10040-Title: Analysis of Growth Trajectory Classes of Crack-cocaine Use via Growth Mixture Modeling

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Objectives: This study is to examine the patterns and correlates of growth trajectory of crack-cocaine use over time. **Methods:** A sample of 430 crack-cocaine users interviewed at four consecutive time points with a 6-month interval in a natural history study in Dayton, Ohio was used for the study. Growth mixture modeling, which is a combination of conventional growth modeling and cluster analysis, was used to study the growth trajectory classes of crack-cocaine use over time. The number of trajectory classes was tested and individuals were classified into classes of the best-fitting model. The shape of growth trajectory of crack use was examined within each class. In addition, socio-demographic factors, such as gender, age, ethnicity, and education, were used to predict the class membership, as well as to predict the growth trajectory, within each class. **Results:** With the sample under study, the best-fitting growth mixture model had two growth trajectory classes: Class 1 - high initial level of crack use and significant decline in crack use over time; and Class 2 - low initial level of crack use and no significant change in crack use over time. Based on posterior membership probability, about 51% of the subjects were classified into Class 1, and 49% into Class 2. The results show that black crack users were more likely to fall into Class 1, while other socio-demographic factors, such as gender, age, and education did not have significant effect on class membership. Within each class, the initial level of crack-cocaine use was not significantly associated with any of the socio-demographic factors. A nonlinear growth trajectory was detected in each class. Among the drug users in Class 1, older and black drug users were less likely to reduce their crack use over time, compared with others. Black drug users were also found less likely to reduce their crack use than others in Class 2, although the crack use in this class did not have significant change on average. **Conclusions:** The growth mixture modeling not only allows the intra-individual changes in outcome measures to be analyzed together with inter-individual differences, it also captures the heterogeneity of growth by including a categorical latent variable (the latent class variable), therefore, allows different subgroups in the sample to follow different growth models. The study suggests the utility of the growth mixture modeling for better understanding of the growth trajectories of drug use in natural history studies.

10132-HEALTH IMPACTS OF COOKING FUELS IN RURAL UTTAR PRADESH, INDIA

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Abstract

The main source of Indoor Air Pollution (IAP) in the rural households in the developing countries is burning of unprocessed biomass fuel for cooking and heating. Biofuel combustion is a major health problem among a large proportion of the world's population particularly the women and children who spend substantial portion of their time indoors when the cooking activity is going on. The paper tries to establish the association between biofuel use and respiratory (bronchitis, asthma, chest infection, TB) and eye diseases as per British Medical Research Council (BMRC, 1986) questionnaire based on a large comprehensive survey carried out by Parikh et al, 2000 at Indira Gandhi Institute of Development Research (IGIDR), Mumbai over a sample of 7564 households (HH) (16264 individuals) in Uttar Pradesh (UP), India. In order to have a random selection with a good spread and proper representation of the population, we used multistage sampling with stratification based on *a priori* information. One of the major highlights of the survey was measurement of Peak Expiratory Flow (PEF) rates, a measure of airways obstruction were also measured for over 15,000 individuals using simple portable peak flow meters. The statistical analysis is done at four levels. At the first level, preliminary data analysis is done in terms of understanding the sample. Secondly new variables are developed from the data collected. Thirdly we looked into the correlation between disease symptoms, socio-economic characteristics and their covariates. In the fourth level, linear and logistic regressions are carried out using SAS/STAT package with adjustments for confounding variables like age, smoking, illiteracy, income, asset possessions, village characteristics, etc. Biofuel cooking has negative impact on the health of the individuals. Years of involvement as well as current involvement in cooking affects Peak expiratory Flow rates. Level of education plays a

vital role in symptom occurrence and more so among females. We observe that even among strictly biofuel using HHs the occurrence rates of respiratory and eye symptoms of females decreases significantly from illiterates to primary education. The occurrence of respiratory symptoms is higher among smokers, males and females alike. Though the symptoms reduce as one moves from indoor kitchens without partition to separate kitchen outside house, higher occurrences are observed in case of open air cooking which maybe due to poverty.

Efficient fuels, adequate ventilation, awareness through education can serve as policy prescriptions for better health status.

