Agency for Toxic Substances and Disease Registry
Guidance for Evaluating Inhalation and Dermal Exposure Using the Shower and Household Water-use Exposure (SHOWER) Model v4.0

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Contents

Figures

Tables

Abbreviations

95UCL	95 percent upper confidence limit of the arithmetic mean
AAC	adjusted air concentration
ABS_{GI}	gastrointestinal absorption factor
ACH	air changes per hour
ADD	administered dermal dose

ADS	Associate Director of Science
AMA	Ambient Monitoring Archive
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ATSDR	Agency for Toxic Substances and Disease Registry
CR	cancer risk
CREG	Cancer Risk Evaluation Guide
CSF	oral cancer slope factor
CTE	central tendency exposure
CV	comparison value
DAD	dermal absorbed dose
EPC	exposure point concentration
ft	feet
HAP	hazardous air pollutant
HQ	hazard quotient
HVAC	heating, ventilation, and air conditioning
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
L	liters
LOAEL	Lowest Observed Adverse Effect Level
m	meters
$\mu g/m^3$	micrograms per cubic meter
µg/kg/day	micrograms per kilogram per day
mg/kg/day	milligrams per kilogram per day
min	minutes
MRL	Minimal Risk Level
NOAEL	No Observed Adverse Effect Level
PCE	tetrachloroethylene
PHA	public health assessment
PHAGM	Public Health Assessment Guidance Manual

PHAST	Public Health Assessment Site Tool
ppb	parts per billion
REUWS	Residential End Uses of Water Survey
RfC	Reference Concentration
RfD	Reference Dose
RME	reasonable maximum exposure
s	seconds
SAMS	Secure Access Management Services
SHOWER model	Shower and Household Water-use Exposure model
TWA	time-weighted average
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound

1. Introduction

This guidance document describes how to evaluate inhalation and dermal exposure to chemicals that occur when people use water indoors for showering, hand washing, and other activities. When people use water indoors, volatile and semi-volatile chemicals in the water will volatilize to indoor air. Inhalation exposure results from people breathing the chemicals in indoor air, and dermal exposure results from skin contact with the chemicals in water.

The ATSDR Shower and Household Water-use Exposure (SHOWER) model predicts indoor air concentrations and dermal uptake associated with indoor water use, allowing ATSDR and state health assessors to evaluate these exposure pathways. The SHOWER model includes two simulation types: residential simulations model exposure in 1- or 2-bathroom houses, and communal shower and bathroom simulations model exposure in facilities where multiple people shower or use the bathroom at the same time. ATSDR's Public Health Assessment Site Tool (PHAST) allows health assessors to perform exposure calculations on SHOWER Model results, including calculation of hazard quotients and cancer risks. The SHOWER model does not simulate exposures involving outdoor activities.

1.1. Background and Objectives

When chemicals are released to the environment, health assessors must evaluate all human exposure pathways. In addition to evaluating oral exposure from contaminated water, health assessors should evaluate dermal uptake from contact with contaminated water and inhalation exposure from chemicals that volatilize to indoor air.

According to ATSDR's online Public Health Assessment Guidance Manual (PHAGM), theoretical and experimental studies have demonstrated that the internal dose from inhalation and dermal exposure to a contaminant while showering can be comparable to the oral dose from drinking contaminated water (ATSDR 2023b; Jo et al. 1990a, 1990b). For example, Andelman (1990) used a one-compartment shower model to estimate a contaminant's average air concentration in a residential bathroom while showering. From this, Andelman developed a formula for estimating the amount of inhalation exposure from household water use, which he compared to oral exposure from drinking household water. He concluded that for adults the amount of inhalation exposure from using contaminated water in a house was comparable to the amount of oral exposure from drinking the water. Thus, early on, doubling the oral dose from drinking water was used by some public health officials as a surrogate to inhalation exposure from showering in water containing volatile organic compounds (VOCs).

