Application of the Residential Population Generator (RPGen) in prediction of Exposure Outcomes for Owners and Renters from Consumer Products using the Combined Human Exposure Model (CHEM)

Alexander East[1], Kristin Isaacs[2], and Daniel Vallero[2]
[1]Oak Ridge Associated Universities, assigned to U.S. Environmental Protection Agency, Office of Research and Development, Center for Computational Toxicology and Exposure, Research Triangle Park, NC 27709
[2]U.S. Environmental Protection Agency, Office of Research and Development, Center for Computational Toxicology and Exposure, Research Triangle Park, NC 27709

Alexander W. East I East.Alexander@epa.gov I 919-541-4064

Abstract

The Residential Population Generator (RPGen) is the first of three modules in the Combined Human Exposure Model (CHEM), which estimates exposure from consumer products. RPGen creates a database of modeled individuals is created by linking data from US census and US housing surveys with physiological characteristics from the National Health and Nutrition Examination Survey data. Characteristics of the generated household and individual influence exposures in CHEM, and this is demonstrated with a case example across 5 chemicals informed by renting or owning a household.

Background

In CHEM, individual exposure is characterized by the residence, activities, and concentration of chemicals in products. These three elements are handled in the Residential Population Generator (RPGen), Product Use Scheduler (PUS) and Source-to-Dose (S2D) respectively. As the first module, RPGen creates:

- a definition of an individual consisting of 126 characteristics
- internally consistent records with demographic, housing, residential, and physiological data.
- variation by age, gender, income, and location, which reflect interindividual variability in exposure-related parameters.
- Product use, and subsequently exposure, is determined by "ever/never" rules in RPGen as well as activity diaries in PUS.

Methods

The activities of an individual in CHEM are determined in PUS. However, some elements from RPGen determine if a household ever uses a product. These are possession of a car, dishwasher ,oven, printer, septic tank, swimming pool, front yard, or if the individual rents or owns a property. As product use was determined by owning or renting more than any other variable from RPGen, it was chosen as the subject of this case study.

- CHEM was ran for 1,000 individuals across all races, genders, and ages.
- 5 chemicals were selected: Dibutyl phthalate, Toluene, Benzyl butyl phthalate, Diethylene glycol, and Naphthalene.
- 'Exposure' was determined as the mg/kg-bw/day intake for both direct and indirect exposure via dermal, ingestion, and inhalation routes.
- These results were compared to SHEDS-HT, an established model for estimation of exposure to consumer products (Isaacs et al. 2014).

Results & Discussion

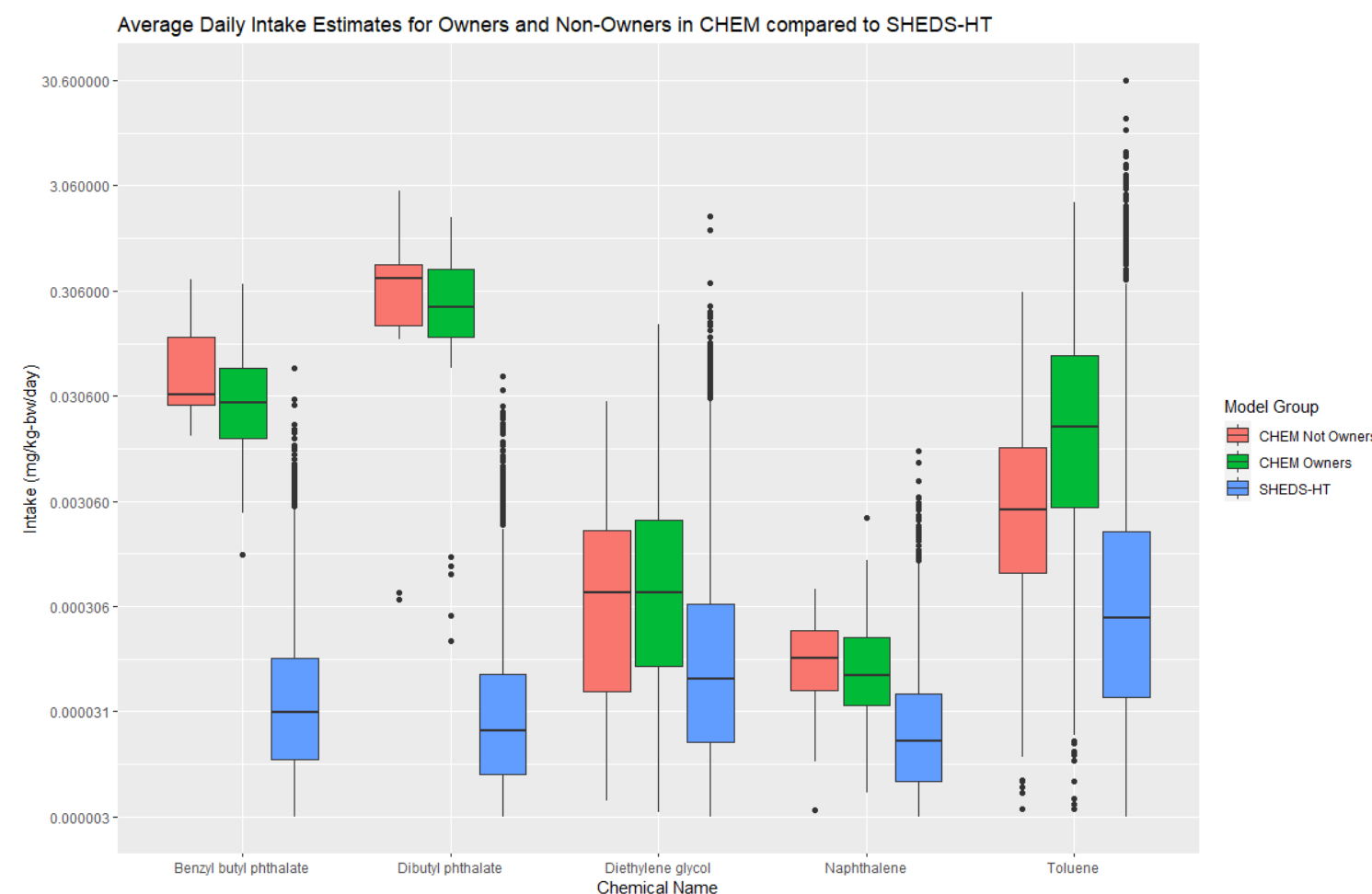Figure 1. Daily Exposure for Owners and Renters in CHEM and SHEDS-HT across 5 Chemicals

