burmaster and Anderson (1994) are summarised below. Application of all principles may not be needed in all cases (for example, for simple assessments application of all principles would not be of value). Detailed guidance on Monte Carlo analysis is provided in Guiding Principles for Monte Carlo Analysis (USEPA, 1997).

1. Show all formulae used to estimate variables in the assessment.

2. Calculate and present point estimates generated using the appropriate deterministic approach before initiating the probabilistic approach.

3. Perform sensitivity analyses on the input variables used in the deterministic calculation. Based upon the results of these analyses, identify the input variables suitable for probabilistic treatment. Discuss any variables not included in the sensitivity analyses.

4. Apply probability techniques only to the pathways and compounds of importance to the assessment. For example, if the initial deterministic assessment indicates that one pathway does not contribute significantly to total exposure, the additional effort of a probabilistic assessment is likely not needed for that pathway.

5. Provide detailed information on the input distributions used in the assessment, including at a minimum: a) graph of the full distribution with the location of the point values use in the deterministic assessment; b) summary statistics including the mean, standard deviation, minimum, 5th percentile, median, 95th percentile and maximum. Justification of the selection of the distribution should also be provided. For parametric distributions, address the influence of the statistical process and the physical, chemical, or biological mechanism creating the random variable on the choice of the distribution.

6. Show how the input distributions capture and represent both the variability and uncertainty in the input variables. Variability denotes true heterogeneity in a well-characterised phenomenon which typically can not be reduced through further measurement (for example, body weight will vary within a population; even if measurements are available for every individual of a population, some level of variability would be expected). Uncertainty denotes lack of knowledge about a poorly characterised phenomenon which may be reducible through further data collection (for example, additional data are needed to better characterise soil ingestion).

7. When possible, use measured data, relevant and representative to the population, place and time in the study, to inform the choice of input distributions. Undertake collection of data as appropriate for driving variables. If measured data are not available, document the use of accepted techniques for estimating distributions for nonmeasured variables.

8. For input variables that were fit quantitatively to measured data, discuss the methods and document the goodness-of-fit statistics. Show plots comparing the parametric fits and data. Discuss any qualitative techniques used to generate distributions.

9. Discuss the presence or absence of moderate or strong (approximately $|\rho| \geq 0.6$) correlations between or among the input variables. If $|\rho| \leq 0.6$, moderate to strong correlations will have little effect on the central portions of output distributions, but may have larger effects on the tails. In some cases, it may be possible that moderate to strong correlations exist but can not be estimated from available data. In this case, to determine if possible correlations are of importance to the analysis, perform probabilistic simulations with the correlations a) set to zero and b) set to a high but plausible value. Along with the results of these correlation sensitivity analyses, discuss how including or ignoring the correlations may affect the assessment results.

10. At a minimum, for each output distribution provide: a) a graph of the variable that includes identification of an allowable criteria, b) the point estimate calculated by the deterministic method, c) a summary statistical table including the mean, standard deviation, minimum, 5th percentile, median, 95th percentile, and maximum.

11. Perform probabilistic sensitivity analyses for all of the key inputs represented by a distribution in the probabilistic assessment in a manner that allows distinction between the effects of variability and the effects of uncertainty in the inputs. Display these results in a graph. Examples of computational and graphical techniques are provided in Ibrekk and Morgan (1983), Burmaster and von Stackelberg (1991), and Hoffman (1993).

12. Investigate the numerical stability of the central moments and tails of the output distribution of the simulation.

13. Provide the name and statistical quality of the random number generator used.

14. Discuss the limits of the methods used and the interpretation of results. Address any possible unresolved sources of bias not included in the analysis. Indicate where additional data could improve the analysis.

# 3. RECEPTOR PHYSIOLOGICAL PARAMETERS

## *3.1 Adult Body Weight*

***Summary***
Data from the 1996 Health Survey for England (HSE) indicate that mean body weight of English adults (≥ 16 years old) is 73 kg. Gender specific mean values for adults are 80 kg for males and 67 kg for females. Median, 5th, and 95th percentile values are 79, 60, and 104, respectively, for males and 65, 49, and 92 for females. Age and gender specific distributions can be approximated using the percentiles in Table 1 or as lognormal distributions with parameters defined in Table 6. Estimates of mean adult (>20 years old) body weight for other European countries are provided in Table 2. Note that the age class represented by "adults" varies between studies.

***Relevant Studies***
Body weight data are available from recent surveys designed to be representative of the population of England or Great Britain. These include the National Diet and Nutrition Survey (NDNS) (Gregory *et al*, 1990, 1995) and the Health Survey for England (HSE) (Prescott-Clarke and Primatesta, 1998a). The data set from the Health Survey for England is based upon a larger sample size and is more robust. Body weight data from the 1996 HSE are reported by gender and age in Table 1. The 1996 HSE data are based upon a large sample size (~15,000 persons aged 16 or older) and are representative of the current English population.

Table 1 data for the 16-24 year age category are similar to combined data from the 1995-1997 HSEs for the same age category (Prescott-Clarke and Primatesta, 1998b). The 1996 HSE data are reported here, rather than the combined data, for consistency with the data for age groups older than 24 years.

The mean body weight for English adults aged 16 and older was 73.2 kg. This value is consistent with both the mean adult body weight of 71.8 kg reported from the US 1976-1980 National Health and Nutrition Examination Survey II (NHANES II) and the commonly used default of 70 kg per adult (USEPA, 1997). This value is 7 kg greater than the 66 kg value used for adults in ECETOC (1994) and for "reference man" by the International Commission on Radiological Protection (ICRP) (Snyder *et al*, 1975). The basis of the 66 kg value is an older data set (pre-1960) of a subset of the US population (Snyder *et al*, 1975). The more recent English and US data are more representative of current conditions and the general populations of these respective countries. A default value sometimes used for lifetime average body weight is 58 kg (McKone and Daniels, 1991). This value is based upon the 66 kg value for adult body weight (assumes a lifetime of 70 years, with an average child body weight of 27 kg for 15 years and an average adult body weight of 66 kg for 55 years).

Country specific estimates of adult (> 20 years of age) body weight are presented in Table 2 (WHO, 1999a). The mean weights are based upon nationally representative data sets for about half of the countries listed, extrapolated to year 2000 based upon analysis of recent trends in body mass. For countries with no data, WHO used values from countries considered to be appropriate proxies. The WHO year 2000 estimates of average UK adult body weight are similar to the 1996 HSE results. Average body weights for adults of most Eastern, Northern and Western European countries are similar to those of the UK (exceptions are Denmark, Finland, Norway, Germany, and the Netherlands, where body weights are greater than those of the UK). Average body weights of Southern European adults tend to be lower than the UK, with the exception of Italy and Greece (which have values similar to the UK).

For English adults, age and gender specific body weight distributions can be directly estimated using the cumulative percentiles provided in Table 1. Cumulative distributions for adult body weight (aged 16 and older) by gender are provided in Tables 3-4 and Figures 1-2. A cumulative distribution for adult body weight of males and females combined (Table 5, Figure 3) was also developed based upon the Table 1 data.

Alternatively, age and gender specific body distributions can be estimated based upon the assumption that body weight is lognormally distributed. Burmaster and Crouch (1997) demonstrated that the US NHANES II body weight data, assessed by age group and gender, followed a lognormal distribution. If the HSE data are also assumed to be lognormally distributed, lognormal distributions can be estimated for UK body weight by age and gender using the statistical information (mean, standard error of the mean, N) provided in Table 1. For example, for adult male body weight a lognormal distribution with arithmetic mean and standard deviation[3] of 80.0 and 13.48 was simulated using Crystal Ball®. The results of a 1000 trial Monte Carlo simulation of the lognormal distribution are generally similar to the original data (lower cumulative percentiles are within 0.5 kg of the original data, 90th and 95th percentiles differ by 3 kg) (Table 6, Figures 4 and 5). Arithmetic means and standard deviations for the HSE body weight data (Table 1) are provided in Table 7.

3 Calculated as SEM * $N^{fi}$ where SEM = standard error of the mean and N = sample size.

***Table 1. Adult body weight - England*** *(Source: UK Office for National Statistics, 1998, © Crown copyright, used with permission)*

| | | | | | Statistics for weight (kg) | | | | | Frequency (%) by weight range (kg) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gender** | **N** | **Age** | **Mean** | **SEM[1]** | **5th** | **10th** | **50th** | **90th** | **95th** | **< 60** | **60-70** | **70-80** | **80-90** | **> 90** |
| Males | 909 | 16-24 | 72.8 | 0.43 | 54.5 | 58.1 | 70.8 | 90.5 | 97.1 | 14 | 33 | 28 | 14 | 10 |
| | 1296 | 25-34 | 80.7 | 0.38 | 60.9 | 64.6 | 79.5 | 98.9 | 105.6 | 4 | 17 | 31 | 26 | 22 |
| | 1353 | 35-44 | 82.4 | 0.36 | 63.1 | 67.0 | 80.9 | 99.6 | 107.6 | 2 | 15 | 30 | 29 | 25 |
| | 1254 | 45-54 | 82.7 | 0.37 | 62.3 | 66.8 | 81.9 | 100.8 | 106.5 | 2 | 14 | 28 | 29 | 27 |
| | 945 | 55-64 | 82.8 | 0.43 | 63.4 | 67.3 | 81.7 | 100.8 | 107.3 | 2 | 14 | 28 | 28 | 28 |
| | 847 | 65-74 | 78.9 | 0.43 | 60.0 | 63.7 | 78.2 | 95.0 | 100.5 | 5 | 18 | 33 | 26 | 18 |
| | 489 | 75+ | 74.1 | 0.51 | 56.6 | 60.7 | 73.2 | 89.1 | 94.1 | 9 | 27 | 36 | 20 | 8 |
| | 7093 | Total | 80.0 | 0.16 | 60.1 | 63.7 | 78.9 | 97.7 | 104.2 | 5 | 19 | 30 | 25 | 21 |
| | | | | | | | | | | **< 50** | **50-60** | **60-70** | **70-80** | **> 80** |
| Females | 1024 | 16-24 | 62.7 | 0.38 | 47.8 | 50.1 | 60.3 | 78.4 | 85.9 | 10 | 38 | 31 | 12 | 8 |
| | 1504 | 25-34 | 67.0 | 0.34 | 50.0 | 53.0 | 64.5 | 84.5 | 91.3 | 5 | 28 | 32 | 20 | 15 |
| | 1501 | 35-44 | 67.8 | 0.35 | 50.4 | 53.3 | 65.0 | 87.2 | 93.7 | 5 | 26 | 34 | 18 | 17 |
| | 1399 | 45-54 | 69.3 | 0.35 | 50.9 | 54.6 | 67.4 | 86.1 | 94.3 | 4 | 20 | 35 | 23 | 18 |
| | 1017 | 55-64 | 70.7 | 0.40 | 52.0 | 55.9 | 69.5 | 87.8 | 95.0 | 3 | 16 | 32 | 27 | 21 |
| | 1023 | 65-74 | 68.2 | 0.40 | 48.2 | 52.8 | 67.0 | 84.6 | 92.0 | 7 | 18 | 35 | 24 | 17 |
| | 771 | 75+ | 63.4 | 0.42 | 44.4 | 49.0 | 62.2 | 79.3 | 83.3 | 12 | 28 | 32 | 20 | 9 |
| | 8239 | Total | 67.3 | 0.14 | 49.3 | 52.6 | 65.3 | 84.8 | 91.7 | 6 | 25 | 33 | 21 | 15 |

1 SEM = Standard Error of the Mean

***Table 2. Estimated Mean Adult (> 20 Years Old) Body Weight for Year 2000 - European Countries*** *(Source: WHO Global database on Body Mass Index WHO, 1999a)*

| Region and Country | Mean Weight Male | Female | Average of M and F |
|---|---|---|---|
| **Eastern Europe** | | | |
| Belarus | 75.77 | 69.27 | 72.52 |
| Bulgaria | 61.07 | 53.93 | 57.50 |
| Czech Rep. | 75.28 | 65.29 | 70.29 |
| Hungary | 79.39 | 68.89 | 74.14 |
| Poland | 75.15 | 60.18 | 67.67 |
| Moldova | 75.77 | 69.27 | 72.52 |
| Romania | 61.07 | 53.93 | 57.50 |
| Russia | 75.77 | 69.27 | 72.52 |
| Slovakia | 75.28 | 65.29 | 70.29 |
| Ukraine | 75.77 | 69.27 | 72.52 |
| **E. Eur. Average** | 74.22 | 66.48 | 70.35 |
| **Northern Europe** | | | |
| Denmark | 83.61 | 68.46 | 76.03 |
| Estonia | 75.77 | 69.27 | 72.52 |
| Finland | 83.61 | 68.46 | 76.03 |
| Iceland | 78.92 | 69.07 | 73.99 |
| Ireland | 77.24 | 67.58 | 72.41 |
| Latvia | 75.77 | 69.27 | 72.52 |
| Lithuania | 75.77 | 69.27 | 72.52 |
| Norway | 78.92 | 69.07 | 73.99 |
| Sweden | 83.61 | 68.46 | 76.03 |
| United Kingdom | 77.24 | 67.58 | 72.41 |
| **N. Eur. Average** | 78.56 | 67.97 | 73.27 |
| **Southern Europe** | | | |
| Albania | 61.07 | 53.93 | 57.50 |
| Bosnia-Herzegovina | 61.07 | 53.93 | 57.50 |
| Croatia | 61.07 | 53.93 | 57.50 |
| Greece | 76.13 | 66.94 | 71.54 |
| Italy | 73.23 | 62.56 | 67.89 |
| Macedonia FYR | 61.07 | 53.93 | 57.50 |
| Malta | 61.07 | 53.93 | 57.50 |
| Portugal | 61.07 | 53.93 | 57.50 |
| Slovenia | 61.07 | 53.93 | 57.50 |
| Spain | 73.23 | 62.56 | 67.89 |
| Yugoslavia | 75.28 | 60.44 | 67.86 |
| **S. Eur. Average** | 71.54 | 61.28 | 66.41 |
| **Western Europe** | | | |
| Austria | 79.39 | 68.89 | 74.14 |
| Belgium | 79.78 | 66.38 | 73.08 |
| France | 77.73 | 66.78 | 72.26 |
| Germany | 84.51 | 71.63 | 78.07 |
| Luxemburg | 77.73 | 66.78 | 72.26 |
| Netherlands | 87.80 | 74.37 | 81.08 |
| Switzerland | 79.42 | 67.60 | 73.51 |
| **W. Eur. Average** | 81.97 | 69.75 | 75.86 |
| **Europe Average** | 76.46 | 66.57 | 71.51 |

*Table 3. Adult Body Weight - Cumulative Distribution for English Males*

| Kg | cumulative % |
|---|---|
| 60.1 | 5 |
| 63.7 | 10 |
| 70.0 | 24 |
| 78.9 | 50 |
| 80.0 | 54 |
| 90.0 | 79 |
| 97.7 | 90 |
| 104.2 | 95 |

*Figure 1. Adult Male Body Weight: Cumulative Distribution*

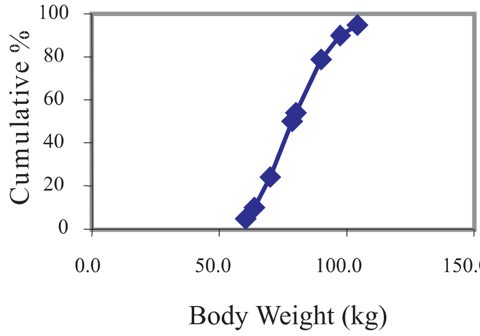



*Table 4. Adult Body Weight - Cumulative Distribution for English Females*

| Kg | cumulative % |
|---|---|
| 49.3 | 5 |
| 50.0 | 6 |
| 52.6 | 10 |
| 60.0 | 31 |
| 65.3 | 50 |
| 70.0 | 64 |
| 80.0 | 85 |
| 84.8 | 90 |
| 91.7 | 95 |

*Figure 2. Adult Female Body Weight: Cumulative Distribution*

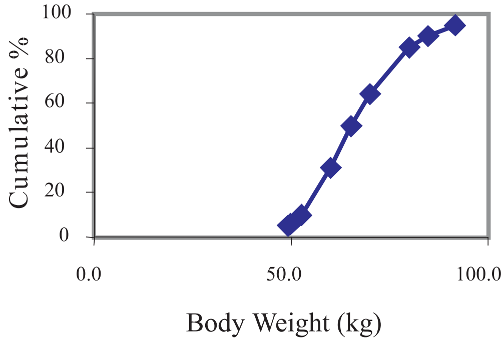
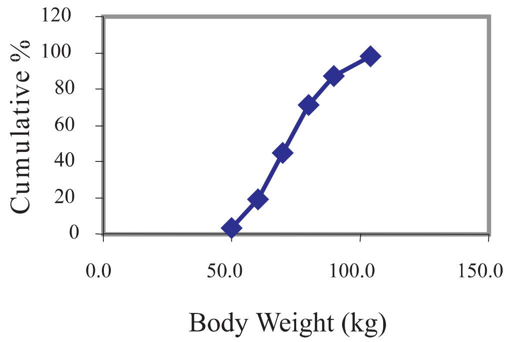



*Table 5. Adult Body Weight - Estimated Cumulative Distribution for M & F combined*

| Kg | cumulative % |
|---|---|
| 50.0 | 3 |
| 60.0 | 19 |
| 70.0 | 45 |
| 80.0 | 71 |
| 90 | 87 |
| 104.0 | 98 |

*Figure 3. Adult Female Body Weight: Estimated Cumulative Distribution*




Estimated basis: calculated using frequency percentiles, N and frequency percentiles of M and F

*Table 6. Comparison of HSE Data and Monte Carlo Simulation of an Estimated Lognormal Distribution for English Adult Males aged 16 to 75+ years*

| Statistics (kg) | HSE Data | MC Simulation |
|---|---|---|
| Mean | 80.0 | 80.6 |
| Std. Dev. | 13.48 | 14.69 |
| 5th | 60.1 | 59.6 |
| 10th | 63.7 | 62.9 |
| 50th | 78.9 | 79.3 |
| 90th | 97.7 | 100.6 |
| 95th | 104.2 | 107.7 |

| Weight range (kg) | Frequency (%) by weight range | |
|---|---|---|
| | HSE Data | MC Simulation |
| < 60 | 5 | 5 |
| 60 - 70 | 19 | 20 |
| 70 - 80 | 30 | 25 |
| 80 - 90 | 25 | 25 |
| > 90 | 21 | 25 |

*Figure 4. Adult Established Male Body Weight - Monte Carlo Simulation using Estimated Lognormal Distribution Parameters*

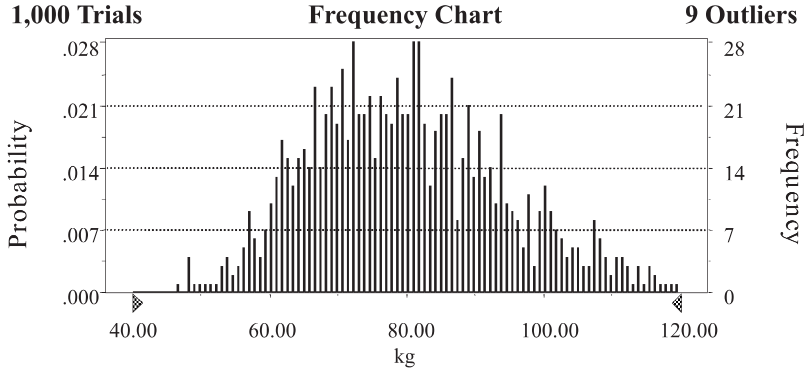



*Figure 5. Adult English Male Body Weight - Comparison of Probability Distributions for HSE Data and Lognormal Monte Carlo Simulation*

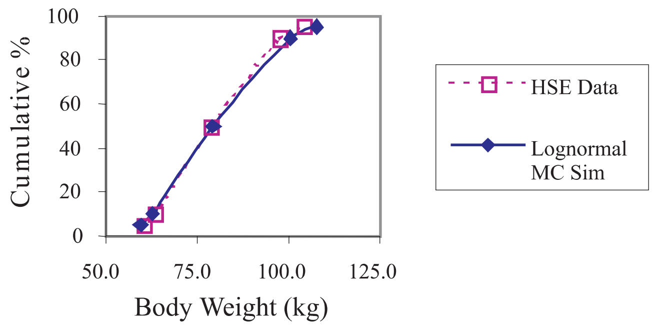


*Table 7. Arithmetic Means and Calculated Standard Deviations for HSE Data by Age and Gender - Adult Body Weight*

| Gender | Age | Mean | Std Dev. |
|---|---|---|---|
| **Males** | 16-24 | 72.8 | 12.96 |
| | 25-34 | 80.7 | 13.68 |
| | 35-44 | 82.4 | 13.24 |
| | 45-54 | 82.7 | 13.10 |
| | 55-64 | 82.8 | 13.22 |
| | 65-74 | 78.9 | 12.51 |
| | 75+ | 74.1 | 11.28 |
| | Total | 80.0 | 13.48 |
| **Females** | 16-24 | 62.7 | 12.16 |
| | 25-34 | 67.0 | 13.19 |
| | 35-44 | 67.8 | 13.56 |
| | 45-54 | 69.3 | 13.09 |
| | 55-64 | 70.7 | 12.76 |
| | 65-74 | 68.2 | 12.79 |
| | 75+ | 63.4 | 11.66 |
| | Total | 67.3 | 12.71 |

## *3.2 Child Body Weight*


***Summary***
Combined data from the 1995-1997 Health Surveys for England indicate a mean body weight of 33 kg for children aged 2-15 years. Percentiles for cumulative distributions are provided in Table 8, with estimated lognormal distribution parameters specified in Table 9. For English children 2-15 years old, median, 5th and 95th percentiles are 29, 14 and 65 kg, respectively, for males and 28, 14 and 63 for females. For younger children, US data are provided in Tables 10-13. Body weight varies significantly with age during the childhood years; the values selected for use in an exposure assessment should correspond to the age(s) of interest for the exposure scenario.


***Relevant Studies***
Body weight data for children are available from HSE and NDNS studies. Data for children aged 2-15 from the 1995-1997 Health Surveys for England are presented by age and gender in Table 8. The mean body weight for ages 2-15, male and females alone or combined, is 33 kg. In comparison, McKone and Daniels (1991) used a default value of 27 kg for children aged 0-15 years and the Italian risk assessment software GIUDATTA© uses a default child body weight of 15 kg (GIUDATTA©, 1999). Because body weight varies significantly with age over the childhood years, the EFH did not recommend a single value for children but rather recommended using body weight data that correspond to the age(s) of interest for a given exposure scenario (USEPA, 1997).

Additional body weight distributions from the 1992-1993 NDNS survey of British children aged 1.5-4.5 years old are provided in Table 14. For similar ages, data from the more recent HSE are slightly greater. The HSE data are based upon a larger sample size and are more recent than the NDNS data.

Arithmetic means and standard deviations summarised in Table 9 were used to generate lognormal distributions. Summary statistics of 1000 trial Monte Carlo simulations are presented in Table 15. The statistics indicate that the lognormal distributions are reasonable estimates of the original data. The lognormal Monte Carlo simulations and the HSE data provided in Table 7 result in similar cumulative probability distributions (Figures 6 and 7).

A robust UK specific data set was not identified for children younger than 2 years of age. Data for US children from birth to 36 months of age (Hamill *et al*, 1979) and 6 months to 18 years of age (NCHS, 1987) are presented in Tables 11-13, and best fit parameters for lognormal distributions are provided in Table 14.

For UK children < 2 years of age, the NCHS data can be used to approximate body weight. Median values of the NCHS set are closer to those of the HSE UK data. The median values of Hamill *et al* (1979) are lower than the median UK values for a given age, but the UK values are presented by yearly age classes whereas the Hamill *et al* values are for age increments of 1-6 months. The Hamill data can be used to approximate body weight for children < 6 months of age (ages not covered in the HSE of NCHS data set) or if smaller age increments are needed.

***Table 8. Child Body Weight - England*** *(Source: UK Office for National Statistics, 1999a, © Crown copyright, used with permission)*

| Gender | N (weighted) | Age | Statistics for weight (kg) Mean | SEM | 5th | 10th | 50th | 90th | 95th |
|---|---|---|---|---|---|---|---|---|---|
| **Males** | 432 | 2 | 14.2 | 0.09 | 11.6 | 12.1 | 14.0 | 16.5 | 17.5 |
| | 479 | 3 | 16.4 | 0.10 | 13.4 | 14.1 | 16.2 | 19.0 | 20.2 |
| | 486 | 4 | 18.4 | 0.11 | 15.0 | 15.7 | 18.1 | 21.5 | 22.5 |
| | 475 | 5 | 20.4 | 0.15 | 16.3 | 17.1 | 20.0 | 24.0 | 25.5 |
| | 490 | 6 | 22.9 | 0.16 | 18.0 | 18.8 | 22.6 | 27.3 | 29.1 |
| | 492 | 7 | 25.8 | 0.19 | 20.5 | 21.4 | 25.0 | 31.0 | 33.7 |
| | 517 | 8 | 29.1 | 0.26 | 22.7 | 23.7 | 28.0 | 35.0 | 39.4 |
| | 446 | 9 | 32.0 | 0.30 | 24.0 | 25.6 | 30.9 | 40.2 | 43.9 |
| | 472 | 10 | 35.6 | 0.34 | 26.7 | 28.0 | 34.4 | 45.2 | 51.8 |
| | 448 | 11 | 40.2 | 0.42 | 29.3 | 31.3 | 38.6 | 51.5 | 55.2 |
| | 447 | 12 | 44.8 | 0.50 | 31.0 | 33.3 | 42.9 | 58.8 | 63.1 |
| | 439 | 13 | 50.8 | 0.58 | 35.0 | 37.7 | 49.0 | 66.0 | 71.6 |
| | 419 | 14 | 56.4 | 0.63 | 39.0 | 41.8 | 54.6 | 73.0 | 79.7 |
| | 412 | 15 | 62.9 | 0.62 | 47.1 | 49.3 | 61.1 | 78.0 | 85.6 |
| | 6455 | Total 2-15 | 32.9 | 0.21 | 14.3 | 15.9 | 28.6 | 57.0 | 64.6 |
| | | | | | | | | | |
| **Females** | 422 | 2 | 13.7 | 0.09 | 11.2 | 11.6 | 13.6 | 15.9 | 16.7 |
| | 460 | 3 | 16.0 | 0.11 | 12.8 | 13.5 | 15.6 | 19.1 | 20.2 |
| | 503 | 4 | 18.3 | 0.12 | 14.7 | 15.3 | 18.0 | 21.5 | 23.4 |
| | 481 | 5 | 20.4 | 0.15 | 16.2 | 16.9 | 20.1 | 24.1 | 25.5 |
| | 475 | 6 | 22.8 | 0.18 | 17.7 | 18.6 | 22.2 | 27.7 | 30.2 |
| | 480 | 7 | 25.9 | 0.26 | 19.8 | 20.4 | 24.6 | 33.7 | 37.9 |
| | 526 | 8 | 28.8 | 0.27 | 21.7 | 22.5 | 27.7 | 36.5 | 41.0 |
| | 437 | 9 | 32.7 | 0.36 | 24.2 | 25.4 | 31.3 | 42.6 | 45.7 |
| | 487 | 10 | 37.1 | 0.38 | 27.8 | 28.7 | 35.4 | 48.1 | 52.9 |
| | 438 | 11 | 42.4 | 0.51 | 28.9 | 31.4 | 40.0 | 56.1 | 62.3 |
| | 422 | 12 | 47.5 | 0.50 | 34.4 | 36.5 | 46.1 | 59.7 | 66.0 |
| | 396 | 13 | 51.8 | 0.53 | 38.9 | 40.7 | 50.1 | 65.7 | 70.6 |
| | 406 | 14 | 56.7 | 0.59 | 41.3 | 45.0 | 54.4 | 71.8 | 80.3 |
| | 361 | 15 | 58.4 | 0.65 | 43.6 | 46.2 | 56.3 | 73.4 | 79.2 |
| | 6293 | Total 2-15 | 32.8 | 0.21 | 13.8 | 15.4 | 28.5 | 56.0 | 62.6 |

***Table 9. Arithmetic Means and Calculated Standard Deviations for HSE Data by Age and Gender - Child Body Weight***

| **Gender** | **Age** | **Child Body Weight (kg)** | |
|---|---|---|---|
| | | **Mean** | **Std Dev.** |
| **Males** | 2 | 14.2 | 1.87 |
| | 3 | 16.4 | 2.19 |
| | 4 | 18.4 | 2.42 |
| | 5 | 20.4 | 3.27 |
| | 6 | 22.9 | 3.54 |
| | 7 | 25.8 | 4.21 |
| | 8 | 29.1 | 5.91 |
| | 9 | 32.0 | 6.34 |
| | 10 | 35.6 | 7.39 |
| | 11 | 40.2 | 8.89 |
| | 12 | 44.8 | 10.57 |
| | 13 | 50.8 | 12.15 |
| | 14 | 56.4 | 12.90 |
| | 15 | 62.9 | 12.58 |
| | 2-15 | 32.9 | 16.87 |
| | | | |
| **Females** | 2 | 13.7 | 1.85 |
| | 3 | 16.0 | 2.36 |
| | 4 | 18.3 | 2.69 |
| | 5 | 20.4 | 3.29 |
| | 6 | 22.8 | 3.92 |
| | 7 | 25.9 | 5.70 |
| | 8 | 28.8 | 6.19 |
| | 9 | 32.7 | 7.53 |
| | 10 | 37.1 | 8.39 |
| | 11 | 42.4 | 10.67 |
| | 12 | 47.5 | 10.27 |
| | 13 | 51.8 | 10.55 |
| | 14 | 56.7 | 11.89 |
| | 15 | 58.4 | 12.35 |
| | 2-15 | 32.8 | 16.66 |