10258-USE OF MIXED EFFECTS MODELS IN ASSESSING RELIABILITY AND AGREEMENT OF ELF-EMF DOSIMETERS

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Background: An epidemiologic multi-center case-control study (SETIL) is currently in progress in Italy to investigate risk factors for childhood leukemia, non-Hodgkin's lymphoma, and neuroblastoma. Previous studies suggested a possible association of occurrence of childhood leukemia with above average levels of exposure to 50 and 60 Hz electromagnetic fields (ELF-EMF). Commercially available EMDEX II™ and EMDEX Lite™ magnetic field meters (Enertech Consultants Ltd, USA) are used to measure residential exposure to ELF-EMF at the current and, when feasible, past dwellings, and at the schools of subjects who enter the study.
Objectives: EMDEX™ meters used in the study are calibrated periodically in a Helmholtz coil facility. The experimental setup consists of a check source generating six different magnetic flux densities at the 50 Hz frequency. Three measurements are taken at each density, where, in turn, one of the three orthogonal sensing coils incorporated into the dosimeter is pointed in the direction of the magnetic field vector. Repeated calibration data were used to assess whether the dosimeters are a) reliable, i.e. reflect the magnetic flux density being measured, and b) exchangeable.
Methods: Linear mixed effects (LME) models extend linear models by incorporating random effects, i.e. additional error terms that account for correlation among observations within the same group. Hierarchical LME models are LME models with nested grouping factors. A hierarchical LME model was fitted to the EMDEX™ calibration data. The model was formulated so as to allow us to distinguish between differences in the behaviour of the EMDEX™ meters due to design factors (model type, flux density level, and coil orientation) and meter-specific differences.
Results: A systematic bias of -0.01 μT was assessed for the EMDEX II™ meters. The overall accuracy for both meters is about 3%. This changes from -0.3% to +5.1% for the EMDEX Lite™ and from +3.1% to +3.7% for the EMDEX II™ if one takes into account the orientation of the sensing coils.
Conclusions: a) Both dosimeters proved to provide reliable measures of the true magnetic flux density being generated. b) Questionable is, however, whether the two meters are exchangeable. In fact, whereas the systematic bias highlighted for the EMDEX II™ meter may be neglected as it agrees with the measurement resolution declared by the constructor, the overall accuracy of the EMDEX Lite™ seems to depend in a much heavier way on the orientation of the sensing coils than the EMDEX II™. Whether one decides to neglect this fact or not will determine how to treat the ELF-EMF measurements taken for the cases and controls who enter the SETIL study.

10273-Setting environmental exposure standards: sensitivity analyses for the synthesis of epidemiological and toxicological evidence

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Introduction: Systematic review and meta-analysis techniques were used to combine data from toxicological and epidemiological studies to aid in the risk assessment process. The possible association between trihalomethanes (THMs) in drinking water and low birth weight (LBW) were used to illustrate the methodology. For each of the thirteen studies (eight toxicological and five epidemiological) a dose-response slope estimate was obtained, these were combined using six different meta-analysis techniques. Assumptions were made in the development of this methodology; several of which are also present in more traditional approaches to standard setting. We present some sensitivity analyses of these assumptions to help assess the robustness of meta-analytical and traditional approaches. Methods: Assumptions of the average water intake and body weight of pregnant women were necessary to transform the exposure measures in the epidemiological and toxicological studies on to the same scale (mg/kg/day); the epidemiological studies used parts per billion. Initial analyses assumed average water intake and body weight to be 2 litres/day and 60kg, respectively. However, evidence suggests actual water intake levels are lower and body weight is greater. The impact of changing these assumptions was assessed. In the initial analyses, a linear dose-response model of the log odds ratio (lnOR) for LBW and exposure to THMs was used. Alternative models explored included: 1) a logit model, 2) a model taking account of the correlation between the lnORs within a study and 3) a model using a log transformation of exposure. The fit of these models was assessed using Akaike's Information Criterion (AIC). Results: Reducing the average water intake assumption and increasing the body weight assumption increased the dose-response slope estimates and their standard errors, i.e. they were steeper with more variation. For example, for one study, the dose-response slope estimates (and standard errors) increased from 149.8 (91.53) in the initial analysis to 457.2 (279.4) when 0.82 l/day water intake and 75 kg body weight was assumed. For the regression models, when log exposure was used in the model, the slope estimates were of a similar magnitude across the disciplines, unlike when exposure was used in

the model. According to AIC, the better fitting models were the linear regression models, not the logit models. Conclusions: We have shown that sensitivity analyses are important particularly when ‘default’ values, such as 2 litres/day water intake and 60 kg body weight, are routinely applied. Similarly, it may be difficult to assess the form of the ‘best’ statistical model; exploration of fit and interpretation of different models should be made. Some of the assumptions made in both meta-analytic and traditional approaches are critical, while others are unimportant. In general, therefore, assumptions made in the standard setting process should be checked by sensitivity analysis wherever possible.