This approach has obvious limitations in that it does not account for chemical contributions to indoor air contamination from non-shower water uses (e.g., faucet, toilet, dishwasher, clothes washer) and from showers by other people, nor does it account for exposure from being in the building the rest of the day. Merely doubling the drinking water dose for volatile chemicals cannot account for these additional exposures, nor does it account for differences in toxicity between inhalation and oral exposures. For these reasons, ATSDR reviewed the work of other scientists, such as T.E. McKone and J.C. Little who developed multi-compartment models that included mixing formulas to estimate how chemicals in air move from room to room (Little 1992; McKone 1987). This multi-compartment approach, which is the basis of the ATSDR

SHOWER model, allows exposure to be based upon not only the exposure that occurs during a shower but also the exposure that occurs from being in the bathroom and main building during the remainder of the day. The ATSDR SHOWER model thus extended the existing modeling science conducted by the pioneering work of Andelman, Giardino, Little, and McKone to include not only multiple compartments and multiple sources but also the contribution from other people and from dermal exposures, which was not done previously (Andelman 1985a, 1985b; Giardino and Andelman 1996; Kim et al. 2004; McKone 1987).

The objectives of the SHOWER model were to develop an approach that

- includes the most common indoor water sources that contribute to inhalation and dermal exposure,
- includes exposure that occurs not only while bathing but also from being in the bathroom,
- includes exposure throughout each day when people are not in the bathroom,
- accounts for non-exposure when persons are away from the building, and
- includes the contribution to exposure from water use by all house residents in residential scenarios and all facility users in communal shower and bathroom scenarios.

Other important objectives of the SHOWER model included

- providing an easy-to-navigate platform requiring minimal input to get results,
- standardizing the exposure scenarios that health assessors can use,
- allowing users to change most of the parameters in the model, and
- allowing the user to choose result units that are consistent with health guidelines and toxicity values.

1.2. Brief Description of the Model

For residential scenarios, the SHOWER model estimates inhalation and dermal exposure for a three- or five-compartment residence consisting of a main house with either one or two bathrooms, each with a separate shower compartment. Health assessors need only enter a site name, a contaminant name, and a water concentration to calculate daily air concentrations and dermal doses for households with up to eight persons. The model not only includes exposure from showering but also includes exposure from people using bathtubs, faucets, toilets, dishwashers and clothes washers, and can account for persons being out of the house and having a bathroom fan on. The model provides default values for most parameters and allows users to customize nearly all of the model's physical and chemical parameters. Allowing users to change parameters, such as bathing duration and sequence, lets them assess the impact of these parameters on exposure and answer specific questions from the community.

For communal shower and bathroom scenarios, the SHOWER model allows health assessors to simulate facilities where multiple people can shower or use the bathroom simultaneously. These include showers and locker rooms in commercial gyms, schools, and dorms, as well as communal bathrooms in offices, commercial daycares, and other buildings. The SHOWER model can simulate facilities that serve up to 1,000 people in a day. Health assessors need only to enter the number of people that use the facility each day along with the contaminant name and water concentration to get summary statistics on inhalation concentrations and dermal doses for all facility users. Similar to the residential scenarios, the SHOWER model provides defaults for and allows users to customize nearly all the physical and chemical parameters used in communal shower and bathroom scenarios.

Communal Shower and Bathroom Scenario "Facilities"

In the SHOWER model, the term "facility" refers to either a single communal shower area with adjoining locker room or to a single communal bathroom area. If a building has separate facilities by gender, family status, accessibility, or other trait, the model should be run separately for each facility.

SHOWER model simulations are either deterministic or stochastic, depending on the scenario type.

- SHOWER model residential scenarios are deterministic. They do not incorporate randomness into the calculations and will always provide the same result for the same set of input values.
- SHOWER model communal shower and bathroom scenarios are stochastic. They incorporate randomness and can provide slightly different results for the same set of input values. The SHOWER model simulates communal shower and bathroom scenarios using Monte Carlo methods, which perform multiple iterations of each scenario to obtain distributions of output results.

Although the residential scenarios are deterministic, the default scenario activity patterns, which determine when people take showers and use water in the house, were derived from Monte Carlo simulations to account for randomness in actual daily water usage. As described further in Appendix B and in the SHOWER model technical document (ATSDR 2024b), ATSDR derived the default scenario activity parameters by developing deterministic scenarios that approximated the 50^{th} and 95^{th} percentile results of Monte Carlo simulations in which shower durations and water usage were simulated stochastically. The scenarios based on these simulations were introduced in version 3.0 of the SHOWER model, and in version 4.0, ATSDR continued to use them for consistency.

The outputs from both the SHOWER model residential and communal shower and bathroom simulations are central tendency exposure (CTE) and reasonable maximum exposure (RME) inhalation concentration and dermal dose estimates. These estimates allow health assessors to follow ATSDR's process for evaluating exposures using ATSDR's recommended cancer and noncancer health guidelines. If estimated daily exposure concentrations and dermal doses exceed health guidelines, health assessors conduct a detailed toxicological evaluation to determine whether harmful effects in the exposed population might be possible. This process is explained in more detail in Section 2.