***Table 10. Smoothed Percentiles of Body Weight (in kg) by Sex and Age: US Children Birth to 36 Months** (Source: USEPA, 1997 citation of Hamill et al, 1979)*

| | Sex and Age | Smoothed Percentile[a] 5th | 10th | 25th | 50th | 75th | 90th | 95th |
|---|---|---|---|---|---|---|---|---|
| | | Weight in Kilograms | | | | | | |
| **Male** | | | | | | | | |
| | Birth | 2.54 | 2.78 | 3.00 | 3.27 | 3.64 | 3.82 | 4.15 |
| | 1 Month | 3.16 | 3.43 | 3.82 | 4.29 | 4.75 | 5.14 | 5.38 |
| | 3 Months | 4.43 | 4.78 | 5.32 | 5.98 | 6.56 | 7.14 | 7.37 |
| | 6 Months | 6.20 | 6.61 | 7.20 | 7.85 | 8.49 | 9.10 | 9.46 |
| | 9 Months | 7.52 | 7.95 | 8.56 | 9.18 | 9.88 | 10.49 | 10.93 |
| | 12 Months | 8.43 | 8.84 | 9.49 | 10.15 | 10.91 | 11.54 | 11.99 |
| | 18 Months | 9.59 | 9.92 | 10.67 | 11.47 | 12.31 | 13.05 | 13.44 |
| | 24 Months | 10.54 | 10.58 | 11.65 | 12.59 | 13.44 | 14.29 | 14.70 |
| | 30 Months | 11.44 | 11.80 | 12.63 | 13.67 | 14.51 | 15.47 | 15.97 |
| | 36 Months | 12.26 | 12.69 | 13.58 | 14.69 | 15.59 | 16.66 | 17.28 |
| **Female** | | | | | | | | |
| | Birth | 2.36 | 2.58 | 2.93 | 3.23 | 3.52 | 3.64 | 3.81 |
| | 1 Month | 2.97 | 3.22 | 3.59 | 3.98 | 4.36 | 4.65 | 4.92 |
| | 3 Months | 4.18 | 4.47 | 4.88 | 5.40 | 5.90 | 6.39 | 6.74 |
| | 6 Months | 5.79 | 6.12 | 6.60 | 7.21 | 7.83 | 8.38 | 8.73 |
| | 9 Months | 7.00 | 7.34 | 7.89 | 8.56 | 9.24 | 9.83 | 10.17 |
| | 12 Months | 7.84 | 8.19 | 8.81 | 9.53 | 10.23 | 10.87 | 11.24 |
| | 18 Months | 8.92 | 9.30 | 10.04 | 10.82 | 11.55 | 12.30 | 12.76 |
| | 24 Months | 9.87 | 10.26 | 11.10 | 11.90 | 12.74 | 13.57 | 14.08 |
| | 30 Months | 10.78 | 11.21 | 12.11 | 12.93 | 13.93 | 14.81 | 15.35 |
| | 36 Months | 11.60 | 12.07 | 12.99 | 13.93 | 15.03 | 15.97 | 16.54 |

[a] Smoothed by cubic spline approximation

***Table 11. Body Weight for US Males, 6 Months to 19 Years of Age*** *(Source: USEPA, 1997 citation of NCHS, 1987)*

| Age | Number of Persons Examined | Mean (kg) | Std Dev. | Percentile | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 5th | 10th | 15th | 25th | 50th | 75th | 85th | 90th | 95th |
| 6 - 11 months | 179 | 9.4 | 1.3 | 7.5 | 7.6 | 8.2 | 8.6 | 9.4 | 10.1 | 10.7 | 10.9 | 11.4 |
| 1 year | 370 | 11.8 | 1.9 | 9.6 | 10.0 | 10.3 | 10.8 | 11.7 | 12.6 | 13.1 | 13.6 | 14.4 |
| 2 years | 375 | 13.6 | 1.7 | 11.1 | 11.6 | 11.8 | 12.6 | 13.5 | 14.5 | 15.2 | 15.8 | 16.5 |
| 3 years | 418 | 15.7 | 2.0 | 12.9 | 13.5 | 13.9 | 14.4 | 15.4 | 16.8 | 17.4 | 17.9 | 19.1 |
| 4 years | 404 | 17.8 | 2.5 | 14.1 | 15.0 | 15.3 | 16.0 | 17.6 | 19.0 | 19.9 | 20.9 | 22.2 |
| 5 years | 397 | 19.8 | 3.0 | 16.0 | 16.8 | 17.1 | 17.7 | 19.4 | 21.3 | 22.9 | 23.7 | 25.4 |
| 6 years | 133 | 23.0 | 4.0 | 18.6 | 19.2 | 19.8 | 20.3 | 22.0 | 24.1 | 26.4 | 28.3 | 30.1 |
| 7 years | 148 | 25.1 | 3.9 | 19.7 | 20.8 | 21.2 | 22.2 | 24.8 | 26.9 | 28.2 | 29.6 | 33.9 |
| 8 years | 147 | 28.2 | 6.2 | 20.4 | 22.7 | 23.6 | 24.6 | 27.5 | 29.9 | 33.0 | 35.5 | 39.1 |
| 9 years | 145 | 31.1 | 6.3 | 24.0 | 25.6 | 26.0 | 27.1 | 30.2 | 33.0 | 35.4 | 38.6 | 43.1 |
| 10 years | 157 | 36.4 | 7.7 | 27.2 | 28.2 | 29.6 | 31.4 | 34.8 | 39.2 | 43.5 | 46.3 | 53.4 |
| 11 years | 155 | 40.3 | 10.1 | 26.8 | 28.8 | 31.8 | 33.5 | 37.3 | 46.4 | 52.0 | 57.0 | 61.0 |
| 12 years | 145 | 44.2 | 10.1 | 30.7 | 32.5 | 35.4 | 37.8 | 42.5 | 48.8 | 52.6 | 58.9 | 67.5 |
| 13 years | 173 | 49.9 | 12.3 | 35.4 | 37.0 | 38.3 | 40.1 | 48.4 | 56.3 | 59.8 | 64.2 | 69.9 |
| 14 years | 186 | 57.1 | 11.0 | 41.0 | 44.5 | 46.4 | 49.8 | 56.4 | 63.3 | 66.1 | 68.9 | 77.0 |
| 15 years | 184 | 61.0 | 11.0 | 46.2 | 49.1 | 50.6 | 54.2 | 60.1 | 64.9 | 68.7 | 72.8 | 81.3 |
| 16 years | 178 | 67.1 | 12.4 | 51.4 | 54.3 | 56.1 | 57.6 | 64.4 | 73.6 | 78.1 | 82.2 | 91.2 |
| 17 years | 173 | 66.7 | 11.5 | 50.7 | 53.4 | 54.8 | 58.8 | 65.8 | 72.0 | 76.8 | 82.3 | 88.9 |
| 18 years | 164 | 71.1 | 12.7 | 54.1 | 56.6 | 60.3 | 61.9 | 70.4 | 76.6 | 80.0 | 83.5 | 95.3 |
| 19 years | 148 | 71.7 | 11.6 | 55.9 | 57.9 | 60.5 | 63.8 | 69.5 | 77.9 | 84.3 | 86.8 | 92.1 |

***Table 12. Body Weight for US Females, 6 Months to 19 Years of Age*** *(Source: USEPA, 1997 citation of NCHS, 1987)*

| Age | Number of Persons Examined | Mean (kg) | Std Dev. | Percentile | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 5th | 10th | 15th | 25th | 50th | 75th | 85th | 90th | 95th |
| 6 - 11 months | 177 | 8.8 | 1.2 | 6.6 | 7.3 | 7.5 | 7.9 | 8.9 | 9.4 | 10.1 | 10.4 | 10.9 |
| 1 year | 336 | 10.8 | 1.4 | 8.8 | 9.1 | 9.4 | 9.9 | 10.7 | 11.7 | 12.4 | 12.7 | 13.4 |
| 2 years | 336 | 13.0 | 1.5 | 10.8 | 11.2 | 11.6 | 12.0 | 12.7 | 13.8 | 14.5 | 14.9 | 15.9 |
| 3 years | 366 | 14.9 | 2.1 | 11.7 | 12.3 | 12.9 | 13.4 | 14.7 | 16.1 | 17.0 | 17.4 | 18.4 |
| 4 years | 396 | 17.0 | 2.4 | 13.7 | 14.3 | 14.5 | 15.2 | 16.7 | 18.4 | 19.3 | 20.2 | 21.1 |
| 5 years | 364 | 19.6 | 3.3 | 15.3 | 16.1 | 16.7 | 17.2 | 19.0 | 21.2 | 22.8 | 24.7 | 26.6 |
| 6 years | 135 | 22.1 | 4.0 | 17.0 | 17.8 | 18.6 | 19.3 | 21.3 | 23.8 | 26.6 | 28.9 | 29.6 |
| 7 years | 157 | 24.7 | 5.0 | 19.2 | 19.5 | 19.8 | 21.4 | 23.8 | 27.1 | 28.7 | 30.3 | 34.0 |
| 8 years | 123 | 27.9 | 5.7 | 21.4 | 22.3 | 23.3 | 24.4 | 27.5 | 30.2 | 31.3 | 33.2 | 36.5 |
| 9 years | 149 | 31.9 | 8.4 | 22.9 | 25.0 | 25.8 | 27.0 | 29.7 | 33.6 | 39.3 | 43.3 | 48.4 |
| 10 years | 136 | 36.1 | 8.0 | 25.7 | 27.5 | 29.0 | 31.0 | 34.5 | 39.5 | 44.2 | 45.8 | 49.6 |
| 11 years | 140 | 41.8 | 10.9 | 29.8 | 30.3 | 31.3 | 33.9 | 40.3 | 45.8 | 51.0 | 56.6 | 60.0 |
| 12 years | 147 | 46.4 | 10.1 | 32.3 | 35.0 | 36.7 | 39.1 | 45.4 | 52.6 | 58.0 | 60.5 | 64.3 |
| 13 years | 162 | 50.9 | 11.8 | 35.4 | 39.0 | 40.3 | 44.1 | 49.0 | 55.2 | 60.9 | 66.4 | 76.3 |
| 14 years | 178 | 54.8 | 11.1 | 40.3 | 42.8 | 43.7 | 47.4 | 53.1 | 60.3 | 65.7 | 67.6 | 75.2 |
| 15 years | 145 | 55.1 | 9.8 | 44.0 | 45.1 | 46.5 | 48.2 | 53.3 | 59.6 | 62.2 | 65.5 | 76.6 |
| 16 years | 170 | 58.1 | 10.1 | 44.1 | 47.3 | 48.9 | 51.3 | 55.6 | 62.5 | 68.9 | 73.3 | 76.8 |
| 17 years | 134 | 59.6 | 11.4 | 44.5 | 48.9 | 50.5 | 52.2 | 58.4 | 63.4 | 68.4 | 71.6 | 81.8 |
| 18 years | 170 | 59.0 | 11.1 | 45.3 | 49.5 | 50.8 | 52.8 | 56.4 | 63.0 | 66.0 | 70.1 | 78.0 |
| 19 years | 158 | 60.2 | 11.0 | 48.5 | 49.7 | 51.7 | 53.9 | 57.1 | 64.4 | 70.7 | 74.8 | 78.1 |

***Table 13. Statistics for Maximum Likelihood Estimate Analysis of US Body Weight, 6 Months to 20 Years** (Source: Burmaster and Crouch, 1997)*

| Best Fit Parameters for Lognormal Distributions for Body Weight (kg) | | | | |
|---|---|---|---|---|
| **Age** | **Females** | | **Males** | |
| | $\mu_2$* | $\sigma_2$* | $\mu_2$* | $\sigma_2$* |
| 6 months to 1 yr | 2.16 | 0.145 | 2.23 | 0.129 |
| 1 to 2 yrs | 2.38 | 0.129 | 2.46 | 0.120 |
| 2 to 3 yrs | 2.56 | 0.113 | 2.60 | 0.118 |
| 3 to 4 yrs | 2.69 | 0.136 | 2.74 | 0.115 |
| 4 to 5 yrs | 2.82 | 0.135 | 2.86 | 0.133 |
| 5 to 6 yrs | 2.93 | 0.164 | 2.98 | 0.140 |
| 6 to 7 yrs | 3.08 | 0.173 | 3.11 | 0.146 |
| 7 to 8 yrs | 3.19 | 0.176 | 3.21 | 0.152 |
| 8 to 9 yrs | 3.31 | 0.157 | 3.32 | 0.180 |
| 9 to 10 yrs | 3.43 | 0.216 | 3.42 | 0.167 |
| 10 to 11yrs | 3.56 | 0.198 | 3.57 | 0.195 |
| 11 to 12 yrs | 3.70 | 0.226 | 3.67 | 0.252 |
| 12 to 13 yrs | 3.82 | 0.214 | 3.77 | 0.224 |
| 13 to 14 yrs | 3.91 | 0.214 | 3.88 | 0.217 |
| 14 to 15 yrs | 3.98 | 0.187 | 4.03 | 0.182 |
| 15 to 16 yrs | 3.99 | 0.159 | 4.09 | 0.159 |
| 16 to 17 yrs | 4.04 | 0.166 | 4.19 | 0.169 |
| 17 to 18 yrs | 4.07 | 0.166 | 4.18 | 0.166 |
| 18 to 19 yrs | 4.06 | 0.148 | 4.24 | 0.16 |
| 19 to 20 yrs | 4.08 | 0.149 | 4.26 | 0.154 |

* $\mu_2$, $\sigma_2$ correspond to the mean and standard deviation, respectively, of the lognormal distribution of body weight (kg) and are expressed in natural logarithms

***Table 14. Child Body Weight from the National Diet and Nutrition Survey*** *(Source: The National Diet and Nutrition Survey: children aged 1.5-4.5 years (Gregory et al, 1995))*

| **Gender** | **N** | **Age** | **Statistics for weight (kg)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Mean** | **Std Dev.** | **2.3** | **9.0** | **25.0** | **50.0** | **75.0** | **91** | **97.7** |
| **Males** | 294 | 1.5-2.5 | 12.6 | 1.6 | 9.4 | 10.4 | 11.6 | 12.6 | 13.6 | 14.8 | 15.9 |
| | 307 | 2.5-3.5 | 14.9 | 1.9 | 11.6 | 12.6 | 13.7 | 14.8 | 15.9 | 17.6 | 19.3 |
| | 251 | 3.5-4.5 | 16.6 | 2.1 | 13.1 | 13.9 | 15.1 | 16.8 | 17.8 | 19.3 | 21.0 |
| | | | | | | | | | | | |
| **Females** | 283 | 1.5-2.5 | 11.9 | 1.6 | 8.8 | 10.1 | 10.8 | 11.7 | 12.8 | 13.9 | 15.2 |
| | 314 | 2.5-3.5 | 14.3 | 1.7 | 11.2 | 12.0 | 13.1 | 14.3 | 15.3 | 16.5 | 17.9 |
| | 258 | 3.5-4.5 | 16.4 | 2.1 | 12.7 | 13.4 | 15.0 | 16.3 | 17.8 | 19.3 | 20.1 |

***Table 15. Child Body Weight: Results of Monte Carlo Simulation of Estimated Lognormal Distributions for HSE Data***

| Gender | Age | Statistics for weight (kg) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Mean | Std Dev. | 5th | 10th | 50th | 90th | 95th |
| **Males** | 2 | 14.2 | 2.0 | 11.3 | 11.9 | 14.0 | 16.9 | 17.8 |
| | 3 | 16.5 | 2.2 | 13.1 | 13.7 | 16.4 | 19.3 | 20.5 |
| | 4 | 18.5 | 2.5 | 14.6 | 15.5 | 18.3 | 21.9 | 22.8 |
| | 5 | 20.2 | 3.2 | 15.1 | 16.1 | 19.9 | 24.4 | 25.6 |
| | 6 | 22.9 | 3.8 | 17.3 | 18.4 | 22.6 | 27.7 | 29.5 |
| | 7 | 25.9 | 4.1 | 19.9 | 21.0 | 25.5 | 31.5 | 33.5 |
| | 8 | 29.3 | 6.1 | 20.6 | 22.0 | 28.8 | 37.2 | 40.1 |
| | 9 | 31.9 | 6.2 | 22.7 | 24.7 | 31.2 | 40.4 | 42.8 |
| | 10 | 35.8 | 7.4 | 25.3 | 27.0 | 34.9 | 45.2 | 48.9 |
| | 11 | 40.5 | 9.2 | 27.1 | 29.9 | 39.2 | 52.4 | 57.1 |
| | 12 | 44.9 | 10.2 | 29.7 | 32.6 | 44.2 | 58.2 | 62.7 |
| | 13 | 50.5 | 12.4 | 33.3 | 35.7 | 49.2 | 67.4 | 72.6 |
| | 14 | 56.5 | 13.0 | 37.5 | 41.0 | 54.7 | 73.7 | 79.0 |
| | 15 | 62.7 | 12.8 | 44.1 | 47.8 | 61.3 | 79.7 | 85.7 |
| | 2-15 | 34.0 | 19.0 | 13.1 | 15.2 | 29.8 | 59.0 | 71.9 |
| | | | | | | | | |
| **Females** | 2 | 13.7 | 1.9 | 10.8 | 11.4 | 13.5 | 16.2 | 17.0 |
| | 3 | 15.9 | 2.3 | 12.4 | 13.1 | 15.7 | 18.9 | 20.0 |
| | 4 | 18.3 | 2.7 | 14.2 | 15.0 | 18.2 | 21.8 | 22.7 |
| | 5 | 20.3 | 3.3 | 15.2 | 16.2 | 20.1 | 24.6 | 26.0 |
| | 6 | 23.0 | 4.0 | 17.1 | 18.2 | 22.6 | 28.2 | 30.4 |
| | 7 | 25.9 | 5.8 | 17.4 | 19.1 | 25.0 | 33.6 | 35.8 |
| | 8 | 28.6 | 6.6 | 19.1 | 20.8 | 27.9 | 37.3 | 40.2 |
| | 9 | 32.6 | 7.9 | 21.8 | 23.4 | 31.6 | 42.8 | 46.1 |
| | 10 | 37.2 | 8.4 | 25.1 | 27.3 | 36.4 | 48.1 | 52.2 |
| | 11 | 42.8 | 10.9 | 27.4 | 30.4 | 41.3 | 56.8 | 63.1 |
| | 12 | 47.6 | 10.0 | 33.1 | 35.5 | 46.8 | 60.5 | 64.5 |
| | 13 | 50.9 | 10.5 | 36.9 | 39.6 | 50.9 | 66.5 | 71.2 |
| | 14 | 56.8 | 11.8 | 40.20 | 42.6 | 55.7 | 72.0 | 77.6 |
| | 15 | 58.8 | 12.2 | 40.50 | 43.7 | 57.7 | 74.6 | 81.0 |
| | 2-15 | 33.0 | 16.8 | 13.45 | 16.0 | 29.2 | 54.8 | 64.7 |

*Figure 6. English Child Body Weight (combined ages 2-15) - Comparison of Gender Specific Probability Distributions for HSE Data and Lognormal Monte Carlo Simulations*

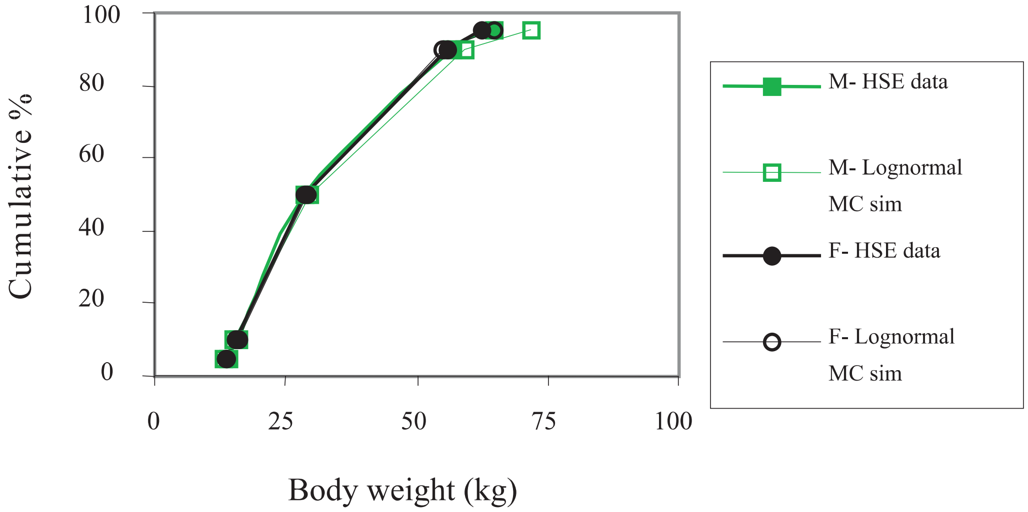
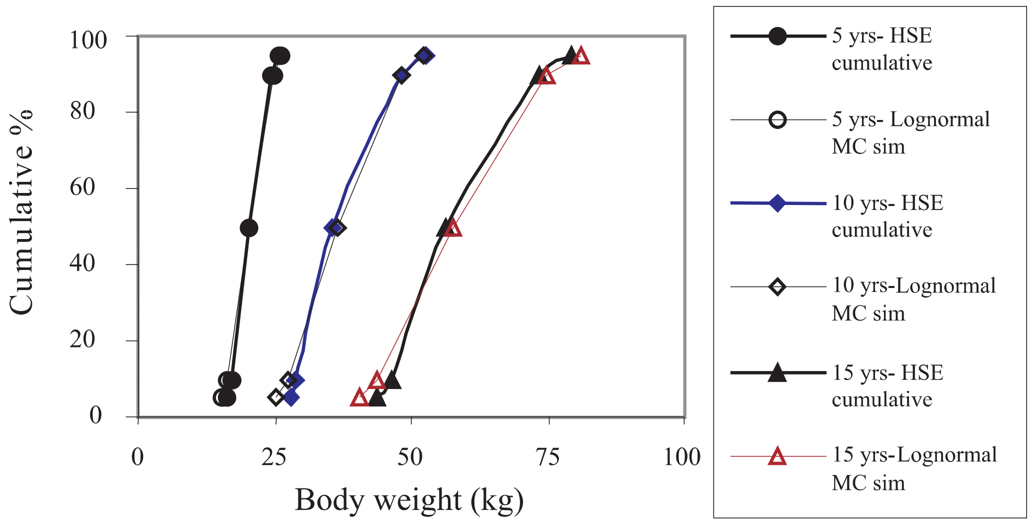



*Figure 7. English Female Child Body Weight - Comparison of Age Specific Distributions for HSE Data and Lorgnormal Monte Carlo Simulation by Age*



## 3.3 Skin Surface Area

### 3.3.1 Total skin surface area

*Summary*
For populations in which both body weight and height are known, skin surface area can be calculated using the USEPA bivariate equation specified in this section. Alternatively, when only body weight data are available, skin surface area can be calculated using either the equation of Costeff or Burmaster. The equation of Burmaster may give a better estimate of central tendency than that of Costeff, but overestimates skin surface area at values above the median. Based upon mean English adult body weight and the equation of Burmaster, total skin surface area is estimated as 2.07 $m^2$ for males and 1.76 $m^2$ for females, with an average of 1.92 $m^2$. Skin surface area varies by both gender and age. Estimated distributions for several gender and age groups are presented in Table 16. Central tendency, upper and lower limits should be generated based upon body weight data representative of the population of interest.

*Relevant Studies*
The direct measurement of body surface area (e.g., by direct coating, triangulation, or surface area integration) is difficult and time-consuming. Because of this difficulty, various formulae have been developed for estimating skin surface area. Typical equations express skin surface area as a function of both height and body weight or of body weight alone (DuBois and DuBois, 1916; Boyd, 1935; Gehan and George, 1970; USEPA, 1989; Burmaster, 1998a; Costeff, 1966).

The bivariate formula developed by the USEPA (1989) is based upon the largest sample set (N=401) and included observations for adults as well as children (although children represented the majority of the sample population) (Murray and Burmaster, 1992). The EPA bivariate formula accounts for >99.6% of the total variation among surface area observations for the sample population (Murray and Burmaster, 1992). Its form is:

$$SA = a\, H^b\, W^c$$

Where SA= Surface Area ($m^2$)
H = Height (cm)
W= Weight (kg)
a = 0.0239
b = 0.417
c = 0.517

When both body weight and height data are available for individuals within a population, the bivariate EPA equation is appropriate to use for estimating skin surface area. In most cases, however, body weight data are readily available but combined body weight and height data for a given individual are limited. Thus, the skin surface area equations based upon body weight alone are more readily applied. The two formulae that estimate skin surface area as a function of body weight alone are:

Equation 1: $SA = (4W + 7)/(W+90)$
where SA = Surface Area ($m^2$)
W = Weight (kg)

Source: Costeff, 1966 in USEPA, 1997, based upon 220 observations of children

and

Equation 2: $SA = a * BW^c$ or $\ln SA = \ln a + c \ln BW$
where SA = Skin Surface Area
BW = Body Weight
and: $\ln a = -2.2781$, $c = 0.6821$ for all 401 people
$\ln a = -2.2752$, $c = 0.6868$ for males
$\ln a = -2.2678$, $c = 0.6754$ for females

Source: Burmaster, 1998a, based upon 401 observations of adults and children

Given that body weight has been demonstrated to be lognormally distributed (Burmaster and Crouch, 1997), using the Burmaster (1998a) equation a distribution for skin surface area can be estimated as:

Equation 3: $SA \sim \exp [\mathrm{Normal}[\mu_{SA}, \sigma_{SA}]]$
where $\mu_{SA} = c * \mu_{BW} + \ln(a)$
and $\sigma_{SA} = c * \sigma_{BW}$

The equation of Costeff (1966) is a simpler formula, but skin surface area distributions can be easily described using the Burmaster (1998) formula if lognormal body weight distributions are known.

Cumulative skin surface area distributions were estimated using the equations of both Costeff and Burmaster for several age and gender categories (Table 16), using Monte Carlo simulations of body weight based upon the lognormal distribution parameters defined in Tables 7 and 9. Both equations resulted in similar skin surface area distributions for children (Table 16, Figures 8-13).

For adults, the Burmaster equation resulted in higher estimates of skin surface area than the equation of Costeff (Table 16, Figures 14-16). This is not unexpected based upon previous assessments of both equations. Both equations have been demonstrated to perform similarly to the bivariate EPA equation for adults, although the Costeff equation slightly underestimated adult male skin surface area (Costeff: mean and median both = 1.89 $m^2$, USEPA bivariate: mean=1.97 $m^2$ and median = 1.96 $m^2$) and the Burmaster (1998a) equation was found to overpredict skin surface area above its median (Murray and Burmaster, 1992; Burmaster, (1998a). If this same trend applies to the UK data, adult skin surface area obtained using the Burmaster (1998a) equation may be a better measure of central values, but values calculated using the Costeff (1966) equation are likely more representative of upper limits. Given the relatively large difference in upper limits (100th percentiles: Costeff 2.49, Burmaster: 3.12; 95th percentiles: Costeff: 2.19, Burmaster 2.51) but smaller difference in values at or below the median (50th percentile: Costeff = 1.91, Burmaster: 2.06), it may be more appropriate to use the equation of Costeff to generate skin surface area distributions for adults. For cases in which only a single central estimate is needed, the equation of Burmaster should be used.

The correlation between skin surface area and body weight should be relatively consistent across populations. Thus, skin surface area estimates for a given population can be made using the above equations and representative body weight data.

Using mean body weights of 80.0 kg for male and 67.3 kg for female adults (Table 1) and the equation of Burmaster (1998a), resulting skin surface areas are 2.07 $m^2$ for males and 1.76 $m^2$ for females, with an average of 1.92 $m^2$ for both genders. This is slightly greater than the values of 1.93 $m^2$ and 1.69 $m^2$ for males and females and average of 1.8 $m^2$ suggested in the AIHC EFS (AIHC, 1994). The AIHC estimates are based upon the bivariate EPA equation and less recent, lower values for body weight. Ninety-fifth percentiles reported in the AIHC EFS were 2.28 and 2.09 $m^2$ for male and female adults, respectively.

***British University study:***
An equation is also available for a study of skin surface area performed at the University of Technology, Loughborough, UK (Jones *et al*, 1985). The sample population consisted of fifteen females aged 17-39 years, thirteen of whom were university students (nationality not specified). The individuals represented a variety of body sizes and shapes. The resulting equation expressed skin surface area as a function of body weight and upper calf circumference:

$SA = 0.327 + 0.0071a + 0.0292b$

where SA = Surface Area ($m^2$)
a = Body Weight (kg)
b = Upper Calf Circumference (cm)

While both body weight and calf circumference are relatively easy to obtain, data on calf circumference are extremely limited. In addition, the study population was not representative of the general population. A comparison of the 15 measured surface area values and estimated surface area values by the equations of Jones, EPA, Costeff, and Burmaster for the general population and females specifically, is provided in Table 17.

### 3.3.2 Surface area of specific body parts

***Summary***
Based upon specific exposure scenarios, the expected fraction of skin exposed can be estimated using the body part specific fractions of total skin surface area provided in Table 18. Total skin surface area, estimated as specified in the previous section, can then be multiplied by the fraction exposed.

***Relevant Studies***
For most typical dermal exposure scenarios, a portion of the body is exposed rather than the entire skin surface. Thus, estimates of surface area for specific body parts may be more useful than estimates of total surface area.

The fraction of total skin surface area represented by individual body parts is presented by age in Table 19. These averages are based upon US data of extremely small sample size (N=1-5 for each yearly category between ages 1-18). Although limited, these data demonstrate how the fraction of total surface area associated with a given part varies with age, particularly for the head and legs. The head area represents a larger proportion of total surface area for children, whereas the legs represent a larger percentage of total surface area for adults.