Average Daily Intake Estimates for Owners and Non-Owners in CHEM compared to SHEDS-HT

Table 1. Summary Statistics for CHEM and SHEDS-HT Output (mg/kg-bw/day)

Name	Model	Houses	Exposed	Mean	Mean (Just Exposed)	95th%
Toluene	CHEM Owners	600	517	0.0737	0.862	0.386
Dibutyl phthalate	CHEM Non-Owners	249	28	0.0601	0.112	0.427
Dibutyl phthalate	CHEM Owners	600	54	0.0291	0.09	0.162
Toluene	SHEDS-HT	10000	9437	0.0233	0.944	0.0147
Benzyl butyl phthalate	CHEM Non-Owners	249	17	0.00682	0.0683	0.0237
Toluene	CHEM Non-Owners	249	102	0.00557	0.41	0.0191
Benzyl butyl phthalate	CHEM Owners	600	32	0.00243	0.0533	0.00257
Diethylene glycol	SHEDS-HT	10000	9998	0.00138	1	0.00327
Diethylene glycol	CHEM Owners	600	266	0.00114	0.443	0.00398
Diethylene glycol	CHEM Non-Owners	249	124	0.000626	0.498	0.00226
Dibutyl phthalate	SHEDS-HT	10000	5227	0.000103	0.523	0.000166
Benzyl butyl phthalate	SHEDS-HT	10000	5170	9.22E-05	0.517	0.000264
Napthalene	CHEM Non-Owners	249	43	0.000021	0.173	0.000156
Napthalene	SHEDS-HT	10000	5512	1.91E-05	0.551	5.68E-05
Napthalene	CHEM Owners	600	83	1.86E-05	0.138	0.000088

- Exposure to Benzyl butyl phthalate, Dibutyl phthalate, Diethylene glycol, Toluene, and Napthalene is higher than the SHEDS-HT results, although the tails of the SHEDS-HT exposure distribution are wider, likely due to a sample size of 10,000 (Figure 1).

- SHEDS-HT provides a conservative exposure estimate (Isaacs et al., 2013), therefore the exposure estimates provided by CHEM are extremely conservative.

- SHEDS-HT is a one-day model; the compared daily estimates negate the longitudinal seasonality in CHEM.

- Across 4/5 chemicals in Figure 1, median exposure was higher for non-owning individuals versus owners.

- In Table 1, the number of exposed households, which had product use during the one-year run, was significantly lower when compared to SHEDS-HT distributions. Diethylene glycol exposure was estimated in 266/600 owned households and 9998/1000 SHEDS-HT individuals.

- CHEM runs exceed 100 hours for a machine with 8GB RAM, while SHEDS-HT estimates were generated in under 5 minutes.

RPGen appends datasets to create a synthetic population for models of exposure. These variables can be integrated into models such as CHEM for more granular population-based exposure results. Challenges include overestimating, processing time and small sample size. The following workflow may be applied to other variables (ethnicity/income) for environmental justice purposes.

References

Isaacs, K. K., Glen, G. W., Egeghy, P. P., Goldsmith, M. R., Smith, L., Vallero, D. A., Brooks, R., Grulke, C. M., & Özkaynak, H. (2014). *Sheds-HT: An integrated probabilistic exposure model for prioritizing exposures to chemicals with near-field and dietary sources*. Environmental Science & Technology, 48(21), 12750–12759.

East, A., Dawson, D., Glen, G., Dionisio, K., Isaacs, K., Hubal, E., & Vallero, D. (2020, December 30). *The Residential Population Generator (RPGen): parameterization of residential, demographic, and physiological data to model Intraindividual Exposure, dose, and risk*. EPA. https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=350496&Lab=CCTE.