The SHOWER model does not calculate oral doses from ingesting contaminated drinking water. Health assessors can use ATSDR's SHOWER Model Exposure Calculator in PHAST to estimate oral doses from drinking water while also conducting exposure calculations on inhalation concentrations and dermal doses imported from the SHOWER model.

1.3. Model Development

ATSDR has released four versions of the SHOWER model:

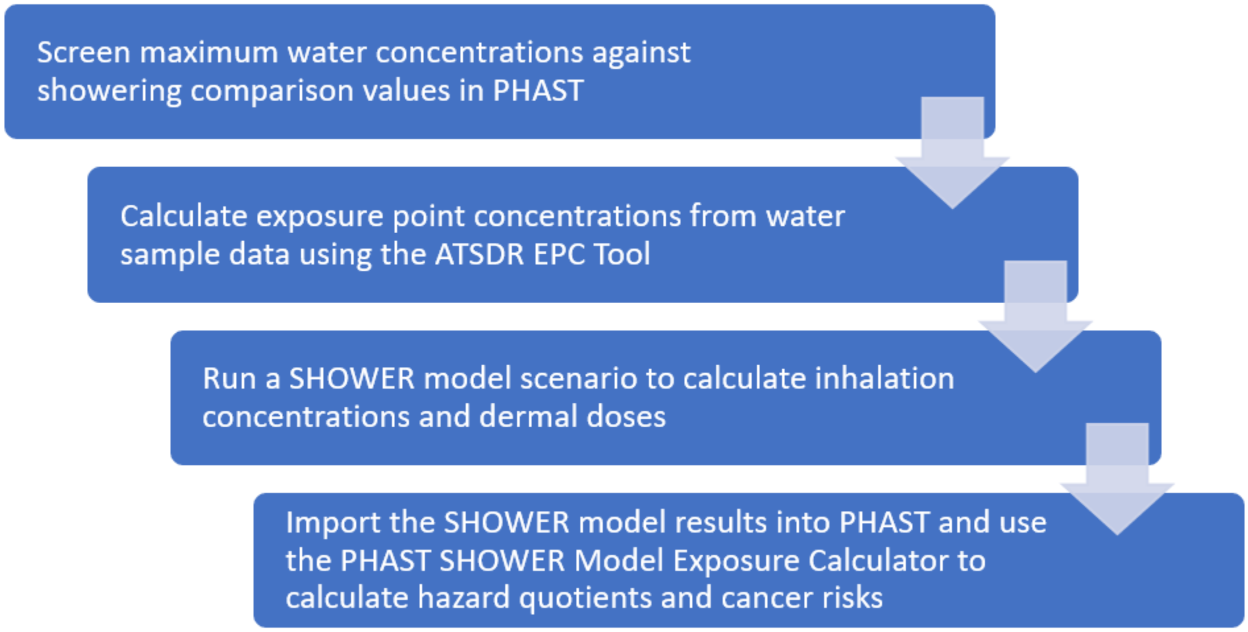
- SHOWER model v1.0 was released in May 2018. It required the user to enter only a contaminant name and concentration to obtain results for a representative household. The model's default report provided exposure results for households with 1, 2, 3, and 4 persons in which family members sequentially took 8-minute showers followed by 5-minute bathroom stays.
- SHOWER model v2.0 was released in February 2020. It expanded upon the functionality of v1.0 by allowing the user to customize many of the model parameters, including, the number of bathrooms, the activity sequence and duration for each household member, the size and layout of the house, and the household appliance parameters (e.g., appliance flow rate, use duration). It also gave users the ability to simulate houses with two bathrooms instead of just one.
- SHOWER model v3.0 was released in May 2022. It provided integration with PHAST and allowed users to export SHOWER model results for import and analysis within the PHAST SHOWER Model Exposure Calculator. It also updated the residential default scenario to include CTE and RME results, and incorporated the effects of contaminant saturation in air into the SHOWER model's governing equations.
- SHOWER model v4.0 was released in September 2024. It added in simulations for buildings with communal shower and bathroom facilities and used Monte Carlo methods to account for randomness in facility usage patterns. Using SHOWER model v4.0, health assessors can simulate exposures in commercial gyms, schools, and other buildings where people shower together in the same facility, and they can simulate exposures in offices and other buildings where people use the bathroom together in the same facility.