Mean proportions for children and adults from the EPA study and a recent review of surface area data (Ihme, 1994) are presented in Table 18. The mean values between the two studies are similar. More detailed information for the US adult data (maximum and minimum percentages by body part) is presented in Table 20.

Exposed skin surface area can be estimated by multiplying the total skin surface area point values or distributions by a constant value representing the fraction of skin that is exposed. The fraction of exposed skin surface will depend upon climate and other aspects specific to a given exposure scenario, such as type of activity. Suggested defaults to use for some exposure scenarios are listed in Table 21 (USEPA, 1997). For hot climates, such as the Mediterranean regions, it may be typical for legs, arms, hands and feet to be exposed. Based upon the Table 18 data, this scenario results in ~50% (children) to 60% (adults) exposed surface area (65-70% if head area is also considered exposed).

If the fraction of skin that is exposed is expected to vary significantly over the exposure period, interpolation may be appropriate. For example, in a scenario with equal amounts of time expected at a low exposure (hands only) and high exposure (legs, arms, hands and feet), a mean value for fraction exposed can be used. Alternatively, if high exposure would be expected for 3/4 of the exposure period and low exposure for 1/4, a weighted average can be taken. If a range of exposures are expected to occur, ex. hands, legs, arms, feet alone or in any combination of two or more, a uniform distribution between the lowest exposure fraction and highest exposure fraction may be more appropriate.

Examples of exposed skin surface area estimation for two exposure scenarios, one with a constant fraction of exposed skin and one with both high and low exposed area, are provided in Appendix A.

*Table 16. Skin Surface Area Distributions based upon Lognormal Body Weight Distributions from HSE Data (1996 for Adult Males, 1995-1997 for Children)*

| SA Equation | Statistics and percentiles for total skin surface area in $m^2$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Adult Males | | Females, 2 yrs | | Males, 2 yrs | | Females, 10 yrs | | Males, 10 yrs | |
| | Costeff | Burmaster | Costeff | Burmaster | Costeff | Burmaster | Costeff | Burmaster | Costeff | Burmaster |
| Mean | 1.91 | 2.08 | 0.59 | 0.60 | 0.62 | 0.64 | 1.20 | 1.17 | 1.19 | 1.12 |
| Std Dev. | 0.17 | 0.25 | 0.06 | 0.05 | 0.06 | 0.06 | 0.18 | 0.18 | 0.16 | 0.17 |
| Percentiles: | | | | | | | | | | |
| 0 | 1.42 | 1.45 | 0.44 | 0.46 | 0.45 | 0.48 | 0.66 | 0.67 | 0.65 | 0.67 |
| 5 | 1.65 | 1.71 | 0.50 | 0.52 | 0.52 | 0.55 | 0.93 | 0.91 | 0.93 | 0.93 |
| 10 | 1.69 | 1.77 | 0.52 | 0.53 | 0.54 | 0.57 | 0.98 | 0.96 | 0.98 | 0.98 |
| 15 | 1.73 | 1.82 | 0.53 | 0.55 | 0.55 | 0.58 | 1.02 | 0.99 | 1.02 | 1.02 |
| 20 | 1.77 | 1.87 | 0.54 | 0.56 | 0.56 | 0.59 | 1.05 | 1.02 | 1.05 | 1.05 |
| 25 | 1.80 | 1.90 | 0.55 | 0.57 | 0.57 | 0.60 | 1.07 | 1.05 | 1.08 | 1.08 |
| 30 | 1.83 | 1.95 | 0.56 | 0.57 | 0.58 | 0.61 | 1.11 | 1.08 | 1.10 | 1.10 |
| 35 | 1.85 | 1.98 | 0.57 | 0.58 | 0.59 | 0.62 | 1.12 | 1.09 | 1.12 | 1.13 |
| 40 | 1.87 | 2.01 | 0.58 | 0.59 | 0.60 | 0.62 | 1.15 | 1.11 | 1.15 | 1.15 |
| 45 | 1.89 | 2.04 | 0.58 | 0.59 | 0.61 | 0.63 | 1.17 | 1.14 | 1.17 | 1.17 |
| 50 | 1.91 | 2.06 | 0.59 | 0.60 | 0.61 | 0.64 | 1.19 | 1.16 | 1.19 | 1.19 |
| 55 | 1.93 | 2.09 | 0.60 | 0.61 | 0.62 | 0.64 | 1.21 | 1.18 | 1.20 | 1.21 |
| 60 | 1.95 | 2.12 | 0.61 | 0.62 | 0.63 | 0.65 | 1.24 | 1.20 | 1.22 | 1.23 |
| 65 | 1.97 | 2.15 | 0.62 | 0.63 | 0.63 | 0.66 | 1.26 | 1.23 | 1.24 | 1.25 |
| 70 | 2.00 | 2.20 | 0.62 | 0.63 | 0.64 | 0.67 | 1.29 | 1.26 | 1.27 | 1.28 |
| 75 | 2.02 | 2.23 | 0.64 | 0.64 | 0.65 | 0.67 | 1.32 | 1.29 | 1.29 | 1.30 |
| 80 | 2.05 | 2.28 | 0.65 | 0.65 | 0.66 | 0.68 | 1.36 | 1.32 | 1.32 | 1.33 |
| 85 | 2.09 | 2.35 | 0.65 | 0.66 | 0.68 | 0.70 | 1.39 | 1.36 | 1.36 | 1.37 |
| 90 | 2.13 | 2.41 | 0.67 | 0.68 | 0.69 | 0.71 | 1.43 | 1.40 | 1.39 | 1.41 |
| 95 | 2.19 | 2.51 | 0.70 | 0.70 | 0.72 | 0.74 | 1.51 | 1.49 | 1.45 | 1.48 |
| 100 | 2.49 | 3.12 | 0.81 | 0.80 | 0.84 | 0.85 | 1.75 | 1.77 | 1.83 | 1.95 |

***Figure 8. Monte Carlo Simulation of Skin Surface Area ($m^2$) for Female Children 2 Years of Age, Calculated Using the Equation of Costeff***

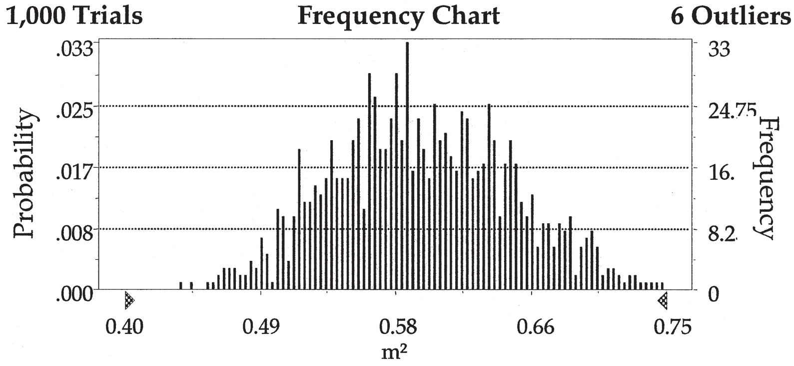



***Figure 9. Monte Carlo Simulation of Skin Surface Area ($m^2$) for Female Children 2 Years of Age, Calculated Using the Equation of Burmaster***

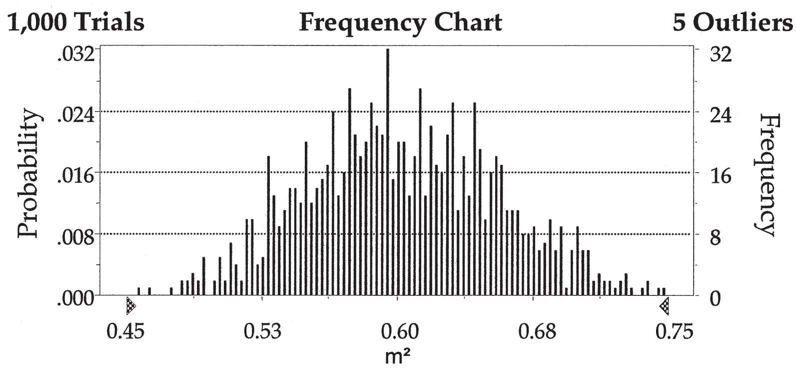



***Figure 10. Monte Carlo Simulation of Skin Surface Area ($m^2$) for Male Children 2 Years of Age, Calculated Using the Equation of Costeff***

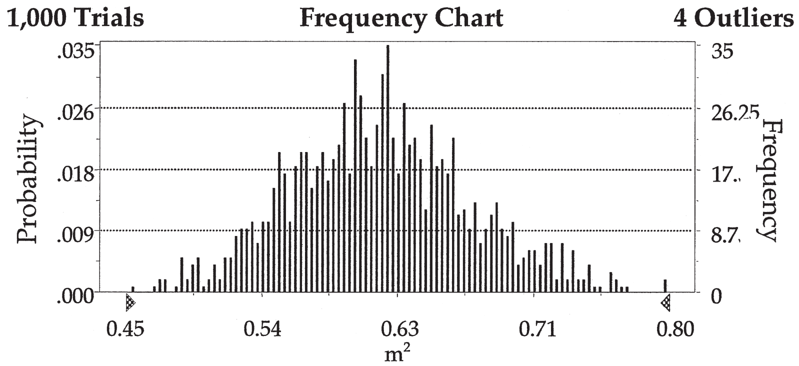


*Figure 11. Monte Carlo Simulation of Skin Surface Area (m2) for Male Children 2 Years of Age, Calculated Using the Equation of Burmaster*

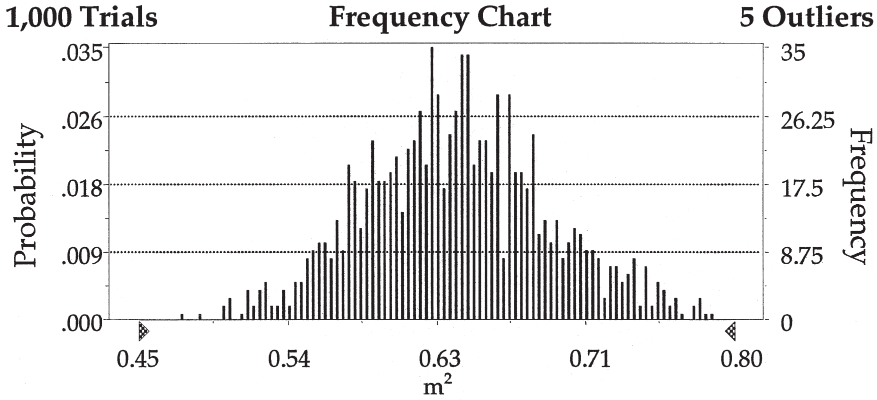



*Figure 12. Comparison of Skin Surface Area Probability Distributions Generated Using the Equations of Costeff and Burmaster and Gender-Specific Lognormal Body Weight Distributions for 2 Year Olds*

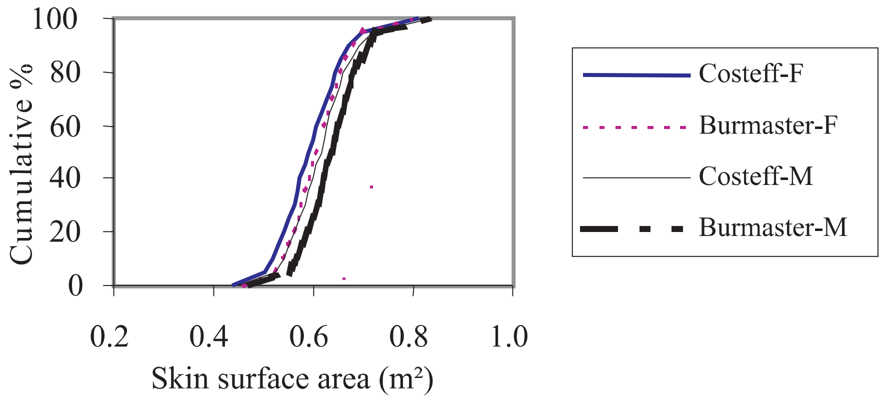



*Figure 13. Comparison of Skin Surface Area Probability Distributions Generated Using the Equations of Costeff and Burmaster and Gender-Specific Lognormal Body Weight Distributions for 10 Year Olds*

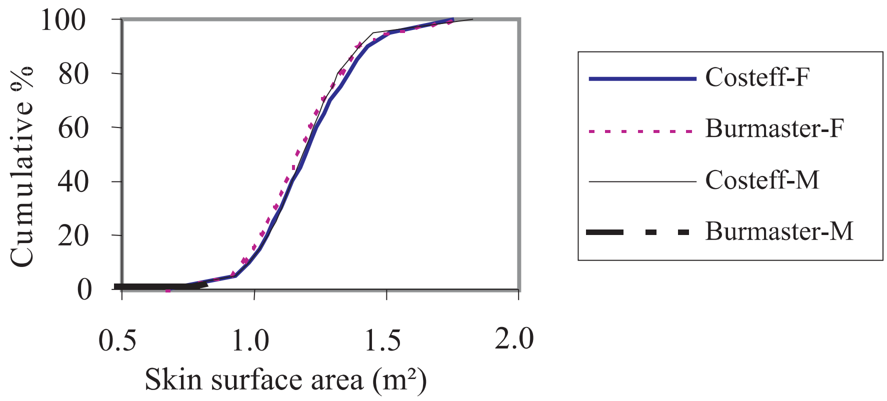


***Figure 14. Monte Carlo Simulation of Adult Male Skin Surface Area Using Costeff Equation***

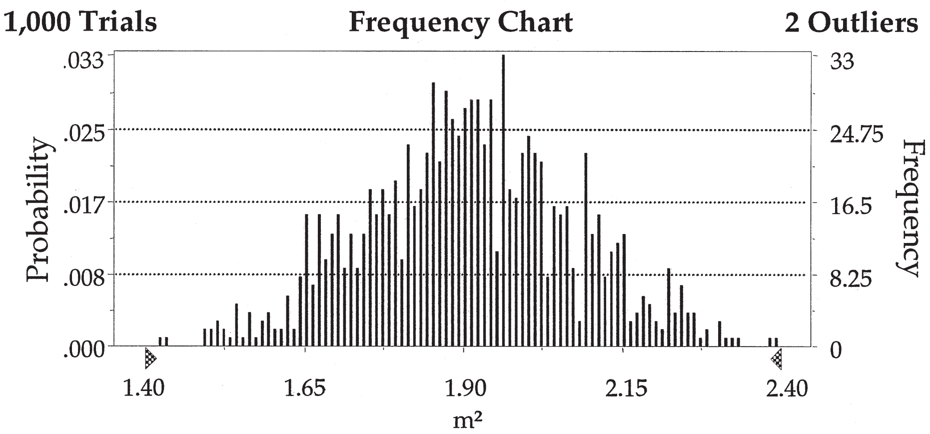



***Figure 15. Monte Carlo Simulation of Adult Male Skin Surface Area Using Burmaster Equation***

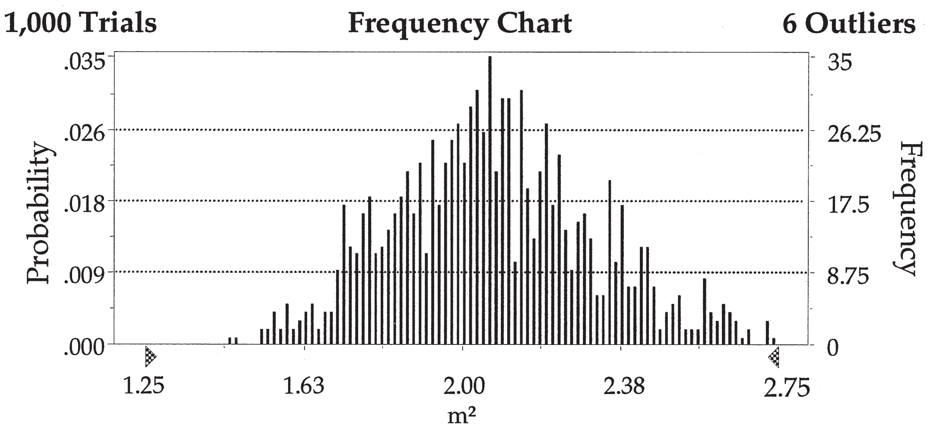



***Figure 16. Adult Male Skin Surface Area: Comparison of Probability Distributions Simulated Using the Equations of Costeff and Burmaster***

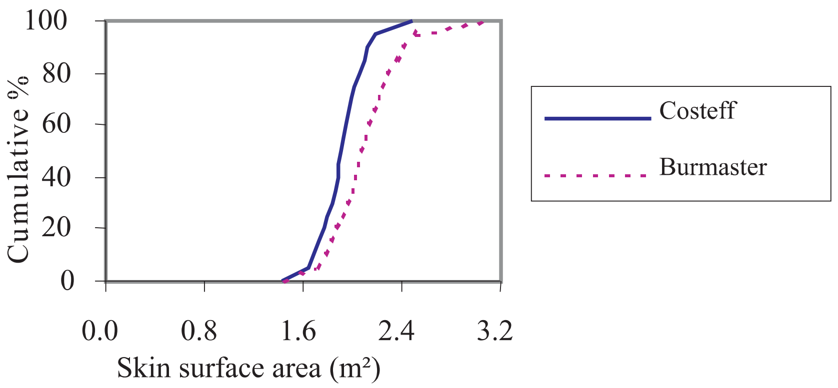


*Table 17. British University Skin Surface Area Study Comparison of Measured Surface Area with Calculated Surface Area*

| Height | Weight | UCC | Surface Area ($m^2$) | | | | | | Difference between calculated and measured surface area | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Measured | UK calc | EPA calc | B calc all | B calc F | C calc | UK calc | EPA calc | B calc all | B calc F | C calc |
| 1.636 | 63.1 | 31.6 | 1.70 | 1.70 | 1.71 | 1.73 | 1.70 | 1.69 | 0.00 | 0.01 | 0.03 | 0.00 | -0.01 |
| 1.719 | 76.2 | 35.8 | 1.95 | 1.91 | 1.92 | 1.97 | 1.93 | 1.88 | -0.04 | -0.03 | 0.02 | -0.02 | -0.07 |
| 1.672 | 64.0 | 33.7 | 1.79 | 1.77 | 1.73 | 1.75 | 1.72 | 1.71 | -0.02 | -0.06 | -0.04 | -0.07 | -0.08 |
| 1.689 | 59.8 | 35.1 | 1.75 | 1.78 | 1.68 | 1.67 | 1.64 | 1.64 | 0.03 | -0.07 | -0.08 | -0.11 | -0.11 |
| 1.701 | 58.4 | 34.2 | 1.77 | 1.74 | 1.67 | 1.64 | 1.61 | 1.62 | -0.03 | -0.10 | -0.13 | -0.16 | -0.15 |
| 1.583 | 61.9 | 36.6 | 1.76 | 1.84 | 1.67 | 1.71 | 1.68 | 1.68 | 0.08 | -0.09 | -0.05 | -0.08 | -0.08 |
| 1.626 | 56.2 | 32.1 | 1.68 | 1.66 | 1.60 | 1.60 | 1.57 | 1.59 | -0.02 | -0.08 | -0.08 | -0.11 | -0.09 |
| 1.678 | 70.2 | 35.4 | 1.91 | 1.86 | 1.82 | 1.86 | 1.83 | 1.80 | -0.05 | -0.09 | -0.05 | -0.08 | -0.11 |
| 1.622 | 80.8 | 38.7 | 2.06 | 2.03 | 1.93 | 2.05 | 2.01 | 1.93 | -0.03 | -0.13 | -0.01 | -0.05 | -0.13 |
| 1.660 | 54.3 | 31.1 | 1.55 | 1.62 | 1.59 | 1.56 | 1.54 | 1.55 | 0.07 | 0.04 | 0.01 | -0.01 | 0.00 |
| 1.547 | 52.2 | 30.3 | 1.63 | 1.58 | 1.51 | 1.52 | 1.50 | 1.52 | -0.05 | -0.12 | -0.11 | -0.13 | -0.11 |
| 1.642 | 79.0 | 36.2 | 1.85 | 1.94 | 1.92 | 2.02 | 1.98 | 1.91 | 0.09 | 0.07 | 0.17 | 0.13 | 0.06 |
| 1.749 | 53.7 | 31.5 | 1.65 | 1.63 | 1.61 | 1.55 | 1.53 | 1.54 | -0.02 | -0.04 | -0.10 | -0.12 | -0.11 |
| 1.577 | 59.3 | 33.0 | 1.65 | 1.71 | 1.63 | 1.66 | 1.63 | 1.64 | 0.06 | -0.02 | 0.01 | -0.02 | -0.01 |
| 1.704 | 47.0 | 31.0 | 1.55 | 1.57 | 1.49 | 1.42 | 1.39 | 1.42 | 0.02 | -0.06 | -0.13 | -0.16 | -0.13 |
| | | | | | | | Mean difference: | | 0.01 | -0.05 | -0.04 | -0.07 | -0.08 |

Height in m
Weight in kg
UCC= Upper calf circumference in cm
UK calc: equation of Jones *et al*, 1985

EPA calc: bivariate EPA equation
B calc all: equation of Burmaster, 1998a using coefficients for males and females combined
B calc F: equation of Burmaster, 1998a using coefficients for females only
C calc: equation of Costeff, 1966

### *Table 18. Percentage of Total Body Surface Area by Body Part*

| Body Part | Source: Ihme, 1994 | | Source: USEPA, 1997 | | |
|---|---|---|---|---|---|
| | Children[1] | Adults[2] | Children[3] (min - max) | Adults[4] (min - max) | Adults[4] N (M:F) |
| Head | 13 | 9 | 13 (9 - 18) | 7 (6 - 11) | 89 (32:57) |
| Neck | 2 | 2 | | | |
| Trunk | | | 34 (30 - 39) | 35 (30 - 42) | 89 (32:57) |
| Arms | | | 13 (12 - 16) | 14 (12-16) | 45 (32:13) |
| Lower arms | 6 | 6 | | 6 (5 - 6) | 6 (6:0) |
| Upper arms | 8 | 8 | | 7 (7 - 8) | 6 (6:0) |
| Hands | 5 | 5 | 5 (5 - 6) | 5 (4 - 7) | 44 (32:12) |
| Legs | | | 27 (18 - 32) | 32 (26 - 35) | 45 (32:13) |
| Thighs | | | | 19 (15 - 22) | 45 (32:13) |
| Lower legs | 11 | 14 | | 13 (11 - 16) | 45 (32:13) |
| Feet | 7 | 7 | 7 (6 - 8) | 7 (6 - 8) | 45 (32:13) |

1 Ages 4 - < 10 years, N not provided
2 Ages 20 - < 75 years, N not provided
3 Average of the mean values for children aged < 1 - 14 year olds, N=19 (8 males:11 females)
4 Average of the mean values for males and females

### *Table 19. Mean Percentage of Total Body Surface Area by Body Part by Age (Source: USEPA, 1997)*

| Age | N (M:F) | Head | Trunk | Hands | Arms | Legs | Feet |
|---|---|---|---|---|---|---|---|
| < 1 | 2 (2:0) | 18.2 | 35.7 | 5.3 | 13.7 | 20.6 | 6.5 |
| 1 < 2 | 2 (1:1) | 16.5 | 35.5 | 5.7 | 13.0 | 23.1 | 6.3 |
| 2 < 3 | 1 (1:0) | 14.2 | 38.5 | 5.3 | 11.8 | 23.2 | 7.1 |
| 3 < 4 | 5 (0:5) | 13.6 | 31.9 | 6.1 | 14.4 | 26.8 | 7.2 |
| 4 < 5 | 4 (1:3) | 13.8 | 31.5 | 5.7 | 14.0 | 27.8 | 7.3 |
| 6 < 7 | 1 (1:0) | 13.1 | 35.1 | 4.7 | 13.1 | 27.1 | 6.9 |
| 9 < 10 | 2 (0:2) | 12.0 | 34.2 | 5.3 | 12.3 | 28.7 | 7.6 |
| 12 < 13 | 1 (1:0) | 8.7 | 34.7 | 5.4 | 13.7 | 30.5 | 7.0 |
| 13 < 14 | 1 (1:0) | 10.0 | 32.7 | 5.1 | 12.1 | 32.0 | 8.0 |
| 16 < 17 | 1 (1:0) | 8.0 | 32.7 | 5.7 | 13.1 | 33.6 | 6.9 |
| 17 < 18 | 1 (1:0) | 7.6 | 31.7 | 5.1 | 17.5 | 30.8 | 7.3 |
| Adult Males | Note 1 | 7.8 | 35.9 | 5.2 | 14.1 | 31.2 | 7.0 |
| Adult Females | Note 1 | 7.1 | 34.8 | 5.1 | 14.0 | 32.4 | 6.5 |
| Average for ages | 1 - 14 | 13.3 | 34.4 | 5.4 | 13.1 | 26.6 | 7.1 |

Note 1 varies by body part, see N in Table 18

***Table 20. Additional Detail of Percentage Total Body Surface Area by Body Part for Adults*** *(Source: USEPA, 1997)*

| **Body Part** | **Adult Males** | | | | | **Adult Females** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **N** | **Mean** | **Std Dev.** | **Min** | **Max** | **N** | **Mean** | **Std. Dev.** | **Min** | **Max** |
| Head | 32 | 7.8 | 1 | 6.1 | 11 | 57 | 7.1 | 0.6 | 5.6 | 8.1 |
| Trunk | 32 | 35.9 | 2.1 | 30.5 | 41 | 57 | 34.8 | 1.9 | 32.8 | 41.7 |
| Upper extremities | 48 | 18.8 | 1.1 | 16.4 | 21 | 57 | 17.9 | 0.9 | 15.6 | 19.9 |
| Arms | 32 | 14.1 | 0.9 | 12.5 | 16 | 13 | 14 | 0.6 | 12.4 | 14.8 |
| Upper arms | 6 | 7.4 | 0.5 | 6.7 | 8.1 | | | | | |
| Forearms | 6 | 5.9 | 0.3 | 5.4 | 6.3 | | | | | |
| Hands | 32 | 5.2 | 0.5 | 4.6 | 7 | 12 | 5.1 | 0.3 | 4.4 | 5.4 |
| Lower extremities | 48 | 37.5 | 1.9 | 33.3 | 41 | 57 | 40.3 | 1.6 | 36 | 43.2 |
| Legs | 32 | 31.2 | 1.6 | 26.1 | 33 | 13 | 32.4 | 1.6 | 29.8 | 35.5 |
| Thighs | 32 | 18.4 | 1.2 | 15.2 | 20 | 13 | 19.5 | 1.1 | 18 | 21.7 |
| Lower legs | 32 | 12.8 | 1 | 11 | 16 | 13 | 12.8 | 1.0 | 11.4 | 14.9 |
| Feet | 32 | 7 | 0.5 | 6 | 7.9 | 13 | 6.5 | 0.3 | 6 | 7 |

*Table 21. **Percentage of Total Surface Area that is Exposed for Various Exposure Scenarios** (Source: USEPA, 1997)*

| Scenario | USEPA Recommendations for Percentage Exposed |
|---|---|
| Swimming and bathing | 75 - 100 |
| Adult outdoor exposure (only head and hands exposed) | 10 |
| Adult outdoor exposure (head, hands, forearms and lower legs exposed) | 25 |
| Moderate climate, winter | 5 |
| Moderate climate, spring and fall | 10 |
| Moderate climate, summer | 25 |

## 3.4 Life Expectancy

### Summary

The average life expectancy of a UK child born in 1998 is 78 years. Life expectancies for European countries are found in Table 22.

### Relevant Studies

Recent statistics on life expectancy for England are provided by gender in Tables 23 and 24. Data indicate that life expectancy has been increasing over the last 25 years and that males have a shorter life expectancy than females. Average life expectancy for a child born in England in 1996 is approximately 77 years (74.6 years for a male, 79.7 years for a female); values for a child born in 1998 in the UK are similar (Table 22). Life expectancies for children born in 1998 are reported for European countries in Table 22 (WHO, 1999b). The UK value of 78 years is slightly greater than the value of 70 years commonly used for risk assessments and the value of 75 years recommended in the EFH based upon US data for 1993 (USEPA, 1997).