10449-The effects of modelling pollution levels on the relative risks obtained from time series studies examining the relationship between air pollution and health

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In conducting time series studies to investigate the relationship between air pollution and a health outcome, for example respiratory mortality, it is important to have a good measure of the level of pollution on any particular day. Often daily measurements are available from a number of monitoring sites across the study. Each of these monitors may measure different sets of pollutants, there may be periods of missing data, and all of the recorded measurements will be subject to error. Here, a (Bayesian) hierarchical model is used for the analysis of such data, addressing the issues described, and specifically, allows information from multiple sites on different pollutants to be combined. This allows an estimate of a 'smoothed', or underlying pollution level for each pollutant at each site to be obtained, incorporating any possible lag structure, along with a measure of uncertainty. These modelled levels of pollution can then be used in time series analyses examining the relationship with health outcome. The measure of uncertainty is particularly useful for accounting for the variation in the pollution level, whether informally, when interpreting the regression coefficients, or more formally via error-in-variables modelling. These methods are applied to levels of a number of pollutants, including PM10, CO, NO and SO2, measured at eight sites in London for the period 1993-96. Associations between the resulting modelled levels of pollution and daily mortality counts in London (from 1993-96) are then examined and compared with those obtained using the original pollution measurements. The sensitivity of relative risks and the width of their confidence intervals are examined with respect to model assumptions, with particular interest in the effect of periods of missing data.

10479-Using Capture-Recapture methods to evaluate potential for ascertainment bias in environmental epidemiology.

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INTRODUCTION: Capture-recapture methods are used increasingly to estimate completeness of disease ascertainment in epidemiology, though not without controversy. We have explored their use in environmental epidemiology for evaluation of potential for bias in measures of association – could patterns be distorted by differential ascertainment? Specifically, we evaluated whether a register of congenital malformations of the eye exhibited patterns of ascertainment that could cause or obscure associations with environmental factors. METHODS: Given five primary sources of cases, to estimate missed and total number of cases we used loglinear models, along with simpler methods on collapsed data. Primary choice of model was based on minimum Bayes Information Criterion (BIC). RESULTS: The optimal model by BIC estimated a total of 577 cases, which given 382 found implies 67.2% completeness (95%CI 55.7-76.4). However, consideration of results from compatible models suggests that true uncertainty is greater than that reflected in the confidence interval. Completeness was much higher for severe cases (the focus of the register: 85.4%; CI 76.9-92.1) and those surviving for more than one year (83.7%; CI 74.0-93.2). There was little variation in ascertainment by socio-economic status of area of residence, but cases were more completely ascertained in less densely populated areas (93.2%, CI 79.5-100 Vs 58.9%, CI 46.0-72.0). This pattern persisted on restriction to severe cases. DISCUSSION: The results suggest that differential ascertainment did not bias a comparison of prevalence across SES groups, but could have biased comparisons across population density. In particular, this might have partially explained an observed excess in rural areas, of interest because of a putative link with pesticides. However, there were too few cases found in truly rural areas for ascertainment to be directly estimated for this population. Uncertainties due to model selection also suggest caution. We conclude that application of these methods has some use in evaluating potential for ascertainment bias, but will usually be limited by uncertainty in estimates of ascertainment completeness, and by cost in statistician time, which came to about two person-months in this study.

10611-Statistical methods for non -steady state exposure estimation using biomarkers

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Biomarker measurements such as blood lead concentrations and hair mercury concentrations are often used to make inferences about previous rates of toxicant intake. Exposure rates are typically estimated using a "steady state" assumption of a constant exposure rate and stable biokinetics over time. Using the steady state model an average biomarker measurement from a specific population is typically multiplied by a steady state ratio obtained from previous biokinetic studies in order to estimate the average rate of toxicant exposure for the population, or the same procedure is applied to the biomarker measurement for each individual in order to estimate individual specific time-averaged toxicant exposure rates. However, toxicant exposures rarely, if ever, occur under steady state conditions, and biomarkers are typically most sensitive to recent toxicant exposures. Moreover, toxicant exposures are typically episodic and vary in magnitude over time. Upper bound exposure estimates, such as those commonly used in risk assessment, are especially likely to be affected by these fallacious assumptions. Methods for biomarker based exposure estimation that do not rely on the steady state model are clearly needed.