Various minor program updates were also made in each of the release versions after SHOWER model v1.0. For questions about the SHOWER model or for additional information about future releases, email showermodel@cdc.gov.

2. The SHOWER Model and the Public Health Assessment Process

The public health assessment (PHA) process for evaluating exposures with the SHOWER model consists of several steps, as shown in Figure 1. Sections 2.1 to 2.4 summarize the overall PHA process for both residential and communal shower and bathroom scenarios, and Sections 3 through 6 provide instructions on completing these steps using the SHOWER Model and other software tools developed by ATSDR. More information about these steps and other aspects of ATSDR's PHA process can be found in ATSDR's PHAGM (ATSDR 2023b).

Figure 1. PHA process for evaluating exposures using the SHOWER model



2.1. CV Screening

The first step in evaluating inhalation and dermal exposures using the SHOWER model is to screen the site's sampling data. In this step, health assessors identify and remove from further evaluation any contaminants with concentrations well below established health-based screening levels. Any contaminants that screen out of the analysis in this step have concentrations well below harmful exposure levels and are not a health concern.

To assist with screening, ATSDR has derived "Showering and Household Water-use" comparison values (CVs), or SHOWER CVs, for screening water concentrations for inhalation and dermal exposures. These SHOWER CVs are based on the SHOWER model's default residential scenario and represent water concentrations below which harmful health effects are not expected from inhalation and dermal exposures to a contaminant in a four-person household where each person takes a morning shower. The SHOWER CVs are protective for both residential and communal shower and bathroom scenarios, such that they can be used for screening both scenario types. Any contaminants with maximum water concentrations below SHOWER CVs are not a health concern and do not need to be evaluated further unless exposure to a mixture of chemicals is possible. ATSDR health assessors should consult with the Associate Director of Science (ADS) when evaluating a mixtures scenario. State health assessors that are part of ATSDR's APPLETREE program should consult with their technical project officer. APPLETREE, which stands for ATSDR's Partnership to Promote Local Efforts to Reduce Environmental Exposure, is a cooperative agreement with state health departments to build their capacity to assess and respond to site-specific issues involving human exposure to hazardous substances in the environment.

PHAST includes a module for screening water concentrations against ATSDR's SHOWER CVs. The module also gives health assessors the option to screen using non-ATSDR CVs and allows health assessors to screen water concentrations using both drinking water and SHOWER CVs at the same time. Health assessors should use the CV module in PHAST for screening, since the CV Screen module for water uses the most up-to-date values of ATSDR's SHOWER CVs.

At some sites, certain contaminants may exist that will not screen out at this step. These include contaminants that do not have screening values, those that have only acute CVs available, and those that are contaminants of concern to the community. More information about these situations and the screening process in general can be found in ATSDR's PHAGM (ATSDR 2023b).

2.2. Calculate EPCs

Any contaminants which did not screen out in the first step are retained for the second step, which is to calculate exposure point concentrations (EPCs). EPCs are representative contaminant concentrations in an exposure unit to which people are exposed for a specific duration during the past, present, or future. EPCs for SHOWER model scenarios are representative water concentrations calculated using exposure unit sampling data. In residential scenarios, each household is a separate exposure unit, and in communal shower and bathroom scenarios, each facility in a building is a separate exposure unit. The term "facility" in communal shower and bathroom scenarios refers to either a single communal shower area with adjoining locker room or a single communal bathroom area. If a building has separate facilities by gender, family status, accessibility, or other trait, each facility should be treated as a separate exposure unit.

ATSDR's typical procedures for calculating EPCs are discussed in ATSDR's *Exposure Point Concentration Guidance for Discrete Sampling* (ATSDR 2022a). Calculated EPCs are either 95 percent upper confidence limits of the arithmetic mean (95UCLs) or maximum detected values. For acute duration evaluations, health assessors should use the statistic (maximum detected concentration or 95UCL) that best aligns with the contaminant's applicable toxicity data as the EPC. For intermediate and chronic duration evaluations, whether to use the maximum or the 95UCL is determined by the number of samples analyzed for the contaminant, the frequency with which the contaminant was detected, and the shape of the contaminant's measured concentration distribution. In general, ATSDR's algorithm for determining whether to use the maximum or the 95UCL for intermediate and chronic duration evaluations is:

- Use the maximum detected concentration as the EPC when:
    - the dataset includes fewer than eight contaminant records,
    - the contaminant was detected fewer than four times,
    - more than 80% of the contaminant records are nondetects, or
    - the dataset includes less than three unique detected values.
- Otherwise, use the 95UCL as the EPC.