***Table 22. Average Life Expectancy at Birth in 1998, European Countries*** *(Source: WHO, 1999b)*

| **Country** | **Life Expectancy (years)** | | |
|---|---|---|---|
| | **M** | **F** | **M + F Average** |
| Albania | 70 | 76 | 73 |
| Armenia | 67 | 74 | 71 |
| Austria | 74 | 80 | 77 |
| Azerbaijan | 66 | 74 | 70 |
| Belarus | 62 | 74 | 68 |
| Belgium | 74 | 81 | 78 |
| Bosnia and Herzegovina | 71 | 76 | 74 |
| Bulgaria | 68 | 75 | 72 |
| Croatia | 69 | 77 | 73 |
| Czech Republic | 70 | 77 | 74 |
| Denmark | 73 | 78 | 76 |
| Estonia | 63 | 75 | 69 |
| Finland | 73 | 81 | 77 |
| France | 74 | 82 | 78 |
| Georgia | 69 | 77 | 73 |
| Germany | 74 | 80 | 77 |
| Greece | 76 | 81 | 79 |
| Hungary | 67 | 75 | 71 |
| Iceland | 77 | 81 | 79 |
| Ireland | 74 | 79 | 77 |
| Israel | 76 | 80 | 78 |
| Italy | 75 | 81 | 78 |
| Kazakhstan | 63 | 72 | 68 |
| Kyrgyzstan | 63 | 72 | 68 |
| Latvia | 62 | 74 | 68 |
| Lithuania | 64 | 76 | 70 |
| Luxembourg | 73 | 80 | 77 |
| Malta | 75 | 79 | 77 |
| Netherlands | 75 | 81 | 78 |
| Norway | 75 | 81 | 78 |
| Poland | 68 | 77 | 73 |
| Portugal | 72 | 79 | 76 |
| Republic of Moldova | 64 | 72 | 68 |
| Romania | 66 | 74 | 70 |
| Russian Federation | 61 | 73 | 67 |
| Slovakia | 69 | 77 | 73 |
| Slovenia | 71 | 78 | 75 |
| Spain | 75 | 82 | 79 |
| Sweden | 76 | 81 | 79 |
| Switzerland | 75 | 82 | 79 |
| Tajikistan | 64 | 70 | 67 |
| The Former Yugoslav Republic of Macedonia | 71 | 75 | 73 |
| Turkey | 67 | 72 | 70 |
| Turkmenistan | 62 | 69 | 66 |
| Ukraine | 64 | 74 | 69 |
| United Kingdom | 75 | 80 | 78 |
| Uzbekistan | 64 | 71 | 68 |
| Yugoslavia | 70 | 75 | 73 |

***Table 23. Male Expectation of Life at Birth (in 1996) and from Selected Ages in England** (Source: UK Government Actuary's Department, 1998,© Crown Copyright, used with permission)*

| Age (in years) | 1982 | 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|---|
| Birth (0) | 71.3 | 73.7 | 74 | 74.1 | 74.4 | 74.6 |
| 5 | 67.3 | 69.3 | 69.6 | 69.7 | 70 | 70.2 |
| 20 | 52.7 | 54.6 | 54.9 | 55 | 55.3 | 55.5 |
| 30 | 43.1 | 45 | 45.3 | 45.5 | 45.7 | 45.9 |
| 50 | 24.5 | 26.3 | 26.6 | 26.7 | 27 | 27.1 |
| 60 | 16.5 | 18 | 18.2 | 18.3 | 18.5 | 18.7 |
| 70 | 10.2 | 11.2 | 11.4 | 11.4 | 11.6 | 11.7 |
| 80 | 5.8 | 6.4 | 6.5 | 6.6 | 6.6 | 6.7 |

***Table 24. Female Expectation of Life at Birth (in 1996) and from Selected Ages in England** (Source: UK Government Actuary's Department, 1998, © Crown copyright, used with permission)*

| Age (in years) | 1982 | 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|---|
| Birth (0) | 77.3 | 79.1 | 79.3 | 79.4 | 79.6 | 79.7 |
| 5 | 73.1 | 74.6 | 74.9 | 74.9 | 75.1 | 75.2 |
| 20 | 58.3 | 59.8 | 60.0 | 60.1 | 60.3 | 60.3 |
| 30 | 48.5 | 50.0 | 50.2 | 50.3 | 50.5 | 50.5 |
| 50 | 29.6 | 30.9 | 31.1 | 31.2 | 31.4 | 31.4 |
| 60 | 21.0 | 22.1 | 22.3 | 22.4 | 22.5 | 22.6 |
| 70 | 13.5 | 14.5 | 14.6 | 14.6 | 14.7 | 14.7 |
| 80 | 7.6 | 8.4 | 8.5 | 8.5 | 8.6 | 8.6 |

# 4. TIME-ACTIVITY PATTERNS

## *4.1 General Observations on Time-Activity Data*

A number of studies have been performed that are related to time budgets of various European populations (Gershuny, 1985). Data are rarely published in a form that is useful for exposure assessment. In addition, data specifically for children were not identified. The parameters of most interest for exposure assessment are those associated with locations where the greatest amount of time is spent (i.e., hours at work, home) or those associated with specific activities where exposure potential may be greater (i.e., field sports, gardening, bathing). Also, time spent indoors vs. outdoors at each of the main locations is of importance. The raw data for several British surveys are available through the University of Essex data archives (http://dawww.essex.ac.uk). Data sets can be purchased or specific analyses can be requested for a fee. The original data for some surveys may be recorded in sufficient detail to produce the types of information needed for exposure assessment.

## *4.2 Weekly Work Hours*

***Summary***

An average of 38-work hours/week is reported by the spring 1998 UK Labour Force Survey (Table 25). Distributions are provided in Table 26. These values represent hours worked per week; additional time spent at the work site during non-working periods, such as lunch, is not included. Less than 4% of the surveyed population worked >60 hours/week. The Labour Force Survey results include both full-time and part-time workers. An average value of 44 hours/week is probably more representative of full-time workers. Data were not identified for the portion of time spent working in a year. Based upon the assumption of 6 weeks for combined vacation and leave, an estimate of ~230 work days/year (46 weeks at 5 days/week) is obtained.

***Relevant Studies***

Average weekly hours at work for the UK are provided in Table 25 for years between 1994 - 1998. These values represent "hours worked per person per week." They include overtime (paid and unpaid), but do not include lunch periods (which may be spent at the work locale). The weekly averages have remained relatively constant over the 1994 -1998 period. These data indicate that typical values for weekly hours at work are 38 hours/week for both males and females, 44 hours/week for males, and 31 hours/week for females. A distribution for hourly work hours is presented in Table 26. These values include both full- and part-time workers. Data from the OECD Labour Force Statistics for 1996 indicate that 8% of males and 45% of females employed in the UK worked part-time (Table 27). Thus, the male value is a better estimate of weekly work hours for full-time workers. The available data are not sufficient to estimate a mean value for full-time workers only. Excluding the lower 8% of responses, the median value for weekly work hours for males still falls in the 31 - 45 hours/week range (the distribution for all male responses is 9% in the < 5 - 30 hours/week range, 52% in the

31 - 45 range, and 39% in the 46 - > 60 range). Results of a 1983/84 time budget survey (Gershuny, 1985) yield similar weekly work hours for full-time employees (42.6 hours/week for full-time male workers, 38.6 hours/week for full-time female workers).

Time budget data for a number of European countries were analysed by Gershuny (1995). A model was developed to estimate the effect of gender, employment status, age and family status and country on the minutes per day spent in each of several activities. The categories used were: “paid work” - includes hours working at home for pay and commuting time; “all domestic unpaid work” - includes core domestic work and other domestic work; “out-of-home leisure - all leisure activities not performed at home; “TV, radio, etc.”; “at home leisure”; and “sleep” - includes personal care. The model prediction for full-time UK workers is 44 hours/week, inclusive of commuting time.

These data do not provide specifics as to time spent at work at a place of employment vs. paid work at home, or the amount of time at home spent in indoors vs. outdoors activity. In addition, details of the time budget surveys upon which they are based are not specified. But they can be used as a rough estimate to indicate the relative amount of time spent at work, at home, or in away-from-home leisure activities by country. Gershuny’s model is presented in Table 28. This model is applied in Table 29 to estimate time spent in full-time paid work (hours/week) by country (age and family status and gender were not considered, just employment status and country).

***Table 25. Average Usual Hours Worked per Person per Week*** *(Source: UK Office for National Statistics, 1999b, © Crown copyright, used with permission)*

| Gender | 1994 | 1995 | 1996 | 1997 | 1998 | Avg | Std Dev. |
|---|---|---|---|---|---|---|---|
| M and F | 38.2 | 38.3 | 38.1 | 38.8 | 38 | 38.28 | 0.31 |
| M | 44.4 | 44.4 | 44.2 | 44.1 | 44 | 44.22 | 0.18 |
| F | 30.6 | 30.7 | 30.6 | 30.8 | 30.8 | 30.70 | 0.10 |

***Table 26. Cumulative Distribution for Usual Hours Worked per Person per Week - Number of People in Employment According to Number of Hours They Usually Work[1]*** *(Source: UK Office for National Statistics[2], 1999c, © Crown copyright, used with permission)*

| Hours/week | All | Males | Females |
|---|---|---|---|
| < 5 | 504 | 118 | 386 |
| 6 - 10 | 1089 | 251 | 839 |
| 11 - 15 | 1075 | 230 | 844 |
| 16 - 20 | 1671 | 300 | 1371 |
| 21 - 25 | 1237 | 232 | 1005 |
| 26 - 30 | 1157 | 257 | 901 |
| 31 - 45 | 12959 | 7593 | 5367 |
| 46 - 50 | 3274 | 2613 | 660 |
| 51 - 55 | 1300 | 1069 | 231 |
| 56 - 60 | 1206 | 1040 | 166 |
| > 60 | 1127 | 963 | 164 |

1 Hours include overtime and exclude lunch breaks
2 Values are presented as found at www.statistics.gov.uk/statbase

***Table 27. Part-time Employment as % of Total Employment*** *(Source: OECD, 1998a (Labour Force Statistics) and b (Employment Outlook), used with Permission) Basis: 1996 data*

| **Country** | **All** | **F** | **M** |
|---|---|---|---|
| Austria | 12.6 | 27.2 | 2.7 |
| Belgium | 14.0 | 30.5 | 3.0 |
| Czech Republic | 6.1 | 10.1 | 3.0 |
| Denmark | 21.5 | 34.5 | 10.8 |
| Finland | 11.6 | 15.3 | 8.3 |
| France | 16.0 | 29.5 | 5.3 |
| Germany | 16.5 | 33.6 | 3.8 |
| Greece | 5.3 | 9.0 | 3.3 |
| Hungary | 5.5 | 8.5 | 2.9 |
| Iceland | 27.9 | 47.4 | 11.0 |
| Ireland | 11.6 | 22.1 | 5.0 |
| Italy | 6.6 | 12.7 | 3.1 |
| Luxembourg | 7.7 | 18.4 | 1.5 |
| Netherlands | 36.5 | 66.1 | 16.1 |
| Norway | 26.6 | 45.9 | 10.2 |
| Poland | 10.6 | 13.4 | 8.3 |
| Portugal | 8.7 | 13.0 | 5.1 |
| Spain | 7.7 | 16.6 | 3.0 |
| Sweden | 23.6 | 39.0 | 9.3 |
| Switzerland | 27.4 | 52.2 | 8.3 |
| Turkey | 23.9 | 38.7 | 17.6 |
| United Kingdom | 24.6 | 44.8 | 8.1 |
| EU-15 | 16.2 | 31.3 | 5.4 |

### *Table 28. Time Use - "World" Countries (Minutes per Day, Adjusted Multiple Classification Analysis Parameters)* *(Source: Gershuny, 1995)*

| | N, weighted | Paid work | All dom work[1] | Core dom work[2] | Other dom work | Out of home leisure | TV etc. | Other at home | Etc.[3] | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| **Grand mean** | | 295 | 231 | 124 | 107 | 113 | 91 | 88 | 622 | 1440 |
| **Sex** | | | | | | | | | | |
| M | 17689 | 43 | -83 | -75 | -8 | 14 | 14 | 9 | 3 | 0 |
| W | 18311 | -42 | 80 | 72 | 8 | -13 | -14 | -8 | -3 | 0 |
| **Employment status** | | | | | | | | | | |
| Full-time | 23587 | 98 | -49 | -30 | -19 | -8 | -7 | -15 | -19 | 0 |
| Part-time | 2539 | -49 | 8 | 4 | 4 | 9 | -3 | 14 | 21 | 0 |
| Non-, un- | -340 | -222 | 116 | 71 | 45 | 16 | 18 | 33 | 40 | 0 |
| **Age and family status** | | | | | | | | | | |
| < 40, no kids | 6799 | 20 | -70 | -36 | -33 | 46 | -10 | 12 | 1 | 0 |
| Pre-school | 8190 | -13 | 52 | 9 | 43 | -13 | -5 | -12 | -9 | 0 |
| School age | 12341 | 0 | 14 | 13 | 2 | -12 | 3 | -3 | -3 | 0 |
| > 40, no kids | 8232 | -4 | -15 | 3 | -18 | -8 | 9 | 6 | 12 | 0 |
| Not known | 439 | -1 | -25 | -15 | -10 | 9 | -11 | 10 | 18 | 0 |
| **Country** | | | | | | | | | | |
| Canada | 2000 | -22 | -13 | -22 | 8 | 4 | 16 | 14 | 1 | 0 |
| Denmark | 2000 | -11 | -70 | -9 | -61 | 63 | 40 | 13 | -35 | 0 |
| France | 2000 | 0 | 9 | 5 | 4 | -26 | -22 | -5 | 44 | 0 |
| Netherlands | 2000 | -41 | -33 | -24 | -9 | 29 | 5 | -8 | -8 | 0 |
| Norway | 2000 | -32 | -5 | 1 | -5 | 51 | -15 | -2 | 2 | 0 |
| UK | 2000 | -17 | -32 | -15 | -17 | -5 | 44 | -11 | 22 | 0 |
| USA | 2000 | 5 | -3 | -16 | 13 | -3 | 32 | -12 | -20 | 0 |
| Hungary | 2000 | 47 | 18 | 17 | 1 | -24 | -21 | -27 | 7 | 0 |
| West Germany[4] | 2000 | 21 | -3 | -3 | 0 | 4 | -21 | -28 | 28 | 0 |
| Poland | 2000 | 46 | 21 | 6 | 15 | -28 | -13 | -9 | -17 | 0 |
| Belgium | 2000 | 25 | -19 | 1 | -19 | -24 | -2 | 5 | 15 | 0 |
| Bulgaria | 2000 | -18 | 22 | -7 | 26 | -16 | -2 | 25 | -8 | 0 |
| Czechoslovakia[4] | 2000 | 34 | 39 | 18 | 21 | -37 | -10 | -6 | -21 | 0 |
| East Germany[4] | 2000 | 12 | 53 | 40 | 13 | -32 | -4 | -21 | -8 | 0 |
| Yugoslavia | 2000 | 22 | 68 | 24 | 44 | -13 | -43 | -20 | -14 | 0 |
| Finland | 2000 | -38 | -21 | -19 | -2 | 12 | 9 | 36 | 2 | 0 |
| Italy | 2000 | -15 | -16 | 15 | -32 | 31 | -10 | 10 | 0 | 0 |
| Australia | 2000 | -18 | -13 | -13 | 0 | 14 | 17 | -9 | 9 | 0 |
| **Multiple R-Squared** | | 0.37 | 0.49 | 0.548 | 0.172 | 0.075 | 0.08 | 0.093 | 0.077 | |

1 All domestic work is the sum of "core domestic work" and "other domestic work".
2 Core domestic work includes cooking and cleaning
3 Personal care, sleep, etc.
4 Based upon older data for former East and West Germany and Czechoslovakia

**Using this table**

Total daily time is the sum of paid work + all domestic work (which is the sum of the next 2 columns, core domestic work and other domestic work) + out of home leisure + TV, etc. + other at home + personal care, sleep, etc. For example, using the grand means: 295 + 231 + 113 + 91 + 88 + 622 = 1440 minutes or 24 hours. To calculate the minutes spent per day in a given activity, the grand mean for the activity is adjusted using the appropriate factor(s). For example, time spent in paid work for a full-time worker in the UK = the grand mean for paid work + full-time adjustment + UK adjustment, or 295 + 98 - 17 = 379 minutes/day. Multiplying this by 7 days/week (as these are daily averages, not adjusted for weekday vs. weekend), yields 2653 minutes or 44 hours/week.

*Table 29. Estimated Weekly Work Hours for Full-time Workers by Country (Based upon the Gershuny 1995 Time Use Model Presented in Table 28)*

| Country specific adjustments | | Adjusted data** | | |
|---|---|---|---|---|
| | Minutes/day | Minutes/day | Hours/week | % of UK |
| Canada | -22 | 371 | 43.3 | 99% |
| Denmark | -11 | 382 | 44.6 | 102% |
| France | 0 | 393 | 45.9 | 105% |
| Netherlands | -41 | 352 | 41.1 | 94% |
| Norway | -32 | 361 | 42.1 | 96% |
| UK | -17 | 376 | 43.9 | 100% |
| USA | 5 | 398 | 46.4 | 106% |
| Hungary | 47 | 440 | 51.3 | 117% |
| West Germany* | 21 | 414 | 48.3 | 110% |
| Poland | 46 | 439 | 51.2 | 117% |
| Belgium | 25 | 418 | 48.8 | 111% |
| Bulgaria | -18 | 375 | 43.8 | 100% |
| Czechoslovakia* | 34 | 427 | 49.8 | 114% |
| East Germany* | 12 | 405 | 47.3 | 108% |
| Yugoslavia | 22 | 415 | 48.4 | 110% |
| Finland | -38 | 355 | 41.4 | 94% |
| Italy | -15 | 378 | 44.1 | 101% |
| Australia | -18 | 375 | 43.8 | 100% |

* Model is based on older data for former East and West Germany and Czechoslovakia

** Adjusted data = base + full-time adjustment + country-specific adjustment

Paid work: = base time + full-time adjustment
= 295 + 98
= 393 minutes/day

## 4.3 Daily Hours at Home/Away


***Summary***

Amount of time spent at home depends upon work status. For full-time UK workers, averages of 15 hours/day at home, 9 hours/day away are estimated based upon 1984 time budget data. For individuals not employed outside of the home, estimated averages are 20.5 hours/day at home, 3.5 hours away. Of the total hours at home, approximately 14 are spent indoors, 1 outdoors for full-time workers. For persons not employed outside the home, a split of 18.5 hours/day indoors, 2-hours/day outdoors is indicated. These values are based upon older data (from 1984), but consistent with other time budget information. Country specific calculations based upon the model of Gershuny (1995) are presented in Table 30. The limitations of this model are discussed below. Data were not available on the number of days away from home in travel each year.


***Relevant Studies***

The UK numbers above are based upon the analysis of 1983/84 Economic and Social Research Council (ESRC) time budget data (Gershuny, 1985), and thus may not be representative of the current UK population. The ESRC survey is based upon a stratified national random sample of UK addresses. Time budget diaries were completed by 1600 individuals >14 years of age. The range in average time spent at home is 14.9-21.3 hours/day (Table 31). Results are provided for all ages combined. Similar values for daily time indoors at home are reported by a more recent (1991) survey of 170 pregnant women residing in Avon, England (Farrow *et al*, 1997). Daily records of time indoors at home were obtained for each expectant mother, the father, and the newborn infant for approximately the last 6 months of pregnancy and first six months after birth. Mothers, fathers and young infants spent an average of 18.4, 14.7, and 19.3 hours/day indoors at home.

The model of Gershuny (1995) results in an intermediate estimate of time at home, approximately 17 hours/day, 7 hours/day away (Table 30). As specified in the previous section, this model is based upon several time budget surveys that probably differed in methodology, and were performed over a range of time. Study details were not provided. Time away from home was calculated as the sum of time at paid work and time in away from home leisure. However, these data do not provide an adequate level of detail for estimating actual time at home. The "paid work" category included paid work performed from the home. The "time at home" estimate included time spent in domestic work such as running errands outside of the home. The actual hours/day at home may not apply but the model results may be useful for estimating the proportion of time spent at home by populations of other countries relative to the UK. Country specific model results range from 16.9-17.8 hours/day at home, without adjusting for employment status.

The UK values reported are similar to median results from the US National Human Activity Pattern Survey (USEPA, 1997). This study estimated that the US population spends approximately 18.4 hours at home/day, 16.4 hours indoors and 2 hours outdoors. The NHAPS data are also broken down by categories such as age, gender, geographic region (climate), and season, and cumulative distributions are provided. These data can be consulted for additional estimates of time spent at home/away (USEPA, 1997).

***Table 30. Estimated Weekly Hours Away from Home by Country (Based upon the Time Use Model of Gershuny, 1995 Presented in Table 28)***

| Country-specific adjustments* (minutes/day) | | Adjusted away leisure (minutes/day) | Work hours** (minutes/day) | Total time away (hours/day) | Total time at home (hours/day) | % of UK |
|---|---|---|---|---|---|---|
| Canada | 4 | 117 | 273 | 6.5 | 17.5 | 99.6% |
| Denmark | 63 | 176 | 284 | 7.7 | 16.3 | 93.0% |
| France | -26 | 87 | 295 | 6.4 | 17.6 | 100.4% |
| Netherlands | 29 | 142 | 254 | 6.6 | 17.4 | 99.1% |
| Norway | 51 | 164 | 263 | 7.1 | 16.9 | 96.1% |
| UK | -5 | 108 | 278 | 6.4 | 17.6 | 100.0% |
| USA | -3 | 110 | 300 | 6.8 | 17.2 | 97.7% |
| Hungary | -24 | 89 | 342 | 7.2 | 16.8 | 95.7% |
| West Germany*** | 4 | 117 | 316 | 7.2 | 16.8 | 95.5% |
| Poland | -28 | 85 | 341 | 7.1 | 16.9 | 96.2% |
| Belgium | -24 | 89 | 320 | 6.8 | 17.2 | 97.8% |
| Bulgaria | -16 | 97 | 277 | 6.2 | 17.8 | 101.1% |
| Czechoslovakia*** | -37 | 76 | 329 | 6.8 | 17.3 | 98.2% |
| East Germany*** | -32 | 81 | 307 | 6.5 | 17.5 | 99.8% |
| Yugoslavia | -13 | 100 | 317 | 7.0 | 17.1 | 97.1% |
| Finland | 12 | 125 | 257 | 6.4 | 17.6 | 100.4% |
| Italy | 31 | 144 | 280 | 7.1 | 16.9 | 96.4% |
| Australia | 14 | 127 | 277 | 6.7 | 17.3 | 98.3% |

* Leisure away from home (base = 113 minutes/day)

** Not adjusted for employment status

*** Model is based upon older data for former East and West Germany and Czechoslovakia

***Table 31. Summary of 1983/84 ESRC Time Activity Data*** *(Source: Gershuny, 1985)*

| Estimated location | Average hours/day spent at each location by employment status and gender | | | | | | | | Average of categories* | % of day |
|---|---|---|---|---|---|---|---|---|---|---|
| | Full-time | | Part-time | | Unemployed | | Nonemployed | | | |
| | M | F | M | F | M | F | M | F | | |
| Home-inside | 13.9 | 14.6 | 15.2 | 17.4 | 17.8 | 19.6 | 18.1 | 19.0 | 16.9 | |
| Home-outside | 1.1 | 0.8 | 2.0 | 1.3 | 2.4 | 1.7 | 2.3 | 1.6 | 1.6 | |
| % of home time outside | 7.2% | 5.4% | 11.7% | 7.1% | 11.8% | 8.0% | 11.1% | 7.7% | 8.8% | |
| Away-indoors | 1.5 | 1.9 | 2.1 | 1.9 | 2.6 | 1.6 | 1.8 | 1.9 | 1.9 | |
| Away-outdoors | 0.7 | 0.5 | 0.8 | 0.7 | 0.8 | 0.7 | 0.8 | 0.7 | 0.7 | |
| Work | 6.8 | 6.1 | 4.6 | 2.7 | 0.4 | 0.3 | 1.0 | 0.7 | 2.8 | |
| Total Home | 14.9 | 15.4 | 17.2 | 18.7 | 20.2 | 21.3 | 20.4 | 20.6 | 18.6 | 78% |
| Total Away (not work) | 2.2 | 2.4 | 2.8 | 2.5 | 3.4 | 2.3 | 2.6 | 2.6 | 2.6 | 11% |
| Total Work | 6.8 | 6.1 | 4.6 | 2.7 | 0.4 | 0.3 | 1.0 | 0.7 | 2.8 | 12% |
| Total Indoors (inc. work) | 22.1 | 22.6 | 21.9 | 21.9 | 20.8 | 21.5 | 20.9 | 21.6 | 21.7 | 90% |
| Total Outdoors | 1.8 | 1.3 | 2.8 | 2.0 | 3.2 | 2.4 | 3.0 | 2.3 | 2.4 | 10% |

Home-inside categories were child care, cooking, dressing, eating, housework, radio, records, sleeping, study at home, talking, tv and video
Home-outside categories were DIY(do it yourself) and gardening
Home-half outside, half inside categories were hobbies, games, home entertainment, reading, writing, relaxing
Away-indoors categories were entertaining away, meetings, pubs, restaurants, religion, shopping, theatre, cinema, museum
Away-outdoors categories were playing sport, walking, watching sport
Away-half indoors, half outdoors categories were domestic travel, errands, leisure travel

Work was considered indoors

* Number is an average across categories and not necessarily representative of the population average (which would weight each category by its percent of the total population)

## 4.4 Time Indoors/Outdoors

***Recommendations***
Average daily values of 22 hours indoors, 2 hours outdoors are estimated for UK adults.

***Relevant Studies***
Based upon data from a 1983/84 ESRC time budget survey, estimated time indoors is ~22 hours/day (Table 31 of previous section). These data are from 1984 and may not be representative of the current population. The results, however, are consistent with a number of other studies. Ott (1988) indicated that time spent outdoors, including travel, in a number of European countries was 2-3 hours/day. Based upon US data, 21 hours are spent indoors, 1.5 hours outdoors and 1.5 hours in travel per day (USEPA, 1997). Values of 22.3 hours indoors and 1.7 hours outdoors per day are recommended in the EFS (AIHC, 1994)

## 4.5 Daily School Hours

***Summary***
A value of 7 hours/day for 190 days per year is estimated for UK children, based upon information provided by the Department for Education and Employment. For secondary school children involved in extracurricular activities, a value of 8 hours/day may be more representative. Children participating in after school or breakfast clubs spend more time per day at school, but data are not available for typical starting or ending time of these activities.

***Relevant Studies***
Information on typical patterns of school attendance was provided by the UK Department for Education and Employment (1999). Typical hours for primary and secondary schools are 9:00 a.m. - 3:30 p.m., although arrival on school premises probably occurs around 8:45 am. It is likely that several minutes are also spent on school premises after dismissal. Based upon 6.5 core hours/day and approximately 15 minutes before and after core hours, estimated time on school premises is 7 hours/school day.

A survey of weekly time for which teachers are present at school to supervise children (i.e., time spent in lessons, collective worship, assembly, registration, breaks and supervision, but not the teachers' lunch periods) is available for 8 primary schools and 10 secondary schools (Department of Education and Science, 1990). The weekly hours do not include lunch periods. This survey reports total weekly hours of 26.4 - 30.0 for primary schools and 28.3 - 30.8 for secondary schools. Dividing by five results in 5.3 - 6.0 hours/day for primary schools and 5.7 - 6.2 hours/day for secondary schools. The sample size is extremely small, but values are consistent with the information provided for typical school hours. If lunch periods are included, daily hours are similar to those estimated above.

Children in secondary school may be involved in extracurricular activities, which typically end about 4:30 pm (one hour additional to the normal school hours). Thus, a total time of 8 hours/day can be used for these children. No information was available for the percentage of children participating in extracurricular activities or the frequency of participation (i.e., how many days/week).

Some children may participate in after school or breakfast clubs, programmes designed for children who need to arrive earlier or stay later than typical school hours. Although specific data are not available, the Department for Education and Employment indicated that only a minority of children, perhaps 10%, participate in these clubs.

The minimum number of school days per year is 190 in the UK (Department of Education and Science, 1990). Information provided by the Department for Education and Employment (2000b) was used to estimate the actual number of school days per year. The department indicated that holidays consist of 6 weeks in summer, 2 weeks at Christmas, 2 weeks at Easter, and ~5 public holidays or teacher training days that occur during the school year. Three additional "half-term" breaks of one week each are also typical. This results in ~14 weeks on holiday, 38 weeks at school per year. At 5 days per school week, the resulting yearly estimate is 190 days, equivalent to the minimum number of days required in the UK. This estimate is based upon perfect attendance, and is thus very probably a conservative value for days at school.

## 4.6 School Time Indoors/Outdoors

***Summary***

Under favourable weather conditions, approximately 2 hours/day may be spent outdoors, 5 hours per day indoors. This value does not include extracurricular activities.

***Relevant Studies***

The UK Department for Education and Employment (1999) indicated that the majority of the school day is spent indoors. Periods that may be spent outdoors under favourable weather conditions include time between arrival on school premises and commencement of school day, after lunch recess, break time, physical education class, and time between dismissal and departure from school premises. Excluding extracurricular activities, time before and after school was estimated as 15 minutes each for a total of 30 minutes. The Department for Education and Employment indicated that typical values for the other activities are: after lunch recess - 30 minutes; break time - 20 minutes; physical education class-45 minutes. For a day in which all of these activities occur outdoors, ~ 2 hours (125 minutes) is spent outside. For a typical school day of 7 hours, this results in ~5 hours indoors. For a child involved in extracurricular activities, the setting of additional time spent at school will depend upon the nature of the activity.

## 4.7 Outdoor Recreation

***Summary***

An average daily value of 0.3 hours is estimated for 365 days/year for adults. Average daily values across gender and employment status ranged from 0.2-0.4 hours/day (Table 32). These values represent population averages from the ESRC time budget survey

(Gershuny, 1985). For US population members who participate in outdoor recreational activity, a median of 2.5 hours has been reported for a day in which outdoor activity took place (US data - cumulative distribution provided in Table 33; 95th and 99th percentiles of 9.6 and 11.5 hours, respectively).

***Relevant Studies***

The average daily value of 0.3 hours is based upon the 1983/84 ESRC time budget survey data (Gershuny, 1985). Only categories estimated to represent away from home, outdoor leisure activities were used to develop this estimate (Table 32). Time allocated to home leisure activities (indoors and outdoors) is already considered under hours per day at home. Away from home leisure activities associated with indoor settings (leisure travel, entertaining away from home, pubs, restaurant, theatre, cinema and visits to museums) were not considered because they are likely to be performed at different locations on different days. All outdoor away from home leisure activities were assumed to take place at the same location each day.

Note, the values above are based upon total outdoor recreation time averaged over the study period, and are representative of a long-term average. The averages include zero values for days in which no outdoor recreational activity was observed and for adults who did not participate at all in this type of activity. Under normal circumstances, outdoor recreational activity will take place for a longer period of daily time, but for only a portion of days in a year. In addition, some adults will not participate in outdoor recreation. Data were not available for the number of days per year that outdoor recreation occurred or for the percent of the population that participated in outdoor recreation.