A model that treats each biomarker measurement as linear combination of previous daily exposure magnitudes has been used as a simple representation of mercury biokinetics. We present maximum likelihood estimates for individual exposure parameters (means and variances) using this model when exposure magnitudes are independent and normally distributed. When exposure patterns are intermittent the daily exposure magnitudes are described by mixture distributions with a probability mass at zero and some continuous density over the range of positive exposure magnitudes. In this case the likelihood function is difficult to obtain and we recommend quasi-likelihood estimates based on general estimating equations. Due to an additive variance structure the quasi-likelihood estimate of the exposure mean depends on the variance parameter; we propose an iterative approach using a new moment estimate of the variance parameter at each step of the iterative weighted least squares algorithm until both parameters have converged.

Simulations suggest that our approach often results in improved exposure estimates compared to the steady state approach under variable or intermittent exposure conditions. Using appropriate biokinetic parameters, these methods may be applicable to other biomarkers as well.

10664-USING THE RESULTS FROM THE REPEATIBILITY QUETIONNAIRE´S STUDY - LIFE STYLE AND HEALTH – IN THE ANALYSES

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Introduction:

The study of reliability was a part of the project funded by the Czech Ministry of Health "Subjective approach of inhabitants of Ostrava to their health in association with their life-style, socio-economic status and education".

Methods:

A random sample of the population in Ostrava was selected for the questionnaire survey. A questionnaire was compiled and sent to 3,000 respondents. After collecting the questionnaires respondents were selected for the repeatability study. From a total of 600 respondents who returned the completed questionnaire, 300 were selected by the date of return of the completed questionnaire in the main study and then every second respondent was chosen. The 300 questionnaires which were same as in the main questionnaire survey were distributed again. This repeatability study took place 6 weeks after the main questionnaire study. The total number of returned and completed questionnaires reached 181 (60.3% of the response rate).

The method of calculating the kappa index and the whole percentage agreement were used for the evaluation of the repeatability study. We evaluated 61 questions, which were divided into five sections (general questions, employment, life-style, health and personality).

Results:

The agreement rate varied from 46 % to 100 % and the value of the kappa index from –0.01 to 1. The agreement performed by the kappa index was divided into 4 groups (≤0.4 – poor; 0.41–0.6 – average; 0.61–0.80 – good; 0.81 – 1 almost perfect). The agreement across our questionnaire was poor in 6.6 % of the questions, average - in 31.1%, good – in 45.9% and almost perfect – in 16.4% of the questions. Next we divided the questions by their content into two groups – the factual questions (group 1) and the questions which answers contain an evaluative or motivational element (group 2). Significant differences ($p<0.001$) were found between groups 1 and 2 in the agreement rate (86.8 %; 72.1%) and the kappa index (0.73; 0.48).

Some of the questions with a poor kappa index were very important for further data modelling so that we tried to increase exploitation of the data by aggregation of the answers or by replacement the questions with another with the similar meaning – e.g. income was replaced by the subjective evaluation of economic situation. For the questions with aggregated answers the kappa index and the percentage agreement were calculated again. When the agreement was better the questions were used for the analyses in aggregated form otherwise the questions were not used.

Conclusions:

It was important to find out that we can rely on the factual questions posed (e.g. marital status, smoking, etc.). With this kind of questions people give true answers and do not tend to alter the information deliberately. The questions where the agreement of answers is evaluated as average or even weak we used three type of solution: a) substitution by the analogous questions with a higher agreement, b) aggregation of the answers if possible, or c) the questions were not used for the analyses.