A more detailed explanation of these criteria can be found in ATSDR's EPC guidance for discrete sampling (ATSDR 2022a).

To implement the algorithm, ATSDR developed the ATSDR EPC Tool. The ATSDR EPC Tool is an R Shiny web-based application that calculates EPCs using discrete environmental data (ATSDR 2022b). It automates the EPC calculation algorithm using the criteria described in ATSDR's guidance document and also includes additional calculation steps for special-case contaminants like dioxins and polychlorinated biphenyls. More details on the EPC calculation process for these special-case contaminants can be found in ATSDR's *Toxic Equivalence Guidance for Dioxins and Dioxin-like Compounds* (ATSDR 2019a) and ATSDR's *Guidance for Calculating Benzo(a)pyrene Equivalents for Cancer Evaluations of Polycyclic Aromatic Hydrocarbons* (ATSDR 2022c).

2.3. Run a SHOWER Model Scenario

When a contaminant exceeds a shower or dermal CV or meets one of the other screening criteria, the third step in the evaluation process is to run the SHOWER model using the calculated EPCs. For residential scenarios, health assessors have the option of running either a default or custom scenario. The default residential scenario provides reasonable maximum exposure (RME) and central tendency exposure (CTE) results for a representative four-person household. In this scenario, four people take consecutive morning showers. The default RME scenario for the 4-person household assumes the first three people take 10-minute morning showers and the fourth person takes a 15-minute morning shower, each followed by 5-minute bathroom stays. The CTE scenario for the 4-person household assumes all four people take 7-minute morning showers, each followed by 5-minute bathroom stays. The SHOWER model provides results for the most highly exposed person in the household, which is the last person to take a morning shower. Anytime site-specific information is not available, health assessors should use results from the default 4-person residential scenario to evaluate the risk of harmful effects from showering in contaminated water.

For sites where additional information is available, health assessors can run a custom residential scenario. In a custom scenario, health assessors can simulate households with one to eight people and houses with either one or two bathrooms. Most of the model parameters can be set to site-specific values in a custom scenario, including building size and layout, appliance flowrates, and bathing times and durations. Health assessors can also use the custom scenarios to answer specific questions from community members, such as how exposures are impacted by taking longer showers or by taking a tub bath instead of a shower.

The SHOWER model also provides default and custom scenario options for communal shower and bathroom scenarios. Default scenarios are available for facilities in commercial gyms, commercial daycares, dorms or barracks, offices, and schools. Default scenario parameter values are assigned based on the building type, facility type (shower and locker room facility or bathroom facility), and the number of people using the facility each day. Custom scenarios allow health assessors to change the parameter values from their defaults and evaluate site-specific conditions.

All SHOWER model scenarios provide two types of outputs:

- The first type are average daily inhalation exposure concentrations based on time-weighted averages of the air concentrations that persons are exposed to as they move throughout the building during the day. Unless otherwise noted, the calculated exposure concentrations will apply to all exposure groups considered in a scenario.

- The second type are exposure-group specific dermal doses, which are calculated based on each person's simulated activities. Activities that contribute to dermal exposures in the SHOWER model are showering, tub bathing, and hand washing.

The default residential scenario and the communal shower and bathroom scenarios calculate both CTE and RME results. In the default residential scenario, the CTE and RME results approximate 50^{th} and 95^{th} percentile exposures, and in the communal shower and bathroom scenarios, they are the 50^{th} and 95^{th} percentile values of the exposure distributions output from the Monte Carlo simulation. For scenarios where both CTE and RME results are provided, health assessors should base the site's public health determination on the RME results because they are more protective.

In addition to inhalation concentrations and dermal doses, the SHOWER model also calculates inhalation doses. For scenarios where residents are not only showering or bathing in contaminated water, but also are drinking contaminated water, health assessors may consider combining the exposure from multiple routes (ingestion, inhalation, dermal) to get a total exposure. When combining inhalation with oral and dermal exposures, the chemical must have the same toxic endpoints via the oral and inhalation routes. Examples include trichloroethylene, tetrachloroethylene, benzene, carbon tetrachloride, mixed xylenes, and chlordane. If this condition is met, health assessors can combine the inhalation dose with the oral and dermal doses to get a total dose from all routes of exposure. Studies cited in ATSDR's toxicological profiles, USEPA's Integrated Risk Information System (IRIS), and other appropriate sources must support this approach.