Results of the US NHAPS survey indicate that for individuals who reported outdoor recreational activity, a 50th percentile of 2.5 hours/day was estimated (distribution provided in Table 33). However, the number of occurrences per year of outdoor activity were not reported. Only 253 of 9386 respondents (~3%) reported participating in outdoor recreational activities during the survey period (USEPA, 1997).

For days in which outdoor recreation occurred, adults (aged 18-64 years) exhibited higher daily median times in outdoor recreation than children (age categories 1-4, 5-11 and 12-17 years) (Table 33). However, it is likely that the frequency (days/year) spent in outdoor recreation is greater for children, based upon typical age related behavioural patterns.

*Table 32. 1983/84 ESRC Time Activity Data for Outdoor, Away from Home Recreation (Source: Gershuny, 1985)*

| Category | Average minutes/day spent in activity by employment status and gender | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Full-time | | Part-time | | Unemployed | | Nonemployed | | Average |
| | M | F | M | F | M | F | M | F | |
| Playing sport | 10.5 | 2.6 | 12 | 3.3 | 10.8 | 2.9 | 8.1 | 5.5 | 7.0 |
| Walking | 8.4 | 4.3 | 7.7 | 4.5 | 7.8 | 16.3 | 15.4 | 7.6 | 9.0 |
| Watching sport | 1.6 | 1.1 | 0.04 | 3.3 | 2.4 | 0.0 | 1.0 | 0.4 | 1.2 |
| SUM | 20.5 | 8 | 19.74 | 11.1 | 21 | 19.2 | 24.5 | 13.5 | 17.2 |
| SUM (hrs/day) | 0.34 | 0.13 | 0.33 | 0.19 | 0.35 | 0.32 | 0.41 | 0.23 | 0.29 |

## 4.8 Shower Duration

*Summary*
Data were not identified for European populations. An average of 7.7 minutes/day is reported for a survey of Australian households. The 95th percentile is 13.5 minutes/day. The distribution of Burmaster (1998b), based upon the Australian data, can be used to estimate shower duration.

*Relevant Studies*
UK or European specific data were not identified for this parameter. Available data are from a survey of 2,500 Australian households (James and Knuiman; Burmaster, 1998b). The mean showering time is 7.7 minutes/day. The mode, median and 95th percentiles are 6.2, 7.2, and 13.5 minutes/day (Burmaster, 1998b). Burmaster (1998b) developed the following distribution for shower duration based upon these data:

$Ts \sim \exp[\text{Normal}(1.9705, 0.3864)]$
Where Ts = shower duration in minutes/day.

These data may not be representative of European customs. In the absence of European specific data, however, they are recommended for use. In addition, data from the US National Human Activity Pattern Survey (NHAPS) on daily time spent bathing can be consulted. The NHAPS data are available as a cumulative distribution, but data are presented for "doers" only (survey participants who did not perform a given activity on the survey day are not included) (USEPA, 1997). The NHAPS data indicate that time spent in the shower or bathtub (minutes/bath) is generally greater for children than adults. Median values are 15 minutes/bath for the general population but 20 minutes/bath for children ≤ 11 years of age. Ninety-fifth percentiles are 35 minutes/bath for the general population and 60 minutes/bath for children (USEPA, 1997).

## *4.9 Employment Tenure*

***Summary***
An employer tenure (time spent working for current employer) of 8 years is reported as an average value for the UK, and 4.4 years as a median. Approximately 10% of the surveyed UK population had an employer tenure of > 20 years (maximum not reported) and 19% under 1 year. Data for the UK and other countries are summarised in Table 34.

***Relevant Studies***
Employment time can be tracked as occupational tenure or employer tenure (USEPA, 1997). Occupational tenure represents the cumulative time a person has worked in his or her current occupation, regardless of the number of employers, periods of unemployment, or periods of employment in other occupations. Employer tenure represents the period of time a person has worked for his or her current employer.

OECD (1993) summarised information on “enterprise” tenure from surveys performed in a number of countries (Table 34). OECD indicates that survey designs varied across countries, but that participants were typically asked how long they had been working for their present employer. Thus, these data are representative of employer tenure rather than occupational tenure.

The median and average enterprise tenure for European countries is greater than those of the US (Table 34). Data on occupational tenure for European countries were not identified. A median US occupational tenure of 6.6 years was reported in the EFH (USEPA, 1997). This value exceeds the median US enterprise (employer) tenure of 3.0 years reported in Table 34. A median working tenure (number of years spent at a specific job) of 4 years was reported in the AIHC EFS based upon US data, with a 95th percentile of 25 years (AIHC, 1994).

**Table 33. Statistics for 24-Hour Cumulative Number of Minutes Spent in Outdoor Recreation, US Data** *(Source: USEPA, 1997)*

| Category | Population Group | N | Mean | Std Dev. | Std Err. | Min | Max | Percentiles 5 | 25 | 50 | 75 | 90 | 95 | 98 | 99 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All | | 253 | 211.23 | 185.48 | 11.661 | 5 | 1440 | 20 | 60 | 165 | 300 | 480 | 574 | 670 | 690 |
| Gender | Male | 140 | 231.78 | 207.41 | 17.529 | 5 | 1440 | 17.5 | 67.5 | 177 | 330 | 502.5 | 600 | 690 | 735 |
| Gender | Female | 112 | 183.67 | 150.15 | 14.188 | 5 | 645 | 20 | 60 | 150 | 255 | 380 | 525 | 585 | 630 |
| Gender | Refused | 1 | 420 | * | * | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 |
| Age (years) | * | 2 | 337.5 | 201.53 | 142.5 | 195 | 480 | 195 | 195 | 337.5 | 480 | 480 | 480 | 480 | 480 |
| Age (years) | 1 - 4 | 13 | 166.54 | 177.06 | 49.109 | 15 | 630 | 15 | 30 | 130 | 180 | 370 | 630 | 630 | 630 |
| Age (years) | 5 - 11 | 21 | 206.14 | 156.17 | 34.078 | 30 | 585 | 60 | 90 | 165 | 245 | 360 | 574 | 585 | 585 |
| Age (years) | 12 - 17 | 27 | 155.07 | 128.28 | 24.687 | 5 | 465 | 5 | 60 | 135 | 225 | 420 | 420 | 465 | 465 |
| Age (years) | 18 - 64 | 158 | 223.61 | 192.97 | 15.352 | 5 | 1440 | 30 | 80 | 172.5 | 310 | 505 | 585 | 690 | 690 |
| Age (years) | > 64 | 32 | 211.06 | 206.59 | 36.521 | 5 | 735 | 5 | 30 | 171 | 375 | 495 | 600 | 735 | 735 |
| Employment | * | 60 | 177.1 | 150.02 | 19.368 | 5 | 630 | 12.5 | 60 | 147.5 | 230 | 395 | 519.5 | 585 | 630 |
| Employment | Full-time | 104 | 210.74 | 153.37 | 15.039 | 5 | 670 | 30 | 82.5 | 180 | 294 | 419 | 511 | 600 | 645 |
| Employment | Part-time | 19 | 205.26 | 204.04 | 46.81 | 30 | 690 | 30 | 60 | 150 | 180 | 570 | 690 | 690 | 690 |
| Employment | Not Employed | 68 | 244.44 | 245.03 | 29.715 | 5 | 1440 | 15 | 60 | 179.5 | 375 | 525 | 690 | 735 | |
| 1440 | | | | | | | | | | | | | | | |
| Employment | Refused | 2 | 187.5 | 10.607 | 7.5 | 180 | 195 | 180 | 180 | 187.5 | 195 | 195 | 195 | 195 | 195 |
| Education | * | 64 | 176.73 | 145.32 | 18.165 | 5 | 630 | 15 | 60 | 152.5 | 225 | 370 | 465 | 585 | 630 |
| Education | < High School | 22 | 259.41 | 177.97 | 37.943 | 5 | 600 | 30 | 105 | 247.5 | 380 | 525 | 600 | 600 | 600 |
| Education | H.S. Graduate | 59 | 238.2 | 228.99 | 29.812 | 15 | 1440 | 20 | 90 | 175 | 310 | 511 | 670 | 690 | |
| 1440 | | | | | | | | | | | | | | | |
| Education | < College | 54 | 218.09 | 172.21 | 23.434 | 5 | 690 | 25 | 65 | 172.5 | 345 | 460 | 550 | 570 | 690 |
| Education | College Grad | 31 | 224.71 | 193.06 | 34.675 | 20 | 690 | 30 | 60 | 150 | 325 | 505 | 645 | 690 | 690 |
| Education | Post Graduate | 23 | 157.61 | 178.18 | 37.153 | 5 | 735 | 10 | 50 | 80 | 200 | 370 | 480 | 735 | 735 |
| Census Region | Northeast | 52 | 189.6 | 160.88 | 22.31 | 5 | 690 | 30 | 60 | 162.5 | 231.5 | 370 | 574 | 670 | 690 |
| Census Region | Midwest | 54 | 212.09 | 228.41 | 31.083 | 5 | 1440 | 20 | 60 | 177.5 | 280 | 419 | 600 | 735 | |
| 1440 | | | | | | | | | | | | | | | |
| Census Region | South | 84 | 217.26 | 175.27 | 19.123 | 5 | 645 | 15 | 62.5 | 150 | 347.5 | 495 | 525 | 600 | 645 |
| Census Region | West | 63 | 220.29 | 179.71 | 22.642 | 10 | 690 | 30 | 75 | 165 | 280 | 545 | 585 | 690 | 690 |
| Day of Week | Weekday | 129 | 197.21 | 195.32 | 17.197 | 5 | 1440 | 15 | 60 | 150 | 275 | 465 | 525 | 670 | 735 |
| Day of Week | Weekend | 124 | 225.81 | 174.26 | 15.649 | 5 | 690 | 20 | 85 | 180 | 310 | 480 | 600 | 690 | 690 |
| Season | Winter | 31 | 196.61 | 165.52 | 29.728 | 5 | 585 | 5 | 60 | 165 | 280 | 440 | 550 | 585 | 585 |
| Season | Spring | 75 | 198.85 | 161.67 | 18.668 | 5 | 690 | 25 | 75 | 180 | 270 | 465 | 545 | 670 | 690 |
| Season | Summer | 102 | 228.16 | 104.18 | 20.217 | 5 | 1440 | 30 | 75 | 179.5 | 325 | 459 | 585 | 690 | 690 |
| Season | Fall | 45 | 203.53 | 193.83 | 28.895 | 5 | 735 | 20 | 60 | 120 | 330 | 505 | 574 | 735 | 735 |

*Table 34. Distribution of Employment by Enterprise (Employer) Tenure, 1991* (Source: OECD, 1993)

| | Australia | Austria[a] | Canada | Finland | France | Germany[d] | Japan[d] | Netherlands[d] | Norway[e] | Spain[g] | Switzerland | UK | USA | Unweighted average[h] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Current tenure (%)** | | | | | | | | | | | | | | |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Under 1 year | 21.4 | 13.8 | 23.5 | 11.9 | 15.7 | 12.8 | 9.8 | 24.0 | 14.9[f] | 23.9 | 17.6 | 18.6 | 28.8 | 18.6 |
| 1 and under 2 years | 13.2 | | 20.0[c] | 12.8 | 10.7 | 10.3 | 16.1[c] | 15.5 | 11.0[f] | 7.7 | 11.7 | 12.4 | 11.6 | |
| 2 and under 5 years | 25.9 | 15.2[b] | 11.9[c] | 24.5 | 15.6 | 17.9 | 11.5[c] | 22.9 | 18.0[f] | 14.8 | 20.7 | 23.9 | 21.3 | |
| Under 5 years | 60.6 | | 55.4 | 49.2 | 42.0 | 41.0 | 37.4 | 62.4 | 43.9[f] | 46.4 | 49.9 | 54.8 | 61.7 | 50.4 |
| 5 and under 10 years | 16.2 | 32.6[b] | 15.2 | 16.7 | 16.2 | 17.8 | 19.7 | 11.4 | 19.7 | 14.0 | 16.8 | 16.1 | 11.7 | 16.0 |
| 10 and under 20 years | 15.2 | 36.7[b] | 19.4 | 21.4 | 25.6 | 24.5 | 23.6 | 15.2 | 24.1 | 21.3 | 18.8 | 19.3 | 17.8 | 20.5 |
| 20 years and over | 8.1 | | 10.0 | 12.8 | 15.8 | 16.7 | 19.3 | 11.0 | 12.3 | 18.4 | 13.8 | 9.6 | 8.8 | 13.0 |
| Unknown | --- | 1.7 | | | 0.4 | | | | | | 0.8 | 0.1 | | |
| **Average tenure (years)** | | | | | | | | | | | | | | |
| All persons | 6.8 | --- | 7.8 | 9.0 | 10.1 | 10.4 | 10.9 | 7.0 | 9.4 | 9.8 | 8.8 | 7.9 | 6.7 | 8.7 |
| Men | 7.8 | --- | 8.9 | 9.4 | 10.6 | 12.1 | 12.5 | 8.6 | 10.2 | 10.6 | 10.4 | 9.2 | 7.5 | 9.8 |
| Women | 5.4 | --- | 6.5 | 8.5 | 9.6 | 8.0 | 7.3 | 4.3 | 8.4 | 8.2 | 6.6 | 6.3 | 5.9 | 7.1 |
| **Median tenure (years)** | | | | | | | | | | | | | | |
| All persons | 3.5 | --- | 4.1 | 5.2 | 7.5 | 7.5 | 8.2 | 3.1 | 6.5 | 6.3 | 5.0 | 4.4 | 3.0 | 5.4 |
| Men | 4.1 | --- | 4.8 | 5.8 | 7.9 | 9.5 | 10.1 | 3.9 | 7.4 | 7.5 | 7.1 | 5.3 | 3.5 | 6.4 |
| Women | 2.9 | --- | 3.3 | 4.9 | 7.0 | 5.0 | 4.8 | 2.0 | 5.8 | 3.3 | 3.6 | 3.7 | 2.7 | 4.1 |

a 1988
b 1 and under 3 years, 3 and under 10 years, and 10 years and over
c 1 and under 3 years and 3 and under 5 years
d 1990
e 1989
f Under 21 months, 21 and under 33 months, 33 and under 57 months, and under 57 months
g 1992
h The unweighted average excludes Austria

## 4.10 Residential Tenure

***Summary***

A median value of 9 years is reported for either current or total residence time based upon US data. Distributions of current residence time are provided in Table 35. Distributions of total residency time by gender and age are provided in Tables 36 and 37. Total residence time by geographic region and housing category are provided in Tables 38 and 39.

***Relevant Studies***

No data were identified for the UK or Europe. In the absence of European specific data, US data were used. These data may not be representative of European populations. Residence time is reported as either total residence time (time between moving into and out of a residence) or current residence time (time since moving into the current residence). A distribution for current residence time based upon a 1991 sample of 93,000 US households is presented in Table 35. Results for total residence time, which must be modelled, are available for two studies: Israeli and Nelson (1992) and Johnson and Capel (1992). Due to differences in modelling approach, the inclusion of age as a factor affecting residence time, and the use of more recent data, the results of Johnson and Capel were assessed to be more representative than those of Israeli and Nelson (AIHC, 1994). Distributions of total residency time by gender and age are provided in Tables 36 and 37.

Results of the Israeli and Nelson study offer the advantage of being reported by household type (urban vs. rural, geographic region). Thus, the Israeli and Nelson results may be more useful for application to specific European regions if these factors are assumed to affect population mobility in the same manner. Total residence time by geographic region and housing category are provided in Tables 38 and 39.

***Table 35. Distribution for Current Residential Tenure, US Data*** *(Source: USEPA, 1997 adaptation of U.S. Bureau of Census, 1993)*

| Years lived in current home | Percent of total households |
|---|---|
| 0-4 | 26.34 |
| 5-9 | 29.04 |
| 10-14 | 11.39 |
| 15-19 | 10.06 |
| 20-24 | 6.69 |
| 24-33 | 8.52 |
| 34-44 | 5.1 |
| 45-54 | 1.9 |
| >55 | 0.95 |
| Total[a]: | 99.99 |

[a] Total does not equal 100 due to rounding errors

***Table 36. Residential Occupancy Period, US Data*** *(Source: USEPA, 1997 citation of Johnson and Capel, 1992)*

| **Statistic** | **Residential occupancy period (years)**<br>**Both genders**<br>**N[a] = 500,000** | <br>**Males only**<br>**N = 244,274** | <br>**Females only**<br>**N = 255,726** |
|---|---|---|---|
| Mean | 11.7 | 11.1 | 12.3 |
| 5th percentile | 2 | 2 | 2 |
| 10th percentile | 2 | 2 | 2 |
| 25th percentile | 3 | 4 | 5 |
| 50th percentile | 9 | 8 | 9 |
| 75th percentile | 16 | 15 | 17 |
| 90th percentile | 26 | 24 | 28 |
| 95th percentile | 33 | 31 | 35 |
| 98th percentile | 41 | 39 | 43 |
| 99th percentile | 47 | 44 | 49 |
| 99.5th percentile | 51 | 48 | 53 |
| 99.8th percentile | 55 | 53 | 58 |
| 99.9th percentile | 59 | 56 | 61 |
| Second largest value | 75 | 73 | 75 |
| Largest value | 87 | 73 | 87 |

a = Number of simulated persons

***Table 37. Residential Occupancy Period by Age, US Data*** *(Source: USEPA, 1997 citation of Johnson and Capel, 1992)*

| **Current Age (years)** | **Residential occupancy period (years)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Mean** | **Percentile** | | | | | |
| | | **25** | **50** | **75** | **90** | **95** | **99** |
| 3 | 6.5 | 3 | 5 | 8 | 13 | 17 | 22 |
| 6 | 8.0 | 4 | 7 | 10 | 15 | 18 | 22 |
| 9 | 8.9 | 5 | 8 | 12 | 16 | 18 | 22 |
| 12 | 9.3 | 5 | 9 | 13 | 16 | 18 | 23 |
| 15 | 9.1 | 5 | 8 | 12 | 16 | 18 | 23 |
| 18 | 8.2 | 4 | 7 | 11 | 16 | 19 | 23 |
| 21 | 6.0 | 2 | 4 | 8 | 13 | 17 | 23 |
| 24 | 5.2 | 2 | 4 | 6 | 11 | 15 | 25 |
| 27 | 6.0 | 3 | 5 | 8 | 12 | 16 | 27 |
| 30 | 7.3 | 3 | 6 | 9 | 14 | 19 | 32 |
| 33 | 8.7 | 4 | 7 | 11 | 17 | 23 | 39 |
| 36 | 10.4 | 5 | 8 | 13 | 21 | 28 | 47 |
| 39 | 12.0 | 5 | 9 | 15 | 24 | 31 | 48 |
| 42 | 13.5 | 6 | 11 | 18 | 27 | 35 | 49 |
| 45 | 15.3 | 7 | 13 | 20 | 31 | 38 | 52 |
| 48 | 16.6 | 8 | 14 | 22 | 32 | 39 | 52 |
| 51 | 17.4 | 9 | 15 | 24 | 33 | 39 | 50 |
| 54 | 18.3 | 9 | 16 | 25 | 34 | 40 | 50 |
| 57 | 19.1 | 10 | 17 | 26 | 35 | 41 | 51 |
| 60 | 19.7 | 11 | 18 | 27 | 35 | 40 | 51 |
| 63 | 20.2 | 11 | 19 | 27 | 36 | 41 | 51 |
| 66 | 20.7 | 12 | 20 | 28 | 36 | 41 | 50 |
| 69 | 21.2 | 12 | 20 | 29 | 37 | 42 | 50 |
| 72 | 21.6 | 13 | 20 | 29 | 37 | 43 | 53 |
| 75 | 21.5 | 13 | 20 | 29 | 38 | 43 | 53 |
| 78 | 21.4 | 12 | 19 | 29 | 38 | 44 | 53 |
| 81 | 21.2 | 11 | 20 | 29 | 39 | 45 | 55 |
| 84 | 20.3 | 11 | 19 | 28 | 37 | 44 | 56 |
| 87 | 20.6 | 10 | 18 | 29 | 39 | 46 | 57 |
| 90 | 18.9 | 8 | 15 | 27 | 40 | 47 | 56 |
| All ages | 11.7 | 4 | 9 | 16 | 26 | 33 | 47 |

***Table 38. Total Residence Time by Household Type[a], US Data** (Source: USEPA, 1997 citation of Israeli and Nelson, 1992)*

| Households | Average Total Residence Time T (years) | Std Dev. $S_T$ | Average Current Residence Time $T_{CR}$ (years) | Households (%) 1985 | 1987 |
|---|---|---|---|---|---|
| All households | 4.55 ± 0.60 | 8.68 | 10.56 ± 0.10 | 100.0 | 100.0 |
| Renters | 2.35 ± 0.14 | 4.02 | 4.62 ± 0.08 | 36.5 | 36.0 |
| Owners | 11.36 ± 3.87 | 13.72 | 13.96 ± 0.12 | 63.5 | 64.0 |
| Farms | 17.31 ± 13.81 | 18.69 | 18.75 ± 0.38 | 2.1 | 1.9 |
| Urban | 4.19 ± 0.53 | 8.17 | 10.07 ± 0.10 | 74.9 | 74.5 |
| Rural | 7.80 ± 1.17 | 11.28 | 12.06 ± 0.23 | 25.1 | 25.5 |
| Northeast Region | 7.37 ± 0.88 | 11.48 | 12.64 ± 0.12 | 21.2 | 20.9 |
| Midwest Region | 5.11 ± 0.68 | 9.37 | 11.15 ± 0.10 | 25.0 | 24.5 |
| South Region | 3.96 ± 0.47 | 8.03 | 10.12 ± 0.08 | 34.0 | 34.4 |
| West Region | 3.49 ± 0.57 | 6.84 | 8.44 ± 0.11 | 19.8 | 20.2 |

a Values of the average current residence time, $T_{CR}$, are given for comparison

***Table 39. Total Residence Time by Household Type, Distribution Data** (Source: USEPA, 1997 citation by Israeli and Nelson, 1992)*

| R(t)[a] = | 0.05 | 0.1 | 0.25 | 0.5 | 0.75 |
|---|---|---|---|---|---|
| All households | 23.1 | 12.9 | 3.7 | 1.4 | 0.5 |
| Renters | 8.0 | 5.2 | 2.6 | 1.2 | 0.5 |
| Owners | 41.1 | 32.0 | 17.1 | 5.2 | 1.4 |
| Farms | 58.4 | 48.3 | 26.7 | 10.0 | 2.4 |
| Urban | 21.7 | 10.9 | 3.4 | 1.4 | 0.5 |
| Rural | 32.3 | 21.7 | 9.1 | 3.3 | 1.2 |
| Northeast Region | 34.4 | 22.3 | 7.5 | 2.8 | 1.0 |
| Midwest Region | 25.7 | 15.0 | 4.3 | 1.6 | 0.6 |
| South Region | 20.7 | 10.8 | 3.0 | 1.2 | 0.4 |
| West Region | 17.1 | 8.9 | 2.9 | 1.2 | 0.4 |

[a] R(t) = fraction of households living in the same residence for t years or more

## *4.11 School Tenure*

***Summary***
Data provided by the UK Department for Education and Employment indicate that typical UK school tenures are 7 years for primary school and 5 years at secondary school. UK data for typical tenure in pre-school or additional voluntary education were not identified.

***Relevant Studies***
Information on typical patterns of school attendance was provided by the UK Department for Education and Employment. School is compulsory for children between the ages of 5-16: primary school for ages 5-11 and secondary school for ages 12-16 (DFEE, 2000a). In England and Wales, compulsory school age commences from the first term after a child's fifth birthday until the last Friday in June in the school year in which the child turns sixteen (DFEE, 2000b).

# 5. RECEPTOR CONTACT RATES

## 5.1 Soil Ingestion Rates

***Summary***
Median soil ingestion rates are estimated as 40 mg/day and 1 mg/day for children and adults, respectively, based upon the studies of Calabrese *et al* (1997) and Stanek *et al* (1997). These data are based upon US studies, but represent the best available information. Data on soil ingestion rates are limited and variable. Region specific differences in child play and hygienic patterns will likely affect typical soil consumption. The current data set are too limited, however, to predict what level of regional variation might be expected, and to prepare distributions of soil ingestion rates. Available data support upper limits of 200 mg/day for children and 300 mg/day for adults. Adult soil ingestion is generally expected to be lower than that of children, based upon age related behavioural patterns. The higher upper limit for adults is related to data variability and indicates the uncertainty in current estimates. The recommended values are based upon studies performed in the summer or autumn; soil ingestion during winter is likely lower.

***Relevant Studies***
Inadvertent soil and dust consumption can occur via food adherence or mouthing of objects or hands. Soil ingestion is probably greater for children than adults due to child behavioural patterns, for example crawling, playing in dirt, and mouthing. Deliberate soil ingestion, or soil pica, is an uncommon behavioural pattern. Very limited data are available on the soil ingestion rates for such individuals. Since soil pica is not considered a typical behaviour, soil ingestion rates for population-based risk assessments are better estimated from studies in subgroups not exhibiting this behaviour. The recent review of Simon (1998) can be consulted for further information on deliberate soil ingestion.

In the first attempt to estimate soil ingestion quantitatively, Binder *et al* (1986) measured levels of soil tracer elements Al, Si, and Ti in feces. These elements were selected since their concentration is high in soil but low in food and their gastrointestinal absorption is low. The amount of soil ingested was calculated based on the fecal and soil concentrations of the tracer elements and the amount of fecal output. Using similar methodology, Clausing *et al* (1987) and van Wijnen *et al* (1990) estimated the amount of soil consumed by children living in the Netherlands. The authors of all of these studies were unable to resolve the widely differing estimates based on the various tracers. These differences were due primarily to lack of accounting for the presence of tracers in food, medicines, diapers and other materials that contact the faeces. For these reasons, the soil ingestion estimates from these studies are considered unreliable.

Calabrese *et al* (1989) and Davis *et al* (1990) used a mass balance approach to estimate soil ingestion in children. With this approach, the levels of tracer substances are measured in food as well as soil and feces of study participants and non-food and soil sources of tracers are minimized. The amount of soil ingested is the difference of the total amount of tracer substance in faeces minus the contribution from food. These studies provide a more accurate estimate of soil ingestion. However, the major sources of errors still remaining in these studies are due to: 1) transit time error, which is reflected in input/output misalignment due to both study design limitations and the presence of high background levels of tracers in ingested food relative to ingested soil; and 2) unknown source error, i.e., non-food non-soil sources for certain elements, particularly Ti. Nonetheless, these studies provided better estimates of soil ingestion.

Based on the knowledge gained from identifying sources of errors in soil ingestion studies, a detection limit model and guidance for selecting tracers for soil ingestion studies were developed (Stanek and Calabrese, 1991; Calabrese and Stanek, 1991; Calabrese and Stanek, 1993; Stanek and Calabrese, 1994). This model relates the log mean square error in percent recovery to the log of the food/soil ratio. The detection limit model and guidance evolved into the "Best Tracer Method" (BTM) which involves ordering of trace elements for each subject-week, based on the food to soil tracer ingestion ratio during the week (Stanek and Calabrese, 1995; Calabrese and Stanek, 1995).

The BTM was applied retrospectively to analyse the data from the Calabrese *et al* (1989) and Davis *et al* (1990) studies. The collective data suggest that the median soil ingestion rate for children is 30-40 mg/day, while the upper 95% estimate is approximately 200 mg/day (Stanek and Calabrese, 1995).

A 7-day mass-balance study of 65 representative children ages 1-4 from Anaconda, Montana, using eight soil tracer substances has recently been conducted (Calabrese *et al*, 1997). The study design included a longer mass-balance period, as well as detailed tracer suppression for food items high in tracer elements included in the study both before and during the sample collection period, and a stronger adult validation study. Using the BTM method, the five best tracer elements were identified as Al, Si, TI, Y, and Zr. According to the BTM, the median soil ingestion was less than 1 mg/day while the upper 95% was 160 mg/day. Based on improvements in study design and analysis, these data may arguably provide the most reliable estimates of soil ingestion in children currently available. However, the study area was a grassy Superfund site. It is possible that the physical nature of the site and possible changes in activity patterns associated with Superfund designation could have led to a depression in soil ingestion rates in this study.

Two soil ingestion studies in adults have been conducted using a mass balance approach, as part of larger studies in children (Calabrese *et al*, 1990, Stanek *et al*, 1997). In the more recent study, ten adults received daily soil capsules containing 20, 100, and 500-mg soil, respectively. A 1-week period separated each study week. Based on 3 weeks of observation, after subtracting the capsule ingestion amounts, the study resulted in a median estimate of 1 mg/day based upon the median of the three trace elements Al, Si, and Y. The 95th percentile was 330 mg/day and the average estimate of soil ingestion was 10 mg/day. These findings represent lower levels of soil ingestion in adults than in the previous mass balance pilot study. However, given the improved study design, the data from the more recent mass balance study by Stanek *et al* (1997), described above, should be considered as the best estimate of a soil ingestion rate in adults.

One limitation of all tracer studies is that they cannot distinguish between the contribution of indoor (dust) vs. outdoor (soil) to tracer element excretory output. Concentrations of tracer elements are generally lower in dust than in soil (Stanek and Calabrese, 1993). Ingestion of household dust from non-soil sources can introduce a bias in the results of soil ingestion tracer studies. Calabrese and Stanek (1992) reported a statistical method to account for the proportion of household dust derived from outdoor sources. Based on this initial work, they estimated that approximately 30% of household dust is from outdoor soil and suggested revising soil ingestion estimates from tracer studies downwards by 31-35%.