10804-A Method for Mapping Population-Based Case-Control Studies Using Generalized Additive Modeling

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Spatial distributions of disease occurrence and risk have traditionally served as tools for identifying exposures of public health concern. Epidemiologists have long mapped routinely collected data such as cancer incidence by county, town or census tract. Interpretation of such data is hampered by the paucity of individual-level covariates, often limited to age and gender. Mapping of the much richer information contained in case-control studies has proven more difficult. However, when cases and controls are appropriately sampled from the population of a geographic area, the odds of disease are proportional to disease incidence. Generalized additive models (GAMs) provide a useful framework for analyzing such data. GAMs are a type of regression that combine smoothing with the ability to analyze binary and other kinds of outcome data. Smoothing on latitude and longitude while controlling for covariates produces maps of the adjusted odds of disease. Comparison of the crude and adjusted maps shows the amount of confounding caused by geographical clustering of individual risk factors (spatial confounding). We smooth using a locally weighted regression smoother (loess), a method that defines neighborhoods based on the k nearest subjects while weighting points within the neighborhood. Loess combines the advantages of nearest neighbor smoothers with the weighting of kernel methods. We choose an optimal degree of smoothing by minimizing Akaike's Information Criterion. GAMs also allow global tests for the importance of location and the construction of variance bands, similar to confidence intervals. We test the method with synthetic data, comparing the results with those produced by a related approach that uses an unweighted nearest neighbor smoother. In a companion paper, we apply the method to data from a population-based case-control study.

10965-STATISTICAL METHODS FOR EVALUATING SAMPLES BELOW DETECTION LIMITS.

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Data below detection limits always present problems for statistical analysis since most statistical methods assume that all values are observed. An *ad hoc* substitution procedure of using half of the detection limit or 0 for non-detects is commonly used, but this procedure begins to seriously bias the results of most analyses when more than 10% of the values are below detection limits. When a large fraction of the measurements are below a detection limit there have been a number of statistical methods developed, but these methods are not easily applied without collaboration with statisticians. Our investigations have looked at simplified methods by simulating values for data below detection limits using quantile-quantile plots to estimate the shape of the distribution. The simulated and observed values are then combined and standard methods of statistical analysis are applied. These simpler methods are compared to the more complicated optimal statistical methods and the *ad hoc* substitution procedure for analysis of variance and linear regression when the dependent variable is below a detection limit. Monte Carlo methods were used to make the comparisons for sample sizes of 25 to 200. The results indicate that the simpler methods are less biased than the *ad hoc* substitution procedure for analysis of variance, but the simplified methods may greatly overestimate the variance compared to maximum likelihood methods when a large fraction of the values are below detection limits. The comparisons between these three methods were also made for a variety of signal to noise ratios, which was found to be an important consideration in choosing a method of statistical analysis. Similar results were found for linear regression. We applied these methods to analyze data on organophosphorus pesticide metabolites in urine of children whose parents work in orchards and may accidentally expose their children with pesticides brought home on clothing and skin. The pesticide metabolite data had multiple detection limits and groups of metabolites were summed for estimates of exposures. The results illustrate that in complex situations the simplified methods has many advantages in reducing bias compared to the *ad hoc* substitution method. However when more than 70% of the values are below the detection limits the advantages of more complex methods outweigh the difficulties of their application.

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11016-Missing values imputation methods for air pollution data: An optimal method applied to Sulpher Diox levels and asthma hospital admissions

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Many environmental data contains lengthy records of sequential missing values due to electronic data collection equipment failure. Practical problem arose in the analysis of Sulpher Dioxide levels and asthma hospital admissions for Sydney Nova Scotia, Canada, where nearly half of the Sulpher Dioxide data were missing. Reliable missing values imputations are required to facilitate the data analysis using standard statistical software package and also to obtain valid estimates of the associations with sparse asthma hospital admissions. Several imputation methods have been proposed for stationary time series data. Interpolation method using between forecasting was recommended for first order non-stationary data. Mean daily average Sulpher Dioxide levels follow a non-stationary time series with a measurement error. An optimal method of forecast was developed extending the between forecast method to include prediction error and the method was validated using observed Sulpher Dioxide data. The imputed values of this method provide the most accurate estimates of the association between asthma hospital admissions as compared to the other methods and can be used using already existing statistical software.

11021-Do occupational studies underestimate exposure effects? Simulations of the healthy worker survivor effect.