In a later publication, this investigative team reported four different methods for distinguishing soil versus dust ingestion: 1) duration correlation; 2) group tracer ratios; 3) individual tracer ratios; and 4) combined multiple simultaneous estimates (Stanek and Calabrese, 1993). They noted that the reliability of the estimate is dependent on the approach used as well as specific features of the individual soil ingestion study such as the soil tracer used. Likely, personal hygiene and household factors also markedly influence these estimates. For technical reasons, the authors placed more reliance on method 3, which indicated that about half of the residual fecal tracers are of dust origin. Given the uncertainties in the estimates, it is not possible at this time to quantify with certainty the proportion of household dust derived from outdoor vs. indoor sources or the proportion of "soil ingestion" represented by soil vs. dust.

## *5.2 Soil Adherence to Skin*

***Summary***
Soil adherence to skin can vary depending upon soil properties, the type of activity resulting in soil contact, and the part of the body that is exposed. Most studies are of non-European populations, but these results are likely applicable to Europe: European data for soil loading on hands falls within the range reported for non-European studies. Although EPA had previously specified an average and upper limit (USEPA, 1992b), its recommendations based upon more recent findings are to use soil adherence data that are activity and body part specific (USEPA, 1997). Limited data on soil adherence by activity and body part are provided in Table 40.

***Relevant Studies***
Most studies report soil adherence based upon soil loading to hands only. Mean values reported from these studies range from 0.5-1.5 mg/cm$^2$ (USEPA, 1997). The results of Roels *et al* (1980), a study of Belgian children, fall within this range (0.9- 1.5 mg/cm$^2$, USEPA, 1997).

The recent work of Kissel *et al* (1996a, b as cited in USEPA, 1997) demonstrates that soil loading varies depending upon body part and activity (Table 40). Moisture content and particle size can also affect soil adherence (USEPA, 1997).

The highest values for soil adherence are for the hands of children playing in mud (Table 40 - geometric means of 35-58 mg/cm$^2$). Soil adherence values for other activities in the same study were 2 to 4 orders of magnitude lower. For the activities studied, geometric means for soil adherence (in mg/cm$^2$) ranged from: 0.0063 - 50.0 for hands, 0.0019 - 11.0 for arms, 0.0008-36.0 for legs, 0.0022 - 24.0 for feet, and 0.0026 - 0.10 for faces.

The EFH recommends that these recent results supercede previous recommendations for soil adherence to skin (previous recommendations were an average of 0.2 mg/cm$^2$, upper end of 1.0 mg/cm$^2$ - USEPA, 1992b). It is recognised, however, that there is need for additional data on soil adherence to skin.

***Table 40. Soil Adherence by Activity and Body Region*** *(Source: USEPA, 1997 citation of Kissel et al, 1996 and Holmes et al, 1996)*

| Activity | Age (years) | N | Dress | Post-Activity Dermal Soil Loadings (mg/cm$^2$)* Geometric mean (Geometric Std Dev.) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Hands | Arms | Legs | Feet | Faces |
| **INDOOR** | | | | | | | | |
| Tae Kwon Do | | 7 | | 0.0063 (1.9) | 0.0019 (4.1) | 0.002 (2.0) | 0.0022 (2.1) | |
| Greenhouse Workers | | 2 | | 0.043 | 0.0064 | 0.0015 | | 0.005 |
| Indoor kids no. 1 | 6-13 | 4 | 3 of 4 in short pants, 2 of 4 in short sleeves, socks, no shoes | 0.0073 (1.9) | 0.0042 (1.9) | 0.0041 (2.3) | 0.012 (1.4) | |
| Indoor kids no. 2 | 3-13 | 6 | 5 of 6 long pants, 5 of 6 long sleeves, socks, no shoes | 0.014 (1.5) | 0.0041 (2.0) | 0.0031 (1.5) | 0.0091 (1.7) | |
| Daycare kids no. 1a | 1-6.5 | 6 | 4 of 6 long pants, 4 of 6 short sleeves, shoes | 0.11 (1.9) | 0.026 (1.9) | 0.030 (1.7) | 0.079 (2.4) | |
| Daycare kids no. 1b | 1-6.5 | 6 | 4 of 6 long pants, 4 of 6 short sleeves, no shoes | 0.15 (2.1) | 0.031 (1.8) | 0.023 (1.2) | 0.13 (0.044) | |
| Daycare kids no. 2 | 1-4 | 5 | 4 of 5 long pants, 3 of 5 long sleeves, all barefoot for part of the day | 0.073 (1.6) | 0.023 (1.4) | 0.011 (1.4) | 0.044 (1.3) | |
| Daycare kids no. 3 | 1-4.5 | 4 | all long pants, 3 of 4 long sleeves, socks and shoes | 0.036 (1.3) | 0.012 (1.2) | 0.014 (3.0) | 0.0053 (5.1) | |
| **OUTDOOR** | | | | | | | | |
| Soccer no. 1 | 13-15 | 8 | 6 of 8 long sleeves, 4 of 8 long pants, 3 of 4 short pants and shin guards | 0.11 (1.8) | 0.011 (2.0) | 0.031 (3.8) | | 0.012 (1.5) |
| Soccer no. 2 | | 8 | | 0.035 (3.9) | 0.0043 (2.2) | 0.014 (5.3) | | 0.016 (1.5) |
| Soccer no. 3 | | 7 | | 0.019 (1.5) | 0.0029 (2.2) | 0.0081 (1.6) | | 0.012 (1.5) |
| Groundskeepers no. 1 | | 2 | | 0.015 | 0.005 | | 0.018 | 0.0021 |
| Groundskeepers no. 2 | | 5 | | 0.098 (2.1) | 0.0021 (2.6) | 0.001 (1.5) | | 0.010 (2.0) |
| Groundskeepers no. 3 | | 7 | | 0.03 (2.3) | 0.0022 (1.9) | 0.0009 (1.8) | 0.0040 | 0.0044 (2.6) |
| Groundskeepers no. 4 | | 7 | | 0.045 (1.9) | 0.014 (1.8) | 0.0008 (1.9) | 0.018 | 0.0026 (1.6) |

* Geometric Mean(Geometric Standard Deviation)

***Table 40. Soil Adherence by Activity and Body Region (continued)***

| Activity | Age (years) | N | Dress | Post-Activity Dermal Soil Loadings ($mg/cm^2$)* Geometric Mean (Geometric Std Dev.) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Hands | Arms | Legs | Feet | Faces |
| **OUTDOOR** | | | | | | | | |
| Groundskeepers no. 5 | | 8 | | 0.032 (1.7) | 0.022 (2.8) | 0.0010 (1.4) | | 0.0039 (2.1) |
| Landscape/Rockery | | 4 | | 0.072 (2.1) | 0.030 (2.1) | | | 0.0057 (1.9) |
| Irrigation Installers | | 6 | | 0.19 (1.6) | 0.018 (3.2) | 0.0054 (1.8) | | 0.0063 (1.3) |
| Gardeners no. 1 | | 8 | | 0.20 (1.9) | 0.050 (2.1) | 0.072 | 0.017 | 0.058 (1.6) |
| Gardeners no. 2 | | 7 | | 0.18 (3.4) | 0.054 (2.9) | 0.022 (2.0) | 0.26 | 0.047 (1.6) |
| Rugby no. 1 | | 8 | | 0.40 (1.7) | 0.27 (1.6) | 0.36 (1.7) | | 0.059 (2.7) |
| Rugby no. 2 | | 8 | | 0.14 (1.4) | 0.11 (1.6) | 0.15 (1.6) | | 0.046 (1.4) |
| Rugby no. 3 | | 7 | | 0.049 (1.7) | 0.031 (1.3) | 0.057 (1.2) | | 0.020 (1.5) |
| Archaeologists | | 7 | | 0.14 (1.3) | 0.041 (1.9) | 0.028 (4.1) | 0.24 (1.4) | 0.050 (1.8) |
| Construction Workers | | 8 | | 0.24 (1.5) | 0.098 (1.5) | 0.066 (1.4) | | 0.029 (1.6) |
| Utility Workers no. 1 | | 5 | | 0.32 (1.7) | 0.20 (2.7) | | | 0.10 (1.5) |
| Utility Workers no. 2 | | 6 | | 0.27 (2.1) | 0.30 (1.8) | | | 0.10 (1.5) |
| Equip. Operators no. 1 | | 4 | | 0.26 (2.5) | 0.089 (1.6) | | | 0.10 (1.4) |
| Equip. Operators no. 2 | | 4 | | 0.32 (1.6) | 0.27 (1.4) | | | 0.23 (1.7) |
| Farmers no. 1 | | 4 | | 0.41 (1.6) | 0.059 (3.2) | 0.0058 (2.7) | | 0.018 (1.4) |
| Farmers no. 2 | | 6 | | 0.47 (1.4) | 0.13 (2.2) | 0.037 (3.9) | | 0.041 (3.0) |
| Reed Gatherers | | 4 | | 0.66 (1.8) | 0.036 (2.1) | 0.16 (9.2) | 0.63 (7.1) | |
| Kids-in-mud no. 1 | 9-14 | 6 | all in short sleeve T-shirts, shorts, barefoot | 35 (2.3) | 11 (6.1) | 36 (2.0) | 24 (3.6) | |
| Kids-in-mud no. 2 | 9-14 | 6 | all in short sleeve T-shirts, shorts, barefoot | 58 (2.3) | 11 (3.8) | 9.5 (2.3) | 6.7 (12.4) | |

* Geometric Mean(Geometric Standard Deviation)

## 5.3 Inhalation Rates

***Summary***

Short-term (hourly) and long-term (daily) inhalation rates are presented in Tables 41 and 42, respectively. These values are based upon US data, but are probably representative of Europeans as well.

***Relevant Studies***

Inhalation rate, also referred to as ventilation rate (VR), will vary depending upon age, gender, weight, health status and level of activity. Ventilation rates are typically measured as minute volume (l of air exhaled/minute), calculated as the volume of air respired in each breath (tidal volume) multiplied by the number of breaths/minute (USEPA, 1997).

Reported literature values for VR are based upon a number of methods (Layton, 1993). These include direct measurement of respired volume, indirectly from heart rate (HR) measurements or self-estimates. The direct method works well for controlled settings, but is not practical for normal living conditions as it requires that a person wear a device for monitoring airflow. For the indirect HR method, HR and VR are measured for a given individual under a variety of physical activities in a controlled setting. These measurements are used to develop equations relating VR to HR. Heart rate, which is less cumbersome to monitor than air flow, is then recorded during normal activities. Ventilation rates are then calculated based upon the VR-HR correlation equations.

Estimates of daily inhalation rate have been based upon the short-term data described above. Inhalation rates are typically grouped into several activity levels. For each activity level, the average inhalation rate is multiplied by the daily time spent at that level. A daily inhalation rate is then calculated by summing the volume of air inhaled for each activity level over the course of a day.

Recently, it has been shown that daily inhalation rates based upon the calculations described above exceed inhalation rates that could be sustained based upon food consumption data (Layton, 1993). The above methods may be used for estimating inhalation rates for short-term exposures, but do not appear to be appropriate for estimates of long-term average inhalation (possibly due to differences in long-term vs. short-term activity patterns). The USEPA recently evaluated available inhalation rate data (USEPA, 1997), and developed the short-term and long-term recommendations summarised in Table 41 and 42. These recommendations are based primarily upon data for the US population, but they can be applied to European populations as well.

### 5.3.1 Short-term rates (hourly inhalation rates by activity level)

The short-term data, separated by age, gender, and activity level, should be reasonably representative of people of any nationality. For a given activity, a similar inhalation rate would be expected for a person of similar body size and gender. This is supported by the similarity of the short-term data to reference inhalation rates reported by ICRP (Snyder *et al*, 1975, Table 41). Basal metabolism is related to body weight (Layton, 1993) and will be similar for UK and US populations given the similarity in body weight. Between ethnic groups, minuted ventilation rates are generally similar (Roy *et al*, 1991).

Inhalation rate data are considered inadequate for estimating distributions for inhalation rates (USEPA, 1997). McKone and Daniel (1991) developed equations relating inhalation rate to body weight for the ICRP data (Table 41). Since they were based upon ICRP data, these equations result in similar values for resting and light activity as ICRP. Using these equations and body weight distributions, distributions can be developed for inhalation rates. This approach is suggested with caution, however: the McKone and Daniel equations are based upon extremely limited data (N=2 for children, N=9 for adults). Any inhalation rate distributions developed should be cross-checked with the range of inhalation rates reported in the literature for similar levels of activity.

Another possible source of inhalation rate distributions for children is the work of Rusconi *et al* (1994). This reference was not evaluated in USEPA (1997). It provides distributions for breathing rate (breaths/minute) by age for Italian children aged 15 days to 3 years old. Respiratory rates were measured for 618 healthy children when awake and calm and when asleep. Repeatability of results was good. Mean, median, and standard deviation of respiratory rate in breaths/minute are provided in Table 43. Centile curves were estimated for each age group as follows:

Awake Data: $\text{Log}_{10}(\text{RR}) = (1.6801 + 0.08592Z_i) - (0.01189 + 0.0004301Z_i)x + 0.0001340x^2$
Asleep Data: $\text{Log}_{10}(\text{RR}) = (1.5773 + 0.09196Z_i) - (0.01314 + 0.0005155Z_i)x + 0.0001765x^2$
Where $Z_i$ = is the normal equivalent deviate corresponding to an ith percentile (for example, Z95 = 1.645) and x = age in months.

If tidal volume data (volume of air exhaled/breath) are available, the equations provided can be used to develop inhalation rate distributions. Tidal volume, however, will vary with age and limited data are available for this age group. Tidal volume for children are summarised for this age group in Table 44.

### 5.3.2 Long-term rates (average daily inhalation rates)

The long-term recommendations in Table 42 are based upon the development of metabolically consistent breathing rates by Layton (1993). Layton used three energy-based approaches for estimating daily inhalation rates: average daily intakes of food energy from dietary surveys, with an upward adjustment to account for under reporting of food consumption; average daily energy expenditure based upon the ratio of total daily expenditure to basal metabolism; and daily energy expenditures based upon time-activity data. The first two approaches yielded consistent results (9.7-11 $m^3$/day and 13-17 $m^3$/day for adult females, and males, respectively). When compared to the first two approaches, the third approach yielded estimates that were greater for females but similar for males (11-15 $m^3$/day and 13-17 $m^3$/day for females and males, respectively). Values from all approaches were below those of the ICRP reference values for males and females (21 and 23 $m^3$/day, respectively; Snyder *et al*, 1975).

The long-term estimate based upon food consumption and long-term energy expenditure may show greater difference among populations given differences in lifestyles and activity levels. However, the estimate of Layton, 1993 is still probably a reasonable representative of European populations as well. Layton used adult food energy intakes of 1400-2400 kcal/day (depending upon age and gender), with caloric intake being approximately 40% fat, 16% protein and 44% carbohydrate. Results of the 1997 UK National Food Survey yield comparable energy intake: an average of 1900 kcal/day, with 38% from fat, 15% protein, and 47% carbohydrate (Slater *et al*, 1998), and thus would result in similar metabolic oxygen demand (11 $m^3$/day average, includes males and females all ages). The 1992-1993 National Diet and Nutrition Survey of British children aged 1.5-4.5 years resulted in a mean energy intake of 1184 kcal/day for boys and 1118 kcal/day for girls, with 36% from fat, 13% from protein and 52% from carbohydrate (Davies, 1997) and results in a daily inhalation rate of 6.5 $m^3$/day. The analysis and results of Layton, which were verified for consistency using more than one data set and approach, are reasonable approximations of long-term daily inhalation rates for the UK population and probably for European populations in general.

***Table 41. Short-term Inhalation Rates ($m^3$/hour)*** *(Source: USEPA, 1997)*

| Population | Activity Level | Mean | Comparison with other studies | |
|---|---|---|---|---|
| | | | **ICRP Reference Man (Snyder *et al*, 1975)** | **McKone and Daniels, 1991*** |
| Adults | | | | |
| | Rest | 0.4 | 0.45 M, 0.36 F | 0.396 |
| | Sedentary | 0.5 | | |
| | Light | 1.0 | 1.2 M, 1.14 F | active: 1.2 |
| | Moderate | 1.6 | | |
| | Heavy | 3.2 | 2.6 M, 1.5 F<br>Maximal exercise: 6.7 M, 5.4 F | |
| Children | | | | |
| | Rest | 0.3 | 0.288 | 0.297 |
| | Sedentary | 0.4 | | |
| | Light | 1.0 | 0.78 | active: 0.81 |
| | Moderate | 1.2 | | |
| | Heavy | 1.9 | | |
| | | | Maximal exercise: 2.0 - 6.8 | |
| Outdoor Workers | | | | |
| | Slow | 1.1 | | |
| | Moderate | 1.5 | | |
| | Heavy | 2.5 | | |
| | Hourly Average | 1.3** | | |

* Based upon the following equations:

child resting IR ($m^3$/hr) = 0.011 x Body weight, average body weight of 27 kg used
child active IR ( $m^3$/hr) = 0.030 x Body weight, average body weight of 27 kg used
adult resting IR ( $m^3$/hr) = 0.006 x Body weight, average body weight of 66 kg used
adult active IR ( $m^3$/hr) = 0.018 x Body weight, average body weight of 66 kg used

** Upper percentile of 3.3

*Table 42. Long-term Inhalation Rates ($m^3$/day)* (Source: USEPA, 1997)

| Population | Gender | Mean | Comparison with other studies ICRP Reference Man (Snyder *et al*, 1975) |
|---|---|---|---|
| Adults | | | |
| 19 - 65 + yrs | F | 11.3 | 21 |
| | M | 15.2 | 23 |
| Children | | | |
| 15 - 18 yrs | F | 12.0 | |
| | M | 17.0 | |
| 12 - 14 yrs | F | 12.0 | |
| | M | 15.0 | |
| 9 - 11 yrs | F | 13.0 | M and F: 15 |
| | M | 14.0 | |
| 6 - 8 yrs | | 10.0 | |
| 3 - 5yrs | | 8.3 | |
| 1 - 2 yrs | | 6.8 | |
| Infants | | | |
| < 1 yr | | 4.5 | 3.8 - 4.7 for 1 yr old, 0.8 for newborn |

*Table 43. Respiratory Rate for Children up to 3 Years of Age* (Source: Rusconi et al, 1994)

| Age (months) | N | Values in breaths/minute Subjects Awake Mean | Median | Std Dev. | Subjects Asleep Mean | Median | Std Dev. |
|---|---|---|---|---|---|---|---|
| < 2 | 104 | 48.0 | 47 | 9.1 | 39.8 | 39 | 8.7 |
| 2 to < 6 | 106 | 44.1 | 42 | 9.9 | 33.4 | 32 | 7.0 |
| 6 to < 12 | 126 | 39.1 | 38 | 8.5 | 29.6 | 28 | 7.0 |
| 12 to < 18 | 77 | 34.5 | 34 | 5.8 | 27.2 | 26 | 5.6 |
| 18 to < 24 | 65 | 32.0 | 32 | 4.8 | 25.3 | 24 | 4.6 |
| 24 to < 30 | 79 | 30.0 | 30 | 6.2 | 23.1 | 23 | 4.6 |
| 30 to < 36 | 61 | 27.1 | 28 | 4.1 | 21.5 | 21 | 3.7 |

***Table 44. Tidal Volume (ml/breath) Data for Children***

| Age | Activity Level | | Reference |
|---|---|---|---|
| | Resting | Maximal | |
| Newborn | 15 | | USEPA, 1997 citation of ICRP, 1981 |
| 9.6 hours | 21 | | USEPA, 1997 citation of ICRP, 1981 |
| 6.6 days | 21 | | USEPA, 1997 citation of ICRP, 1981 |
| 20 hrs- 13 wks | | 51 | USEPA, 1997 citation of ICRP, 1981 |
| 7 months | 42 | | Martonen *et al*, 1989 calculated from equation of Hofmann, 1982 |
| 12 months | 48 | | USEPA, 1997 citation of ICRP, 1981 |
| 22 months | 84 | | Martonen *et al*, 1989 calculated from equation of Hofmann, 1982 |
| 48 months | 152 | | Martonen *et al*, 1989 calculated from equation of Hofmann, 1982 |

## *5.4 Food Consumption Rates*

Consumption rates for various food groups will vary across regions and cultures (Tables 45, 46) (ECETOC, 1994; Grigg, 1993; van de Ven-Breken *et al*, 1990). This effort focused on UK consumption of food items that could preferentially have contact with contaminated sites (e.g., home-grown fruit and vegetables, fish and shellfish). Most food surveys do not address home-grown or home caught consumption. In addition, results are typically presented as point values rather than distributions. A list of general food surveys identified for Europe is presented in Table 47 (the references for these studies can be consulted for further European dietary information).

The data summarised here from national food surveys are representative of the UK in general, but significant variations in eating patterns have been reported among the regions of the UK. Adult populations of Scotland, Wales and the northern part of England show significantly lower frequency of consumption of fresh fruit and fruit juice but higher frequency of consumption of red meat and fish than south-east populations (Whichelow *et al*, 1991). Eating patterns in the UK also vary with age and gender (Whichelow *et al*, 1991; Hackett *et al*, 1997).

The Ministry of Agriculture, Fisheries and Food (MAFF) sponsors a continuous National Food Survey (NFS) of 6,500 UK households each year (Slater *et al*, 1998). The survey reports average food and drink consumption and expenditure per person per week. The survey data cover the UK, and are available for Northern Ireland, Scotland, Wales and regions of England. The survey was initiated in 1940, and for continuity purposes most results are expressed for Great Britain, although some are available on a UK basis.

The NFS sample population is selected to be representative of mainland Britain (including Anglesey and the Isle of Wight, but not the Scilly Isles, the area north of the Caledonian

Canal nor the islands off the Scottish mainland). Each household is surveyed for one week and the households surveyed are changed regularly. Surveys are performed continuously throughout the year.

Consumption estimates in the NFS are based upon food purchased, home-produced, and free food consumed (Slater *et al*, 1998). These data represent the quantity of food entering the home, not individual consumption. Free food that is obtained from a personal farm, garden, business, hedgerow or allotment is recorded as it is used. Thus, values for these food sources may be more representative of actual consumption than values for purchased items, but waste and the number of household members consuming each item are not documented. Consumption data on food purchased and eaten outside of the home is also collected but analyzed separately.

Estimates of total dietary intake are also available from the MAFF National Diet and Nutrition Surveys (NDNS) (Gregory *et al*, 1990, 1995). These surveys focus on specific age groups and are cross sectional studies designed to be representative of the national British population (England, Scotland and Wales).

For the NDNS of British children aged 1.5-4.5 years, a record of weighed dietary intake was obtained for four consecutive days for each participating child (1675 children participated). Each four-day period included 2 weekend days and 2-week days, with Mondays and Tuesdays being equally represented as Thursdays and Fridays. Information from the 2-week days was weighted to 5 days and the weighted information added to the 2 weekend days to calculate average daily intake. The survey was performed over a 12-month period (July 1992 - June 1993) to account for possible seasonal variations in dietary intake. Foods eaten in and out of the home were included.

The NDNS does not provide any information on consumption of home-grown items. Home-grown consumption data, while extremely limited, are provided in the NFS; thus, NFS data serve as the basis for the estimates of home-grown consumption. Data are taken from the 1997 main survey of Great Britain; the survey population was 75% adults and 25% children (Slater *et al*, 1998).

***Table 45. Average Food Consumption in the European Community and its Member Countries*** *(Source: ECETOC, 1994 citation of Euromonitor 1992, European Marketing Data and Statistics. Used with permission.)*

| Intake of | Average food consumption (kg per capita per year) | | | | | | | | | | | | Range | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EC | B | DK | F | D | GR | IRL | I | NL | P | SP | UK | min | max |
| Meat[1] | 94.0 | 105.0 | 108.9 | 109.9 | 104.9 | 76.4 | 87.3 | 87.5 | 88.8 | 68.4 | 95.0 | 77.3 | 68.4 | 109.9 |
| Beef and veal | 22.0 | 22.3 | 18.1 | 30.7 | 23.7 | 19.0 | 19.0 | 26.8 | 19.3 | 13.6 | 11.5 | 17.0 | 11.5 | 30.7 |
| Pork | 40.7 | 49.1 | 69.1 | 37.6 | 63.2 | 22.2 | 34.7 | 30.8 | 47.6 | 25.9 | 47.4 | 24.8 | 22.2 | 69.1 |
| Other | 21.7 | 19.3 | 13.3 | 25.2 | 12.6 | 29.5 | 26.7 | 20.9 | 18.5 | 21.9 | 27.4 | 25.0 | 12.6 | 29.5 |
| Fish | 10.1 | 10.2 | 41.8 | 7.5 | 7.4 | 7.2 | 12.6 | 10.1 | 9.8 | 24.7 | 20.3 | 3.5 | 3.5 | 41.8 |
| Milk + yogurt | 82.4 | 67.8 | 74.2 | 65.8 | 65.8 | 66.9 | 173.6 | 69.7 | 79.3 | 52.1 | 102.6 | 122.3 | 52.1 | 173.6 |
| Butter | 4.9 | 8.6 | 6.9 | 8.6 | 8.5 | 1.0 | 5.5 | 2.4 | 3.9 | 0.9 | 0.6 | 4.2 | 0.6 | 8.6 |
| Cheese | 14.5 | 12.6 | 12.8 | 22.4 | 17.4 | 22.1 | 5.4 | 17.6 | 15.0 | 5.2 | 5.5 | 8.0 | 5.2 | 22.4 |
| Fruit + vegetables | 205.6 | 173.8 | 149.8 | 194.0 | 196.4 | 248.3 | 148.3 | 277.5 | 242.5 | 165.4 | 252.6 | 131.6 | 131.6 | 277.5 |
| Cereals | 116.5 | 98.7 | 93.1 | 101.8 | 99.6 | 145.2 | 144.7 | 160.0 | 74.5 | 125.4 | 97.7 | 119.6 | 74.5 | 160.0 |
| Potatoes | 83.3 | 97.6 | 62.9 | 73.6 | 69.6 | 86.4 | 140.2 | 38.0 | 87.0 | 111.5 | 107.0 | 106.7 | 38.0 | 140.2 |

1 Total does not reflect the sum of the subgroups

***Table 46. Average Food Consumption in the European Community and its Member Countries*** *(Source: ECETOC, 1994 citation of Euromonitor 1992, European Marketing Data and Statistics. Used with permission.)*

| Intake of | Average food consumption in g per kg bodyweight per day[1] | | | | | | | | | | | | Range | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **EC** | **B** | **DK** | **F** | **D** | **GR** | **IRL** | **I** | **NL** | **P** | **SP** | **UK** | **min** | **max** |
| Meat | 4.4 | 5.0 | 5.1 | 5.2 | 5.0 | 3.6 | 4.1 | 4.1 | 4.2 | 3.2 | 4.5 | 3.7 | 3.2 | 5.2 |
| Beef and veal | 1.0 | 1.1 | 0.9 | 1.5 | 1.1 | 0.9 | 0.9 | 1.3 | 0.9 | 0.6 | 0.5 | 0.8 | 0.5 | 1.5 |
| Pork | 1.9 | 2.3 | 3.3 | 1.8 | 3.0 | 1.0 | 1.6 | 1.5 | 2.2 | 1.2 | 2.2 | 1.2 | 1.0 | 3.3 |
| Other | 1.0 | 0.9 | 0.6 | 1.2 | 0.6 | 1.4 | 1.3 | 1.0 | 0.9 | 1.0 | 1.3 | 1.2 | 0.6 | 1.4 |
| Fish | 0.5 | 0.5 | 2.0 | 0.4 | 0.3 | 0.3 | 0.6 | 0.5 | 0.5 | 1.2 | 1.0 | 0.2 | 0.2 | 2.0 |
| Milk + yogurt | 3.9 | 3.2 | 3.5 | 3.1 | 3.1 | 3.2 | 8.2 | 3.3 | 3.7 | 2.5 | 4.8 | 5.8 | 2.5 | 8.2 |
| Butter | 0.2 | 0.4 | 0.3 | 0.4 | 0.4 | 0.0 | 0.3 | 0.1 | 0.2 | 0.0 | 0.0 | 0.2 | 0.0 | 0.4 |
| Cheese | 0.7 | 0.6 | 0.6 | 1.1 | 0.8 | 1.0 | 0.3 | 0.8 | 0.7 | 0.2 | 0.3 | 0.4 | 0.2 | 1.1 |
| Fruit + vegetables | 9.7 | 8.2 | 7.1 | 9.2 | 9.3 | 11.7 | 7.0 | 13.1 | 11.5 | 7.8 | 11.9 | 6.2 | 6.2 | 13.1 |
| Cereals | 5.5 | 4.7 | 4.4 | 4.8 | 4.7 | 6.9 | 6.8 | 7.6 | 3.5 | 5.9 | 4.6 | 5.6 | 3.5 | 7.6 |
| Potatoes | 3.9 | 4.6 | 3.0 | 3.5 | 3.3 | 4.1 | 6.6 | 1.8 | 4.1 | 5.3 | 5.1 | 5.0 | 1.8 | 6.6 |

1 Averages over lifetime assuming average bodyweight of 58 kg (table 1 values divided by 58 kg and 365 days/year)

**Table 47. Surveys of European Food Consumption or Purchasing**

| Country | Reference | Food Item | Comments |
| --- | --- | --- | --- |
| **Multiple Countries:** | | | |
| Various European countries | van de Ven-Breken *et al*, 1990, study by Dutch Institute for Health and Environment -RIVM | | review of dietary information, provides references for a number of studies, includes information on home-grown consumption |
| 14 European countries: B, DK, FIN, FR, G, GR, ICL, I, NL, N, P, S, SW, UK | TRANSFAIR study, van Poppel, 1998 | | studied market baskets in 14 European countries, then 100 food samples representative of the total fat and trans fatty acid intake were purchased in 1995-1996, analyzed, and TFA intake estimated based upon each country's food-consumption survey data |
| Europe | Grigg, 1993 | All | consumption and eating behaviour differ by country |
| **Individual Countries** | | | |
| Denmark | Andersen *et al*, 1996 | All | 7 day record, N = 3098, performed in 1995 |
| France | SECODIP , Chambolle *et al*, 1995 | All | household purchases throughout a year, N=6000 |
| France | Le Francois *et al*, 1996 | All | food eaten outside of the home (Out of Home Food Survey managed by CREDOC, done in 1994) |
| Germany, Dortmund area | DONALD study, Forschungsinstitut für Kindernahrung, Dortmund, cited on European Commission web page | | infants and young persons in families from favourable social backgrounds, all, 3 day weighed diet records |
| Germany | Schneider *et al*, 1995 | Vegetables | Distributions |
| Great Britain | Gregory *et al*, 1990 | All | British adults diet study |
| Great Britain | Mills and Tyler, 1992 | All | British infants 6-12 months |
| Great Britain | Gregory *et al*, 1995 | All | British 1.5-4.5 yrs old |
| Netherlands | Dutch National Food Consumption Survey, Hulshof and Van Staveren, 1991 | | > 6000 people, 10 different age groups and various food classes, detailed dietary data, may include home-grown |
| Russia | Martinchik *et al*, 1996 | All | Moscow schoolchildren 10 and 15 yrs old, 24 hr recall for 2 consecutive days |
| Scotland | Payne and Belton, 1992 | All | 7-day weighted inventory of food and nutrient intake for 153 healthy children 2-5 yrs old in Edinburgh |
| Spain | Pérez-Llama *et al*, 1996 | All | adolescents in SE Spain, recall of previous 24 hr, relative consumption of various food groups |
| Spain | Estívariz *et al*, 1996 | Milk products | Madrid schoolchildren, 24 hr recall for 2 days and estimated food intake record for 2 days |

### 5.4.1 Home-grown vegetable and fruit consumption rate

*Summary*

Few data are available for consumption of home produced items. For the British population as a whole, including all households that do not consume home produced items, average weekly consumption of home produced items over the course of a year is provided in Table 48. Based upon home-grown consumption information for rural populations of other countries, the following values in g/person/day are estimated for Great Britain: average 52, upper limit 87 for fresh vegetables; average 53, upper limit 106 for fresh potatoes; average 11, upper limit 43 for fruit. The assumptions used in the estimates are detailed below, and should be reviewed for relevance to a given exposure scenario before these values are applied.

*Relevant Studies*

The average consumption of home-grown items across the UK population was estimated as the difference between the yearly averages for consumption and purchase (g/person/week) for the 1997 NFS survey (Table 48) (Slater *et al*, 1998). These data are extremely limited, however. For each item, the portion of the survey population that consumes home-grown items and the period over which they are consumed needs to be known to estimate relevant consumption rates. For some particular items, for example rhubarb and fresh peas and fresh beans, home produced items represent significant proportions of consumption. However, consumption of these items is low relative to other vegetables or fruits (Table 48). In addition, consumption of fresh peas and beans (both purchased and home-grown) is low compared to the total consumption of peas and beans from all sources. With further analysis, the archived NFS data could be used to develop better estimates of home-grown consumption (archived data are available from the University of Essex data archives, http://dawww.essex.ac.uk).

A useful observation based upon the data in Table 48 is that only a small portion of the population average consumption for home produced vegetables is due to processed vegetables (1 g/person/week out of 61 g/person/week total). The majority of home produced vegetables are consumed fresh.

Studies of rural populations of France and Greece estimate that home-grown produce represents ~60% of vegetable consumption, 50% of potato consumption, and 25% of fruit consumption (van de Ven-Breken *et al*, 1990). These values are averages for the study populations.

Total weekly consumption of the fresh vegetable items (excluding potatoes) for which consumption exceeds purchase is 685 g/person/week (Table 48). Based upon an average of 60% consumption, a daily consumption of 60 g/person/day home produced vegetables is calculated. An upper limit can be estimated as 98 g/person/day assuming 100% home production. For some items, such as leeks, fresh home-grown produce will be available throughout most of the year. For other items, such as cucumbers and tomatoes, this is likely not the case. Cucumbers, tomatoes, peas and beans represent 155 g/person/week of home consumption that is likely to occur for only a portion of the year. Subtracting these values results in an average consumption of 530 g/person/week. Applying the

60% and 100% fractions as average and upper estimates to this value results in 45 g/person/day as an average and 76 g/person/day as an upper estimate for consumption of nonseasonal vegetables.

In the absence of specific data, an average yearly value for home-grown consumption was estimated assuming that each of the conditions above (all fresh vegetables available or limited availability) apply for half a year. This results in a final average of 52 g/person/day and upper limit of 87 g/person/day.

For potatoes, assuming home production accounts for 50% of fresh potato consumption, 53 g/person/day is estimated as an average value. An upper limit of 106 g/person/day is also calculated. Since potatoes store very well, consumption may occur throughout the entire year.

Total weekly fruit intake for categories where consumption exceeded purchase is 299 g/person/week (Table 48). Assuming 25% of this is home-grown results in an average daily consumption of 11 g/person/day, with an upper limit of 43 g/person/day based upon 100% home production. Since the predominant portion of this consumption is related to items which store well (apples, pears, frozen fruit), these values can be applied over the course of a year.

Mean consumption of home-grown produce for a German population are presented in Table 49 by age (Ihme, 1994). Consumption values for fruit and vegetables are greater than those estimated for the UK, while values for potatoes are lower. The country data in Table 45 indicate that per capita fruit and vegetable consumption in Germany is 150% of the UK value, and German potato consumption is 65% that of the UK. The estimated values for British vegetable and potato home-grown consumption are thus consistent with the German values, but the British estimate of home-grown fruit consumption is low in comparison. The relative ratios between adult and child consumption may be applicable for countries in which similar age-specific dietary patterns are expected. Detailed distributional information for US home-grown consumption, by age, season and geographic region, is presented in the EFH (USEPA, 1997).

***Table 48. Summary of Home-grown Vegetable and Fruit Consumption from NFS***
*(Based upon: Slater et al, 1998)*

| **Category and Individual Items** | **Consumption and Purchase (g/person/week)*** | | | **% Home-grown** |
|---|---|---|---|---|
| | **Total Consumption** | **Total Purchase** | **Home-grown consumption** | **of total consumption**** |
| **VEGETABLES** | | | | |
| Fresh | | | | |
| Potatoes | 745 | 724 | 21 | 2.8% |
| Cabbage, fresh | 59 | 55 | 4 | 6.8% |
| Cauliflower, fresh | 84 | 82 | 2 | 2.4% |
| Leafy salad, fresh | 57 | 55 | 2 | 3.5% |
| Peas, fresh | 6 | 4 | 2 | 33.3% |
| Beans, fresh | 17 | 10 | 7 | 41.2% |
| Total fresh green vegetables | 251 | 234 | 17 | 6.8% |
| Carrots, fresh | 115 | 113 | 2 | 1.7% |
| Turnip and swede, fresh | 31 | 30 | 1 | 3.2% |
| Other root vegetables, fresh | 22 | 20 | 2 | 9.1% |
| Onions, shallots, leeks, fresh | 97 | 90 | 7 | 7.2% |
| Cucumber, fresh | 35 | 34 | 1 | 2.9% |
| Tomatoes, fresh | 97 | 90 | 7 | 7.2% |
| Miscellaneous fresh vegetables | 65 | 63 | 2 | 3.1% |
| Total other fresh vegetables | 497 | 475 | 22 | 4.4% |
| Total fresh vegetables where consumption exceeds purchase (excluding potatoes) | 685 | 646 | 39 | 5.7% |
| All sources | | | | |
| Potatoes | 914 | 893 | 21 | 2.3% |
| Peas | 75 | 73 | 2 | 2.7% |
| Beans | 147 | 140 | 7 | 4.8% |
| All other frozen vegetables and vegetables products | 48 | 47 | 1 | 2.1% |
| Total processed vegetables | 568 | 567 | 1 | 0.2% |
| Total vegetables, excluding potatoes and potato products | 1120 | 1080 | 40 | 3.6% |
| **TOTAL ALL VEGETABLES** | 2061 | 2000 | 61 | 3.0% |
| **FRUIT** | | | | |
| Fresh | | | | |
| Apples | 179 | 173 | 6 | 3.4% |
| Pears | 47 | 46 | 1 | 2.1% |
| Stoned fruit | 47 | 44 | 3 | 6.4% |
| Soft fruit, other than grapes | 21 | 17 | 4 | 19.0% |
| Rhubarb | 3 | 1 | 2 | 66.7% |
| Total fresh fruit | 712 | 696 | 16 | 2.2% |
| Frozen fruit/fruit products | 2 | 1 | 1 | 50.0% |
| Total other fruit and fruit products | 356 | 354 | 2 | 0.6% |
| Total fruit where consumption > purchase | 299 | 282 | 17 | 5.7% |
| **TOTAL FRUIT** | 1068 | 1050 | 18 | 1.7% |

* Only items with differences between consumption and purchase are listed

** Note 1.9% represents one weeks consumption over a year

***Table 49. Home-grown Consumption of Vegetables and Fruit** (Source: Ihme, 1994)*

| Age (years) | Amount consumed (arithmetic means in g/day) Fruit | Potatoes | Leaf Vegetables | Legumes | Fruit Vegetables | Root Vegetables | Leaf, Fruit, Root Vegetables and Legumes |
|---|---|---|---|---|---|---|---|
| 0 - <1 | 51 | 0 | 14 | 10 | 8 | 12 | 44 |
| 1 - <4 | 57 | 19 | 21 | 8 | 10 | 24 | 63 |
| 4 - <7 | 64 | 37 | 19 | 5 | 12 | 25 | 61 |
| 7 - <10 | 56 | 2 | 8 | 6 | 5 | 14 | 33 |
| 10 - <15 | 60 | 32 | 18 | 7 | 14 | 27 | 66 |
| 15 - <20 | 42 | 25 | 25 | 6 | 18 | 23 | 72 |
| 20 - <75 | 91 | 30 | 28 | 10 | 17 | 36 | 91 |
| Lifelong Average | 82 | 28 | 26 | 9 | 15 | 33 | 83 |

### 5.4.2 Fish and shellfish consumption rate

*Summary*

National Food Survey data indicate an average of 20 g fish/person/day for Britons. An average shellfish consumption of 1g/person/day is also reported.

*Relevant Studies*

Average UK fish and shellfish consumption rates are available from the 1997 NFS (Table 50) (Slater *et al*, 1998). Average fish consumption (not including shellfish) is 20 g/person/day. The average for shellfish consumption is 1 g/person/day.

Consumption of recreationally caught fish was estimated as the difference between average consumption and purchase (in g/person/week). These values represent the average consumption of non-purchased fish for the population of Great Britain, but do not represent average intake for anglers or other consumers of non-purchased fish. Other UK or European specific data were not identified for consumption of recreationally caught fish.

Detailed US data for fish consumption of anglers is provided in the EFH (USEPA, 1997). The US values, however, appear to be underestimates of European fish consumption. Based upon the country specific data provided in Table 45, European fish consumption averaged 3.5-41.8 kg per capita per year, or 10-115 g/person/day. In contrast, the US recommendations are: 5-17 g/person/day mean intake with upper limits of 13-39 g/person/day for freshwater anglers, and 2-7 g/person/day mean intake with upper limits of 7-26 g/person/day for marine anglers (USEPA, 1997).

***Table 50. Summary of Fish Consumption from NFS** (Source: Slater et al, 1998)*

| | Values (g/person/week) | | | % Non-purchased |
|---|---|---|---|---|
| | Consumption | Purchase | Non-purchased | |
| White, filleted, fresh | 16 | 15 | 1 | 6.3% |
| White, unfilleted, fresh | 2 | 2 | | |
| White, uncooked, frozen | 18 | 18 | | |
| Fat, fresh, other than herring | 13 | 12 | 1 | 7.7% |
| White, processed | 6 | 5 | 1 | 16.7% |
| Fat, processed, filleted | 2 | 2 | | |
| Fat, processed, unfilleted | 2 | 2 | | |
| Shellfish | 7 | 7 | | |
| Cooked fish | 11 | 11 | | |
| Canned salmon | 8 | 8 | | |
| Other canned/bottled fish | 23 | 23 | | |
| Fish products, not frozen | 11 | 11 | | |
| Frozen convenience fish products | 28 | 28 | | |
| Total fish | 146 | 144 | 2 | 1.4% |

### 5.4.3 Meat and beef consumption rate

*Summary*

Average beef consumption of 16 g/person/day and meat consumption of 134 g/person/day is reported for the current UK population based upon the NFS data presented in Table 51. For other European populations, the information provided in Tables 45 and 46 can be used to estimate daily consumption.

*Relevant Studies*

Average UK consumption data are available from the 1997 NFS (Slater *et al*, 1998). Distributions of consumption are not available. The data set for this study is archived at the University of Essex. Data sets or analysis of the data can be requested on a fee basis.

The 1997 NFS estimates of beef and meat consumption (Table 51) are lower than the earlier UK data presented in Tables 45 and 46. Recent UK food surveys have noted a decline in beef consumption (Slater *et al*, 1998). It is unlikely that beef consumption has been reduced by the same level in other European countries. Thus, the data in Tables 45 and 46 can be used as best estimates of beef and meat consumption for other countries in Europe.

***Table 51. NFS Meat Consumption Data** (Source: Slater et al, 1998)*

| | g/person/week | g/person/day |
|---|---|---|
| Beef and veal | 110 | 16 |
| Mutton and lamb | 56 | 8 |
| Pork | 75 | 11 |
| Bacon and ham, uncooked | 72 | 10 |
| Poultry, uncooked | 221 | 32 |
| Other meat and meat products | 406 | 58 |
| | | |
| Total meat (Great Britain) | 940 | 134 |
| Total meat (UK) | 940 | 134 |

## 5.5 Drinking Water Consumption Rate

***Summary***
Average values of 1.1 l/day for adults and 0.5 l/day for 1-11 year olds are reported based upon a 1980 survey of Great Britain. Distributions are presented in Tables 52 and 53.

***Relevant Studies***
Drinking water is estimated as total tapwater ingestion. This basis excludes water ingestion from bottled beverages. Bottled items are likely to originate from different water sources (USEPA, 1997). Total tapwater ingestion is a better estimation of intake from the greatest single water source. Total tapwater includes tapwater consumed directly and in prepared items such as tea, coffee and other drinks.

Data representative of Great Britain are available from a 1980 survey (Hopkin and Ellis, 1980). The survey sampled 3564 individuals from 1320 households in England, Scotland and Wales. One limitation of this study is that it was performed in September and October and does not cover seasonal variation in water intake. Results are presented in Table 52 by age and gender and Table 53 for the total survey population. These values represent average water intake. Environmental temperature and personal activity level will affect water intake rate. Limited data are available for characterizing drinking water intake under varying conditions. Short-term (hourly) uptake rates for varying temperatures and physical activity ranges from 0.21-0.65 l/hour (McNall and Schlegel, 1968) for young adult males. Longer term measured data are not available.

The mean tapwater consumption of adults aged 18-55+ is 1.1 l/day. This value is lower than the EPA and AIHC reference value of 1.4 l/day for adults based upon US data. The value of 1.1 l/day is consistent with the average of 1l/day used in the MAFF assessment of total dietary nitrate and nitrite (MAFF, 1997).

The survey of Hopkin and Ellis (1980) included tapwater intake for 1-4 and 5-11 year olds. For 1-4 year olds the average daily intake was 0.47 l/day. This is lower than the average tapwater intake of 0.61-0.87 l/day based upon similarly aged Canadian children. However, it is greater than the intake of tapwater reported in a recent survey (1992-1993 NDNS) of UK 1.5-4.5 year olds. The “tapwater” category from the NDNS survey included water used to prepare hot and cold drinks in addition to tapwater consumed directly. In addition, the NDNS data were collected over the course of a full year, so seasonal variability is taken into account. The NDNS data also indicate that tapwater consumption by the UK population may be lower than that of populations in Canada and the US.

Average tapwater intake, based upon the data of Hopkin and Ellis (1980) is 0.5 l/day for 1-11 year olds (Table 52).

***Table 52. Summary of Total Tapwater Intake for Males and Females (l/day)*** *(Source: USEPA, 1997 citation of Hopkin and Ellis, 1980)*

| Age Group (years) | Number | | Mean Intake (l/day) | | Approx. Std. Error of Mean (l/day) | | Approx. 95% Confidence Interval for Mean (l/day) | | 10 and 90 Percentiles (l/day) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female |
| 1 - 4 | 88 | 75 | 0.477 | 0.464 | 0.0403 | 0.0453 | 0.396 - 0.558 | 0.373 - 0.555 | 0.17 - 0.85 | 0.15 - 0.89 |
| 5 - 11 | 249 | 201 | 0.550 | 0.533 | 0.0223 | 0.0239 | 0.505 - 0.595 | 0.485 - 0.581 | 0.22 - 0.90 | 0.22 - 0.93 |
| 12 - 17 | 180 | 169 | 0.805 | 0.725 | 0.0372 | 0.0328 | 0.731 - 0.8790 | 0.659 - 0.791 | 0.29 - 1.35 | 0.31 - 1.16 |
| 18 - 30 | 333 | 350 | 1.006 | 0.991 | 0.0363 | 0.0304 | 0.933 - 1.079 | 0.930 - 1.052 | 0.45 - 1.62 | 0.50 - 1.55 |
| 31 - 54 | 512 | 551 | 1.201 | 1.091 | 0.0309 | 0.0240 | 1.139 - 1.263 | 1.043 - 1.139 | 0.64 - 1.88 | 0.62 - 1.68 |
| 55+ | 396 | 454 | 1.133 | 1.027 | 0.0347 | 0.0273 | 1.064 - 1.202 | 0.972 - 1.082 | 0.62 - 1.72 | 0.54 - 1.57 |

***Table 53. Intake of Total Liquid, Total Tapwater, and Various Beverages (l/day)*** *(Source: USEPA, 1997 citation of Hopkin and Ellis, 1980)*

| Beverage | All Individuals | | | | | | Consumers Only[a] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean Intake | Approx. Std. Error. of Mean | Approx. 95% Confidence Interval for Mean | 10 and 90 Percentiles | 1 and 99 Percentiles | Percentage of Total Number of Individuals | Mean Intake | Approx. Std. Error of Mean | Approx. 95% Confidence Interval for Mean |
| Total Liquid | 1.589 | 0.0203 | 1.547 - 1.629 | 0.77 - 2.57 | 0.34 - 4.50 | 100.0 | 1.589 | 0.0203 | 1.547 - 1.629 |
| Total Liquid Home | 1.104 | 0.0143 | 1.075 - 1.133 | 0.49 - 1.79 | 0.23 - 3.10 | 100.0 | 1.104 | 0.0143 | 1.075 - 1.133 |
| Total Liquid Away | 0.484 | 0.0152 | 0.454 - 0.514 | 0.00 - 1.15 | 0.00 - 2.89 | 89.9 | 0.539 | 0.0163 | 0.506 - 0.572 |
| Total Tapwater | 0.955 | 0.0129 | 0.929 - 0.981 | 0.39 - 1.57 | 0.10 - 2.60 | 99.8 | 0.958 | 0.0129 | 0.932 - 0.984 |
| Total Tapwater Home | 0.754 | 0.0116 | 0.731 - 0.777 | 0.26 - 1.31 | 0.02 - 2.30 | 99.4 | 0.759 | 0.0116 | 0.736 - 0.782 |
| Total Tapwater Away | 0.201 | 0.0056 | 0.190 - 0.212 | 0.00 - 0.49 | 0.00 - 0.96 | 79.6 | 0.253 | 0.0063 | 0.240 - 0.266 |
| Tea | 0.584 | 0.0122 | 0.560 - 0.608 | 0.01 - 1.19 | 0.00 - 2.03 | 90.9 | 0.643 | 0.0125 | 0.618 - 0.668 |
| Coffee | 0.190 | 0.0059 | 0.178 - 0.202 | 0.00 - 0.56 | 0.00 - 1.27 | 63.0 | 0.302 | 0.0105 | 0.281 - 0.323 |
| Other Hot Water Drinks | 0.011 | 0.0015 | 0.008 - 0.014 | 0.00 - 0.00 | 0.00 - 0.25 | 9.2 | 0.120 | 0.0133 | 0.093 - 0.147 |
| Cold Water | 0.103 | 0.0049 | 0.093 - 0.113 | 0.00 - 0.31 | 0.00-0.85 | 51.0 | 0.203 | 0.0083 | 0.186 - 0.220 |
| Fruit Drinks | 0.057 | 0.0027 | 0.052 - 0.062 | 0.00 - 0.19 | 0.00-0.49 | 46.2 | 0.123 | 0.0049 | 0.113 - 0.133 |
| Non Tapwater | 0.427 | 0.0058 | 0.415 - 0.439 | 0.20 - 0.70 | 0.06-1.27 | 99.8 | 0.428 | 0.0058 | 0.416 - 0.440 |
| Home-brew | 0.010 | 0.0017 | 0.007 - 0.013 | 0.00 - 0.00 | 0.00-0.20 | 7.0 | 0.138 | 0.0209 | 0.096 - 0.180 |
| Bought Alcoholic Beverages | 0.206 | 0.0123 | 0.181 - 0.231 | 0.00 - 0.68 | 0.00-2.33 | 43.5 | 0.474 | 0.0250 | 0.424 - 0.524 |

[a] Consumers only is defined as only those individuals who reported consuming the beverage during the survey period

## 5.6 Breast Milk Consumption Rate

***Summary***
In the absence of more specific data, the USEPA recommendations summarised in Table 58 can be used. The USEPA recommendations are based upon the weighted averages of several studies and are similar to the values reported for Swedish infants (Table 57). For 1-6 month old infants, mean daily breast milk intake is estimated as 742 ml with an upper percentile of 1033 ml. A 12-month average value of 688 ml/day with an upper percentile of 980 ml/day can also be used. A cumulative distribution for the infant age at which British mothers stopped breast-feeding is presented in Table 55.

***Relevant Studies***
The Ministry of Agriculture, Fisheries and Food (MAFF) sponsored a study of food and nutrient intakes of British infants (Mills and Tyler, 1992). The infant survey population was designed to be representative of children < 2 years old in Great Britain. The sample size was 488 mothers and 491 infants (3 sets of twins). Overall, in the first 1-2 weeks after birth, 55% of mothers solely breast-fed their child, 9% provided a combination of breast milk and infant formula, and 36% were solely bottle-fed. Incidence of breast-feeding varied by region (Table 54). A cumulative distribution for the number of weeks that a mother breast-fed her child is presented in Table 55.

The amount of breast milk ingested was estimated only during the ages of 6-12 months. Breast milk consumption was not directly measured, but estimated based upon the number and duration of feedings. Feeding periods of ten minutes or longer were assumed to be full feeds. The ingested amount for a full feed was estimated as 135 g for infants aged 6-7 months and 100 g for infants aged 8-12 months, based upon the data of Paul *et al* (1988). For feeding periods shorter than 10 minutes, intake was estimated proportionally (i.e., intake for an 8 month old infant feeding for 5 minutes was estimated as 50 g). Mean and median intake for consumers only and the entire survey population (consumers and nonconsumers combined) are provided in Table 56. These values, however, are based upon combined data for exclusively breast-fed infants and infants who received both breast milk and formula, and are representative of neither one. Thus, their value for exposure assessment is limited.

Results of several other European studies are summarised in the USEPA EFH (Table 57). No UK studies were cited, but breast milk consumption values for Swedish infants were similar to those of US infants (Tables 58). USEPA recommendations for mean and upper intake limits are summarised in Table 58. The study results that form the basis for these recommendations are also provided. The sample size for most studies is small (N=25-30 breast-fed infants for each Swedish study, N=13-73 for each US study) and may not be representative of the general population. Note, the USEPA recommendations are based upon studies for infants which were exclusively breast-fed for the study duration or at least the first few months of life. Data for only one study, Neville *et al* (1998), were corrected for insensible water loss. Consumption may be overestimated without this correction, but average values were generally consistent across studies. More detailed information can be found in the EFH (USEPA, 1997). The USEPA recommendations can be used for European populations in the absence of more specific data; the USEPA recommendations are based upon the weighted averages of several studies and are similar to the values reported for Swedish infants.

***Table 54. Incidence of Breast-feeding* by Region (percent)*** *(Source: Mills and Tyler, 1992)*

| Region | Incidence of breast-feeding** | Incidence of exclusive breast-feeding |
|---|---|---|
| Scotland | 55 | 51 |
| Northern England | 57 | 43 |
| Midlands, E. Anglia | 60 | 48 |
| Wales and SW England | 63 | 58 |
| South East and London | 77 | 70 |
| | | |
| Overall Survey Population | 64 | 55 |

* Breast-feeding defined as receiving some breast milk during the first 1-2 weeks of life

** Infants fed some infant formula in addition to breast milk

***Table 55. Duration of Breast-feeding - Results of a Survey of British Mothers*** *(Source: Mills and Tyler, 1992)*

| Duration (weeks) | Number of infants | Sample % who stopped | Cumulative % breast-feeding |
|---|---|---|---|
| 1-3 | 53 | 22.5 | 22.5 |
| 4-8 | 58 | 24.6 | 47.1 |
| 9-12 | 24 | 10.2 | 57.3 |
| 13-16 | 19 | 8.0 | 65.3 |
| 17-20 | 14 | 5.9 | 71.2 |
| 21-24 | 19 | 8.0 | 79.2 |
| 25-28 | 14 | 5.9 | 85.1 |
| 29-32 | 15 | 6.4 | 91.5 |
| 33-36 | 9 | 3.8 | 95.3 |
| 37-40 | 7 | 3.0 | 98.3 |
| 41-44 | 3 | 1.3 | 99.6 |
| 47 | 1 | 0.4 | 100 |
| Total | 236 | | |

***Table 56. Breast Milk Consumption (g/infant/week), British Data*** *(Source: Mills and Tyler, 1992)*

| Age Group | Consumers[1] | | All infants[2] | | | Typical portion size (g) | |
|---|---|---|---|---|---|---|---|
| | **Mean** | **Median** | **% who ate** | **Mean** | **Median** | **Mean** | **Median** |
| 6-9 months | 2665 | 2425 | 19 | 517 | 0 | | |
| 9-12 months | 1313 | 1050 | 10 | 131 | 0 | | |
| 6-12 months (combined above) | 2239 | 2025 | 15 | | | 105 | 108 |

Estimated daily intake for consumers in g/day (weekly intake divided by 7):

| Age Group | Mean | Median |
|---|---|---|
| 6-9 months | 381 | 346 |
| 9-12 months | 188 | 150 |
| 6-12 months | 320 | 289 |

1 Intake in g/infant/week
2 Intake in g/infant/week

***Table 57. European Data for Breast Milk Consumption*** *(Source: USEPA, 1997)*

| Region | Age | N | Mean intake (ml/day) | Range (ml/day) | Reference |
|---|---|---|---|---|---|
| Industrialized and Developing Countries | to 4 or 5 months | | 728 - 777 | 437 - 1165 | NAS, 1991 |
| Sweden | 1 month | 25 | 637 | 350 - 835 | Hofvander *et al*, 1982 |
| Sweden | 6 weeks | 26 | 724 | | Köhler *et al*, 1984 |
| Sweden | 2 months | 25 | 750 | 558 - 956 | Hofvander *et al*, 1982 |
| Sweden | 3 months | 25 | 753 | 582 - 903 | Hofvander *et al*, 1982 |
| Sweden | 14 weeks | 21 | 705 | | Köhler *et al*, 1984 |
| Sweden | 4.5 months | 30 | 765 | | Axelsson *et al*, 1987 |
| Sweden | 22 weeks | 13 | 701 | | Köhler *et al*, 1984 |
| Sweden | 5.5 months | 30 | 715 | | Axelsson *et al*, 1987 |
| Sweden | 26 weeks | 12 | 669 | | Köhler *et al*, 1984 |

NAS and Axelsson *et al* data were reported in ml/day. Other values reported in g/day were converted to ml/day using a factor of 1.03 g/ml breast milk

***Table 58. Breast Milk Intake Rates for US Breast-fed Infants*** *(Source: USEPA, 1997)*

| **USEPA 1997 Recommended Breast Milk Intake Values** | | |
|---|---|---|
| **Age** | **Mean (ml/day)*** | **Upper percentile (mean + 2 std dev.)** |
| 1-6 months | 742 | 1033 |
| 12 month average | 688 | 980 |

| **Detailed Data:** | | | | |
|---|---|---|---|---|
| **Age** | **N** | **Mean (ml/day)*** | **Upper percentile (mean + 2 std dev.)** | **Reference** |
| 1 month | 11 | 600 | 918 | Pao *et al*, 1980 |
| | 37 | 729 | 981 | Butte *et al*, 1984 |
| | 13 | 747 | 1095 | Neville *et al*, 1988 |
| | 16 | 673 | 1057 | Dewey and Lönnerdal, 1983 |
| | Weighted Mean | **702** | | |
| 3 months | 2 | 833 | ... | Pao *et al*, 1980 |
| | 37 | 702 | 923 | Butte *et al*, 1984 |
| | 12 | 712 | 934 | Neville *et al*, 1988 |
| | 16 | 782 | 1126 | Dewey and Lönnerdal, 1983 |
| | 73 | 788 | 1046 | Dewey *et al*, 1991b |
| | Weighted Mean | **759** | | |
| 6 months | 1 | 682 | ... | Pao *et al*, 1980 |
| | 13 | 744 | 978 | Neville *et al*, 1988 |
| | 11 | 896 | 1140 | Dewey and Lönnerdal, 1983 |
| | 60 | 747 | 1079 | Dewey *et al*, 1991b |
| | Weighted Mean | **765** | | |
| 9 months | 12 | 600 | 1027 | Neville *et al*, 1988 |
| | 50 | 627 | 1049 | Dewey *et al*, 1991b |
| | Weighted Mean | **622** | | |
| 12 months | 9 | 391 | 877 | Neville *et al*, 1988 |
| | 42 | 435 | 923 | Dewey *et al*, 1991a; 1991b |
| | Weighted Mean | **427** | | |

* Consumption in g/day converted to ml/day using the factor of 1.03 g/ml breast milk

## 6. DATA GAPS

While this document includes data for European countries in general, its primary focus is on the UK. Future expansion of additional data for other countries would be useful for improving the accuracy of exposure assessments for other European populations.