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The healthy worker survivor effect (HWSE) occurs when workers who leave employment have, on average, poorer health than those who stay, leaving the healthier employees to accrue higher cumulative exposures. Job-leaving may also be associated with past exposures, as, for instance, when very short-term workers tend to be those who were given the 'dirtiest' jobs, such as maintenance. G-estimation is an analysis method designed to obtain an unbiased estimate of exposure effects in such circumstances. Occupational cohorts were simulated by (1) randomly assigning workers an age-at-hire based on empirical data and a death time based on U.S. lifetables; (2) assigning a binary exposure at hire, randomly, and thereafter, conditional on exposure in the previous interval, for those at work. Several parameters were then varied. (a) The relationship between exposure and mortality was allowed to be null, moderate or large; in the latter two cases, age at death was advanced as a function of years exposed. (b) Job-leaving (for those at work) and job-returning (for those off-work) were assigned in one of three ways:, i) at random, ii) conditional on past exposure alone, and iii) conditional on both past exposure and underlying health status, represented by proximity of death. (c) Follow-up was either to death of the entire cohort, or for 30 years, in which case workers still alive were censored at end of follow-up. Each cohort consisted of 1,000 workers, and each scenario was replicated 100 times. When follow-up was till death, G-estimation provided unbiased estimates of the relationship between exposure and mortality with or without an effect of exposure on mortality, for all job-leaving and job-returning rules. Coverage probabilities were excellent, but power was low. With 30 years of follow-up, bias up to 20% was observed. However, standard Cox model analysis, in all scenarios where job-leaving was influenced by underlying health status (i.e., whenever the HWSE was present), showed either an attenuated harmful effect of exposure, or a protective effect, in spite of the true life-shortening of exposure. The bias in standard person-time analysis is magnified when follow-up is only 30 years. This simulation study demonstrates that in occupational cohort studies, standard methods of analysis in the presence of what appears to be a modest healthy worker survivor effect yield invalid, downwardly biased effect estimates. Since occupational studies often serve as a basis for risk assessment, these findings have implications for the evaluation and regulation of environmental chemicals and the protection of public health.

11136-Determination of probability distributions for transfer efficiencies

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In the current experimental literature there is not much published about dermal exposure analysis. However, scientists continue to develop human exposure model frameworks that require experimentally derived parameters. Today dermal exposure models use stochastic techniques to sample parameter distributions (e.g., environmental concentrations, transfer efficiencies, surface area, etc.). Large data sets for environmental contaminants (e.g., radionuclides, air pollutants, etc.) have shown experimentally determined concentrations usually have lognormal distributions. Since transfer efficiencies represent the fraction of a surface contaminant transferred to skin during a contact event, it is likely that transfer efficiencies are lognormally distributed as well. To use experimental data for modeling purposes the data need to be critically evaluated for internal consistency and experimental uncertainty. Examination of the literature confirms that no single study is large enough to provide the basis for parameter distribution evaluation. Therefore, it is necessary to pool data from multiple studies. While several studies in the current literature report measurements of transfer efficiencies, the experimental designs are so inconsistent it might not be possible to pool the data. Results of the literature review were organized in a database by chemical, method, and surface types. Studies reporting only mean values were not included. Values included in the database were compared using a nonparametric analysis of variance method, (Kruskal-Wallis Test), to determine if different data sets arise from the same distribution. Combined data were evaluated using the Chi-square and Kolmogorov-Smirnov goodness of fit tests for normal, lognormal and uniform distributions. Our literature review identified 35 studies directly reporting transfer efficiencies. These studies comprise 25 different methods, 25 chemicals, and 10 surface types. Only 12 studies reported actual individual experimental data and these were used for fitting distributions. For example, 5 studies published raw data for transfer efficiencies of chlorpyrifos from carpet. These studies involved 6 different methods resulting in 10 distinct data sets. Three data sets reported transfer efficiencies from hand presses. Although different liquids were used to moisten the hands, the data sets were not significantly different (Kruskal-Wallis $p=0.16$). The combined data set may possibly be distributed normally ($n=18$, Chi-sq $p=0.16$, Kolmogorov-Smirnov $p=0.26$) or lognormally ($n=18$, Chi-sq $p=0.71$, Kolmogorov-Smirnov $p=0.79$). A similar analysis confirmed that 5 data sets reporting values from cloth roller and PUF roller methodologies could also be combined (Kruskal-Wallis $p=0.27$). Other permutations of the data sets were evaluated which included quite different methodologies (i.e., cloth roller and hand presses). Similar analyses were conducted using different chemicals and surface types. Results of this evaluation underscore the difficulty of fitting distributions for transfer efficiencies. Clearly, additional data are needed to verify the accuracy of model input parameter distributions. Future studies need to be designed to provide large data sets that are systematically collected to provide more accurate representation of the variability of transfer efficiencies. Furthermore increased effort should be placed on developing studies that more accurately represent transfer to human skin from surfaces.