Data, from any country, are limited for both soil ingestion and soil adherence to skin. Additional studies are needed to quantify better these exposure factors.

Distributions are available for US time-activity data and food consumption rates, but distributional data are not available for European populations. UK time-activity data are limited even for point estimates of average or median values. Archived data from UK time-activity and food consumption surveys may be recorded in sufficient detail to develop distributions. Time-activity and food consumption surveys have been identified for some non-UK European countries, but the level of detail for records of these studies was not evaluated.

Inhalation rate data specific to the UK or Europe were not identified, and US data were insufficient to develop distributions. Other data not identified for the UK or Europe included shower duration, occupational tenure, and residential tenure.

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## APPENDIX A. EXAMPLES OF EXPOSED SKIN SURFACE AREA CALCULATIONS

Exposure scenarios evaluated:
Exposed population for both: English Adult Females

Scenario 1: Constant exposure of legs, arms, hands and feet (60% total surface area)
Scenario 2: Varied exposure: 75% low (lower legs+ lower arms = 19% total surface area and 25% high (legs, arms, hands feet = 60% total surface area)

Step 1 (for both scenarios): Monte Carlo simulation of body weight
Used lognormal distribution for adult female body weight based upon HSE data
Distribution parameters: lognormal with arithmetic meant 67.3 and standard deviaton=12.71

Step 2 (for both scenarios): Monte Carlo simulation of total skin surface area
Used equation of Costeff, Skin Surface Area in $m^2=(4W+7) / (W+90)$, where W= Body weight

For Scenario 1:
Step 3: Exposed skin surface area is estimated as 0.6 X the Monte Carlo simulation of total skin surface area

For Scenario 2:
Step 3: Monte Carlo simulation of fraction of exposed skin surface area.
Discrete distribution specified where 0.19 (fraction of total skin surface area associated with lower arms and legs) has a probability of 0.75 and 0.60 (fraction of skin associated with arms, legs, hands and feet) has a probability of 0.25

## *Crystal Ball Reports for Monte Carlo Simulations*

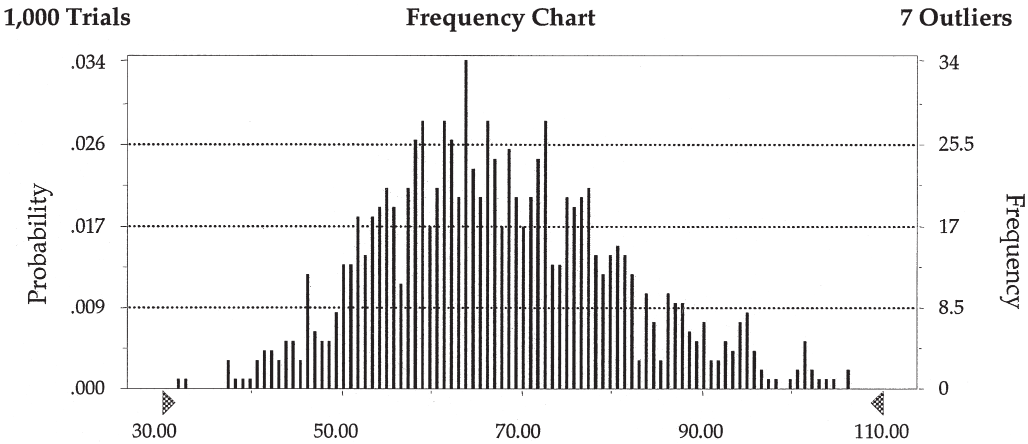
### *Forecast: Adult Female Body Weight, Lognormal Simulation*

**Summary**

Display Range is from 30.00 to 110.00
Entire Range is from 32.33 to 123.84
After 1,000 Trials, the Std. Error of the Mean is 0.44

| Statistics | Value |
|---|---|
| Trials | 1000 |
| Mean | 67.92 |
| Median | 66.51 |
| Mode | --- |
| Std Dev. | 13.80 |
| Variance | 190.35 |
| Skewness | 0.58 |
| Kurtosis | 3.73 |
| Coeff. of Variability | 0.20 |
| Range Minimum | 32.33 |
| Range Maximum | 123.84 |
| Range Width | 91.51 |
| Mean Std. Error | 0.44 |

### *Forecast: Adult Female Body Weight, Lognormal Simulation*



### *Forecast: Adult Female Body Weight, Lognormal Simulation (continued)*

| **Percentiles:** | | |
|---|---|---|
| | **Percentile** | **Value** |
| | 0% | 32.33 |
| | 5% | 46.98 |
| | 10% | 51.78 |
| | 15% | 54.17 |
| | 20% | 56.20 |
| | 25% | 58.36 |
| | 30% | 59.86 |
| | 35% | 61.77 |
| | 40% | 63.52 |
| | 45% | 64.75 |
| | 50% | 66.51 |
| | 55% | 68.38 |
| | 60% | 70.16 |
| | 65% | 72.05 |
| | 70% | 74.25 |
| | 75% | 76.43 |
| | 80% | 78.66 |
| | 85% | 81.34 |
| | 90% | 86.59 |
| | 95% | 92.98 |
| | 100% | 123.84 |
| End of Forecast | | |

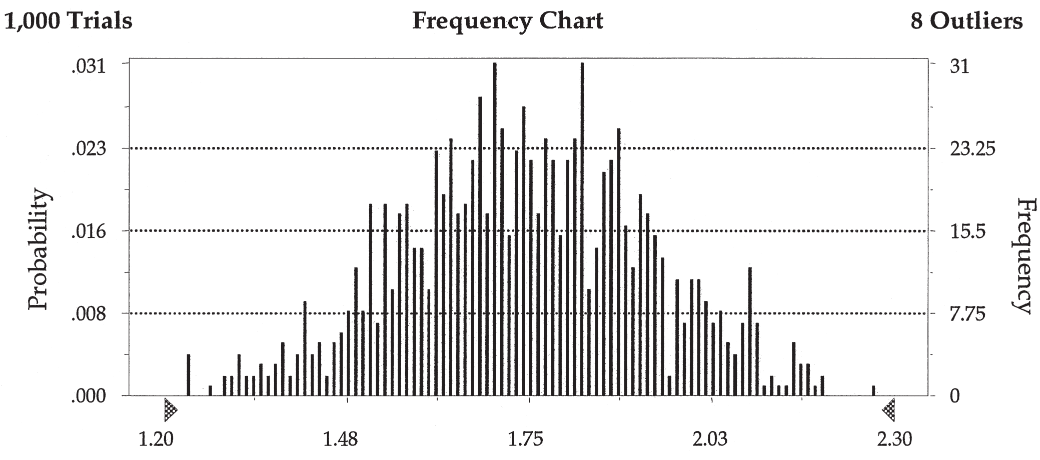
### *Forecast: Adult Female Skin Surface Area - Costeff Equation*

**Summary**

Display Range is from 1.20 to 2.30
Entire Range is from 1.11 to 2.35
After 1,000 Trials, the Std. Error of the Mean is 0.01

| Statistics | | Value |
|---|---|---|
| | Trials | 1000 |
| | Mean | 1.75 |
| | Median | 1.74 |
| | Mode | --- |
| | Std Dev. | 0.19 |
| | Variance | 0.04 |
| | Skewness | 0.02 |
| | Kurtosis | 3.08 |
| | Coeff. of Variability | 0.11 |
| | Range Minimum | 1.11 |
| | Range Maximum | 2.35 |
| | Range Width | 1.23 |
| | Mean Std. Error | 0.01 |

### *Forecast: Adult Female Skin Surface Area - Costeff Equation*



### *Forecast: Adult Female Skin Surface Area - Costeff Equation (continued)*

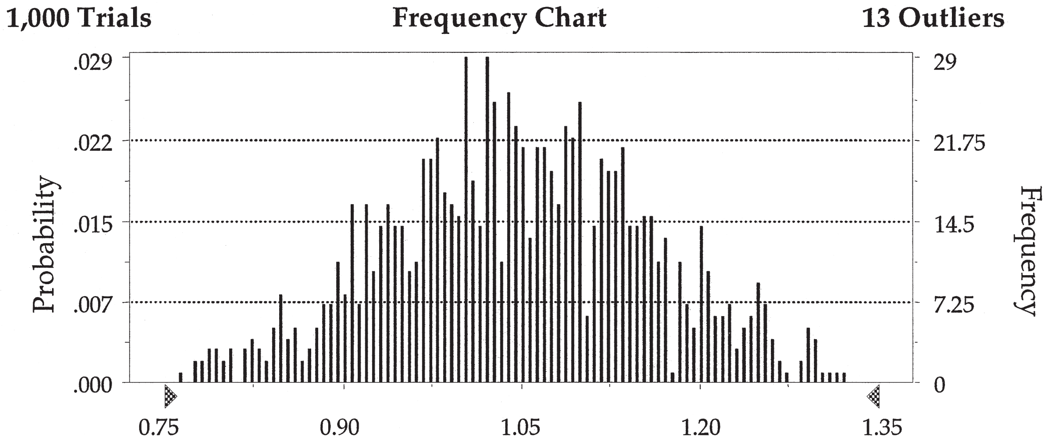
| **Percentiles:** | | |
|---|---|---|
| | **Percentile** | **Value** |
| | 0% | 1.11 |
| | 5% | 1.42 |
| | 10% | 1.51 |
| | 15% | 1.55 |
| | 20% | 1.59 |
| | 25% | 1.62 |
| | 30% | 1.64 |
| | 35% | 1.67 |
| | 40% | 1.70 |
| | 45% | 1.72 |
| | 50% | 1.74 |
| | 55% | 1.77 |
| | 60% | 1.80 |
| | 65% | 1.82 |
| | 70% | 1.85 |
| | 75% | 1.88 |
| | 80% | 1.91 |
| | 85% | 1.94 |
| | 90% | 2.00 |
| | 95% | 2.07 |
| | 100% | 2.35 |
| End of Forecast | | |

### *Forecast: Adult Female Exposed SSA, Constant 60% Exposure*

| **Summary** | |
|---|---|
| | Display Range is from 0.75 to 1.35<br>Entire Range is from 0.67 to 1.41<br>After 1,000 Trials, the Std. Error of the Mean is 0.00 |

| **Statistics** | | **Value** |
|---|---|---|
| | Trials | 1000 |
| | Mean | 1.05 |
| | Median | 1.05 |
| | Mode | --- |
| | Std Dev. | 0.12 |
| | Variance | 0.01 |
| | Skewness | 0.02 |
| | Kurtosis | 3.08 |
| | Coeff. of Variability | 0.11 |
| | Range Minimum | 0.67 |
| | Range Maximum | 1.41 |
| | Range Width | 0.74 |
| | Mean Std. Error | 0.00 |

### *Forecast: Adult Female Exposed SSA, Constant 60% Exposure*



### *Forecast: Adult Female Exposed SSA, Constant 60% Exposure (continued)*

**Percentiles**:

| | Percentile | Value |
|---|---|---|
| | 0% | 0.67 |
| | 5% | 0.85 |
| | 10% | 0.91 |
| | 15% | 0.93 |
| | 20% | 0.95 |
| | 25% | 0.97 |
| | 30% | 0.99 |
| | 35% | 1.00 |
| | 40% | 1.02 |
| | 45% | 1.03 |
| | 50% | 1.05 |
| | 55% | 1.06 |
| | 60% | 1.08 |
| | 65% | 1.09 |
| | 70% | 1.11 |
| | 75% | 1.13 |
| | 80% | 1.14 |
| | 85% | 1.16 |
| | 90% | 1.20 |
| | 95% | 1.24 |
| | 100% | 1.41 |

End of Forecast

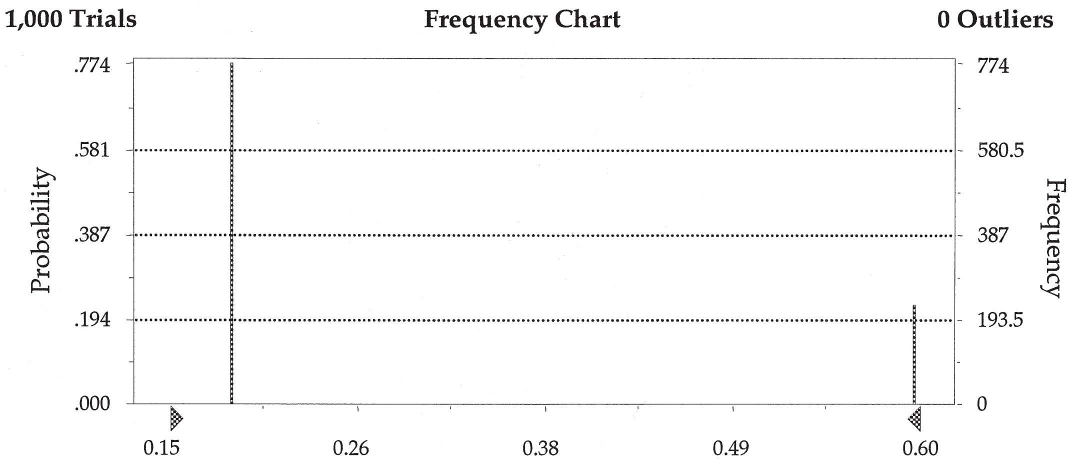
### *Forecast: Varied Exposure - Fraction Exposed (75% Low, 25% High)*

**Summary**

Display Range is from 0.15 to 0.60 percent exposed
Entire Range is from 0.19 to 0.60 percent exposed
After 1,000 Trials, the Std. Error of the Mean is 0.01

| **Statistics** | | **Value** |
|---|---|---|
| | Trials | 1000 |
| | Mean | 0.28 |
| | Median | 0.19 |
| | Mode | 0.19 |
| | Std Dev. | 0.17 |
| | Variance | 0.03 |
| | Skewness | 1.31 |
| | Kurtosis | 2.71 |
| | Coeff. of Variability | 0.61 |
| | Range Minimum | 0.19 |
| | Range Maximum | 0.60 |
| | Range Width | 0.41 |
| | Mean Std. Error | 0.01 |
| End of Forecast | | |

### *Forecast: Varied Exposure (75% Low, 25% High)*



### *Forecast: Varied Exposure (75% Low, 25% High) (continued)*

| **Percentiles:** | | |
|---|---|---|
| | **Percentile** | **Percent exposed** |
| | 0% | 0.19 |
| | 5% | 0.19 |
| | 10% | 0.19 |
| | 15% | 0.19 |
| | 20% | 0.19 |
| | 25% | 0.19 |
| | 30% | 0.19 |
| | 35% | 0.19 |
| | 40% | 0.19 |
| | 45% | 0.19 |
| | 50% | 0.19 |
| | 55% | 0.19 |
| | 60% | 0.19 |
| | 65% | 0.19 |
| | 70% | 0.19 |
| | 75% | 0.19 |
| | 80% | 0.60 |
| | 85% | 0.60 |
| | 90% | 0.60 |
| | 95% | 0.60 |
| | 100% | 0.60 |
| End of Forecast | | |

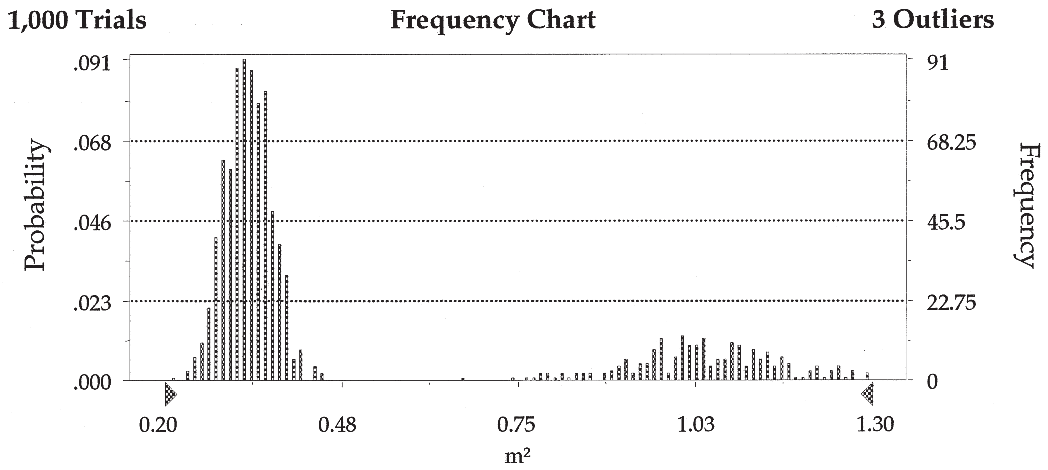
### *Forecast: Adult Female Exposed SSA, Varied Exposure*

**Summary**

Display Range is from 0.20 to 1.30 square meters
Entire Range is from 0.21 to 1.39 square meters
After 1,000 Trials, the Std. Error of the Mean is 0.01

| **Statistics** | | **Value** |
|---|---|---|
| | Trials | 1000 |
| | Mean | 0.49 |
| | Median | 0.35 |
| | Mode | --- |
| | Std Dev. | 0.31 |
| | Variance | 0.09 |
| | Skewness | 1.39 |
| | Kurtosis | 3.17 |
| | Coeff. of Variability | 0.62 |
| | Range Minimum | 0.21 |
| | Range Maximum | 1.39 |
| | Range Width | 1.18 |
| | Mean Std. Error | 0.01 |

### *Forecast: Adult Female Exposed SSA, Varied Exposure*



### *Forecast: Adult Female Exposed SSA, Varied Exposure (continued)*

**Percentiles**:

| | Percentile | Square Meters |
|---|---|---|
| | 0% | 0.21 |
| | 5% | 0.28 |
| | 10% | 0.29 |
| | 15% | 0.30 |
| | 20% | 0.31 |
| | 25% | 0.32 |
| | 30% | 0.32 |
| | 35% | 0.33 |
| | 40% | 0.33 |
| | 45% | 0.34 |
| | 50% | 0.35 |
| | 55% | 0.35 |
| | 60% | 0.36 |
| | 65% | 0.37 |
| | 70% | 0.38 |
| | 75% | 0.40 |
| | 80% | 0.91 |
| | 85% | 1.01 |
| | 90% | 1.06 |
| | 95% | 1.13 |
| | 100% | 1.39 |

End of Forecast

## APPENDIX B. POTENTIAL SOURCES OF ADDITIONAL INFORMATION FOR REGION SPECIFIC EXPOSURE FACTORS

| Publication Reference | Type of Information Included | Comments | Purchase Source | Price |
|---|---|---|---|---|
| European Marketing Data and £185, Statistics, 1999 US$370 | Life expectancy at birth; population by age group; average working week in non-agricultural activities 1977-94, average working week in manufacturing 1977-95; economically active population by age group; 1996 per capita consumption of meat and fish, fresh produce, dairy products and eggs, bakery products, convenience and miscellaneous foods, snack foods and hot drinks; production of meat, cereal, selected crops, fishery products; indices of agricultural and food output | Not specified if average values or distributions are provided | Euromonitor (www.euromonitor.com) | |
| World Marketing Data and £795, Statistics, 1999 US$2100 | Similar to above, but for world not just Europe and some data are more current (i.e. food consumption data are for 1997, weekly work hours are through 1997) | Not specified if average values or distributions are provided | Euromonitor (www.euromonitor.com) | |
| Gardening in Europe £3950, US$7900 | Trends in garden ownership, changing leisure patterns, garden marketing by sector by country, population trends | Specificity of data not provided (i.e.- gardening includes lawns and ornamental, not just food production); not specified if average values or distributions are provided | Euromonitor (www.euromonitor.com) | |
| Consumer Lifestyles in £895, Eastern Europe US$1790 | Housing trends, food consumption, attendance at leisure venues by type | Not specified if average values or distributions are provided | Euromonitor (www.euromonitor.com) | |
| General Household Survey. Living in Britain: results from the 1995 General Household Survey. Office of National, Statistics Social Survey Division. 1997 | Sampled population: private households in Britain; housing and migration; job mobility; educational activity | Not specified if average values or distributions are provided | The Stationery Office, London; University of Essex Data Archives (Biron catalog number 33090) | |

## APPENDIX B. CONTINUED

| Publication Reference | Type of Information Included | Comments | Purchase Source | Price |
|---|---|---|---|---|
| British Household Panel Survey Combined Work-Life History Data, 1990-1995 | Sampled population: households in Britain and individual household members; occupational history | Not specified if average values or distributions are provided; raw data are available but user needs to know codes (alternatively, for a fee, analyses can be performed) | ESRC Research Centre on Micro-Social Change (part of the Institute for Social and Economic Research; University of Essex Data Archives (Biron catalog number 33196) | |
| Family, work and leisure in the London region | Main study: Adult population of London metropolitan region. Date of first release: 1973; hours at work, leisure activities by home based or other. Diaries for married respondents between ages of 30-49 also on record | Dated, London adults only; not specified if average values or distributions are provided | University of Essex Data Archives (Biron Catalog number 33155) | |
| UK Banbury Activity/ Travel Survey | Population: defined sector of Banbury, N=204 households. Sept-Oct 1976, diaries of activities with location | Not specified if average values or distributions are provided; raw data are available | CESSDA Integrated Data Catalog (http://dastar.essex.ac.uk), (UK data archive number 1095) | |
| UK Northern Ireland Health and Activity Survey, 1994 | Northern Ireland adults (>16 yrs), N=1200; associated reports: MacAuley, D., *et al* 1994. Northern Ireland Health and Activity Survey Report (Belfast:HMSO); Kelly, F. and S. Ogle.1994. Northern Ireland Health and Activity Survey Main Findgins (Belfast:HMSO) | Not specified if average values or distributions are provided; raw data are available | CESSDA Integrated Data Catalog (http://dastar.essex.ac.uk), (UK data archive number 3469) | |
| UK ESRC/Manchester University Macclesfield Survey, 1983 | Household heads aged 20-60 years in six wards of Macclesfield, N=669, Nov-Dec 1983; occupation, life and work histories, home-grown foods (keyword under employment opportunity), leisure time activities | Raw data are available | CESSDA Integrated Data Catalog (http://dastar.essex.ac.uk), (UK data archive number 2559) | |

## APPENDIX B. CONTINUED

| Publication Reference | Type of Information Included | Comments | Purchase Source | Price |
|---|---|---|---|---|
| New Cronos database | Macroeconomic and social database for the EU Member States and in many cases, Japan, the US, and the central European countries and main economic partners of the EU; labour force survey, population surveys, agricultural surveys | Raw data are available | Eurostat Data Shop | ECU 8000, can request prices for individual mains collections or tables |
| Leisure Trends 1998 | Hobbies and sport, gardening; another leisure reference gave frequency of leisure activities by location but not duration of each frequency, another gardening reference gives demographic information about garden ownership but unsure if data are specific to vegetable or fruit gardens vs. lawn and ornamental gardens | Data format unknown, don't know if values relevant to exposure assessment, such as time spent at various locations, or % of families with vegetable gardens | Mintel (www.mintel.co.uk), Marketing Intelligence consumer market research | £137 |

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No. 23 Evaluation of the Toxicity of Substances to be Assessed for Biodegradability
No. 24 The EEC 6th Amendment: Prolonged Fish Toxicity Tests
No. 25 Evaluation of Fish Tainting
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No. 53 DHTDMAC: Aquatic and Terrestrial Hazard Assessment (CAS No. 61789-80-8)
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No. 68 Assessment Factors in Human Health Risk Assessment
No. 69 Toxicology of Man-Made Organic Fibres
No. 70 Chronic Neurotoxicity of Solvents
No. 71 Inventory of Critical Reviews on Chemicals (Only available to ECETOC members)
No. 72 Methyl tert-Butyl Ether (MTBE) Health Risk Characterisation
No. 73 The Value of Aquatic Model Ecosystem Studies in Ecotoxicology
No. 74 QSARs in the Assessment of the Environmental Fate and Effects of Chemicals
No. 75 Organophosphorus Pesticides and Long-term Effects on the Nervous System
No. 76 Monitoring and Modelling of Industrial Organic Chemicals, with Particular Reference to Aquatic Risk Assessment
No. 77 Skin and Respiratory Sensitisers: Reference Chemicals Data Bank
No. 78 Skin Sensitisation Testing: Methodological Considerations
No. 79 Exposure Factors Sourcebook for European Populations (with Focus on UK Data)

## *Joint Assessment of Commodity Chemicals (JACC) Reports*

No. Title

No. 1 Melamine
No. 2 1,4-Dioxane
No. 3 Methyl Ethyl Ketone
No. 4 Methylene Chloride
No. 5 Vinylidene Chloride
No. 6 Xylenes
No. 7 Ethylbenzene
No. 8 Methyl Isobutyl Ketone
No. 9 Chlorodifluoromethane
No. 10 Isophorone
No. 11 1,2-Dichloro-1,1-Difluoroethane (HFA-132b)

No. 12 1-Chloro-1,2,2,2-Tetrafluoroethane (HFA-124)
No. 13 1,1-Dichloro-2,2,2-Trifluoroethane (HFA-123)
No. 14 1-Chloro-2,2,2-Trifluoromethane (HFA-133a)
No. 15 1-Fluoro 1,1-Dichloroethane (HFA-141B)
No. 16 Dichlorofluoromethane (HCFC-21)
No. 17 1-Chloro-1,1-Difluoroethane (HFA-142b)
No. 18 Vinyl Acetate
No. 19 Dicyclopentadiene (CAS: 77-73-6)
No. 20 Tris-/Bis-/Mono-(2 ethylhexyl) Phosphate
No. 21 Tris-(2-Butoxyethyl)-Phosphate (CAS:78-51-3)
No. 22 Hydrogen Peroxide (CAS: 7722-84-1)
No. 23 Polycarboxylate Polymers as Used in Detergents
No. 24 Pentafluoroethane (HFC-125) (CAS: 354-33-6)
No. 25 1-Chloro-1,2,2,2-tetrafluoroethane (HCFC 124) (CAS No. 2837-89-0)
No. 26 Linear Polydimethylsiloxanes (CAS No. 63148-62-9)
No. 27 n-Butyl Acrylate (CAS No. 141-32-2)
No. 28 Ethyl Acrylate (CAS No. 140-88-5)
No. 29 1,1-Dichloro-1-Fluoroethane (HCFC-141b) (CAS No. 1717-00-6)
No. 30 Methyl Methacrylate (CAS No. 80-62-6)
No. 31 1,1,1,2-Tetrafluoroethane (HFC-134a) (CAS No. 811-97-2)
No. 32 Difluoromethane (HFC-32) (CAS No. 75-10-5)
No. 33 1,1-Dichloro-2,2,2-Trifluoroethane (HCFC-123) (CAS No. 306-83-2)
No. 34 Acrylic Acid (CAS No. 79-10-7)
No. 35 Methacrylic Acid (CAS No. 79-41-4)
No. 36 n-Butyl Methacrylate; Isobutyl Methacrylate (CAS No. 97-88-1) (CAS No. 97-86-9)
No. 37 Methyl Acrylate (CAS No. 96-33-3)
No. 38 Monochloroacetic Acid (CAS No. 79-11-8) and its Sodium Salt (CAS No. 3926-62-3)
No. 39 Tetrachloroethylene (CAS No. 127-18-4)
No. 40 Peracetic Acid (CAS No. 79-21-0) and its Equilibrium Solutions

## *Special Reports*

No. Title

No. 8 HAZCHEM; A Mathematical Model for Use in Risk Assessment of Substances
No. 9 Styrene Criteria Document
No. 10 Hydrogen Peroxide OEL Criteria Document (CAS No. 7722-84-1)
No. 11 Ecotoxicology of some Inorganic Borates
No. 12 1,3-Butadiene OEL Criteria Document (Second Edition) (CAS No. 106-99-0)
No. 13 Occupational Exposure Limits for Hydrocarbon Solvents
No. 14 n-Butyl Methacrylate and Isobutyl Methacrylate OEL Criteria Document
No. 15 Examination of a Proposed Skin Notation Strategy
No. 16 GREAT-ER User Manual

## *Documents*

No. Title

No. 32 Environmental Oestrogens: Male Reproduction and Reproductive Development
No. 33 Environmental Oestrogens: A Compendium of Test Methods
No. 34 The Challenge Posed by Endocrine-disrupting Chemicals
No. 35 Exposure Assessment in the Context of the EU Technical Guidance Documents on Risk Assessment of Substances

No. 36 Comments on OECD Draft Detailed Review Paper: Appraisal of Test Methods for Sex-Hormone Disrupting Chemicals
No. 37 EC Classification of Eye Irritancy
No. 38 Wildlife and Endocrine Disrupters: Requirements for Hazard Identification
No. 39 Screening and Testing Methods for Ecotoxicological Effects of Potential Endocrine Disrupters: Response to the EDSTAC Recommendations and a Proposed Alternative Approach
No. 40 Comments on Recommendation from Scientific Committee on Occupational Exposure Limits for 1,3-Butadiene
No. 41 Persistent Organic Pollutants (POPs) Response to UNEP/INC/CEG-I Annex 1
No. 42 Genomics, Transcript Profiling, Proteomics and Metabonomics (GTPM). An Introduction