2.4. Perform Exposure Calculations in PHAST

After running a SHOWER model scenario, the fourth step is to perform exposure calculations in PHAST to determine whether any contaminants require a detailed toxicological evaluation. Exposure calculations involve calculating pathway-specific hazard quotients (HQs) to evaluate noncancer health effects and involve calculating cancer risks (CRs) to assess risks from carcinogens.

- HQs are calculated by dividing a duration-specific noncancer exposure concentration or dose by its corresponding health guideline. Health guidelines include ATSDR Minimal Risk Levels (MRLs) and USEPA Reference Concentrations (RfCs) and Reference Doses (RfDs). When a pathway-specific HQ is less than or equal to 1, the exposure is unlikely to cause noncancer health effects from exposure to that chemical and that pathway alone. HQs greater than 1 indicate that a detailed noncancer toxicological evaluation is necessary to determine if doses or concentrations are approaching or exceeding harmful levels identified in animal and human studies.
- CRs are calculated for inhalation exposures by multiplying a contaminant's adjusted air concentration (AAC) by its inhalation unit risk (IUR) and for oral and dermal exposures by multiplying its oral and dermal doses by its oral cancer slope factor (CSF). The duration of exposure in years is also factored into calculating the CR. CRs represent the estimated number of increased cases of cancer in a population that might result from

exposure to a particular contaminant under site-specific exposure conditions. For example, a cancer risk of 1.0×10^{-6} represents one possible excess cancer case in a population of one million people similarly exposed to a contaminant in tap water at a specified concentration and duration. ATSDR conducts a detailed cancer toxicological evaluation for contaminants with cancer risks greater than 1.0×10^{-6}.

The PHAST SHOWER Model Exposure Calculator allows health assessors to import SHOWER model data and calculate HQs and CRs for inhalation and dermal exposures using ATSDR's current health guidelines, IURs, and CSFs. For sites where people are also drinking the water, the SHOWER Model Exposure Calculator also allows health assessors to calculate HQs and CRs for ingestion exposures. For sites with both ingestion and dermal exposure estimates, PHAST will calculate combined oral and dermal doses and will generate HQs and CRs based on the combined results. Health assessors should use combined results rather than ingestion-only or dermal-only results whenever people are drinking the water and using it for other purposes.

The data imported from the SHOWER model represent exposures over a 24-hour period. The SHOWER model does not identify the days per week, weeks per year, or years per lifetime over which exposures occurred, so health assessors must identify those exposure factors in PHAST. Depending on the scenario loaded, PHAST gives health assessors the option of calculating results using either default or site-specific exposure factors, which include the duration of exposure. Default residential scenarios assume continuous exposure, whereas default communal shower and bathroom scenarios assume either continuous or intermittent exposure based on the building type, as identified in PHAST's output reports. Custom scenarios are site-specific and must use site-specific exposure factors in PHAST.

PHAST will calculate both CTE and RME HQs and CRs for any exposure routes with both CTE and RME results imported from the SHOWER model. When both are provided, health assessors should use the RME results to determine whether any contaminants require a detailed toxicological evaluation. More information on performing cancer and noncancer toxicological evaluations can be found in ATSDR's PHAGM (ATSDR 2023b).

Further details on the inhalation and dermal exposure calculations performed in PHAST are outside the scope of this document, but more information can be found in ATSDR's exposure dose guidance documents for the inhalation, dermal, and ingestion exposure routes (ATSDR 2018, 2020). In addition, see ATSDR's *Exposure Dose Guidance for Determining Life Expectancy and Exposure Factor* (ATSDR 2016) for more information on estimating cancer risk using either default or site-specific exposure durations and occupancy periods.

3. CV Screening

The first step in the SHOWER model evaluation process is to screen out site contaminants in water that do not pose a concern for inhalation or dermal exposures. Health assessors can screen contaminants using the PHAST Water CV Screening module. After logging into the CDC Secure Access Management Services (SAMS) Portal (https://sams.cdc.gov), PHAST can be accessed at https://csams.cdc.gov/PHAST/Home/Index. If you do not have access to SAMS or PHAST, email phast@cdc.gov for assistance. Figure 2 shows the PHAST Home screen. Click on the CV

Screen button to access the CV Screen menu options, and select **Water** to access the Water CV Screening module (Figure 3).

Figure 2. The PHAST home screen.

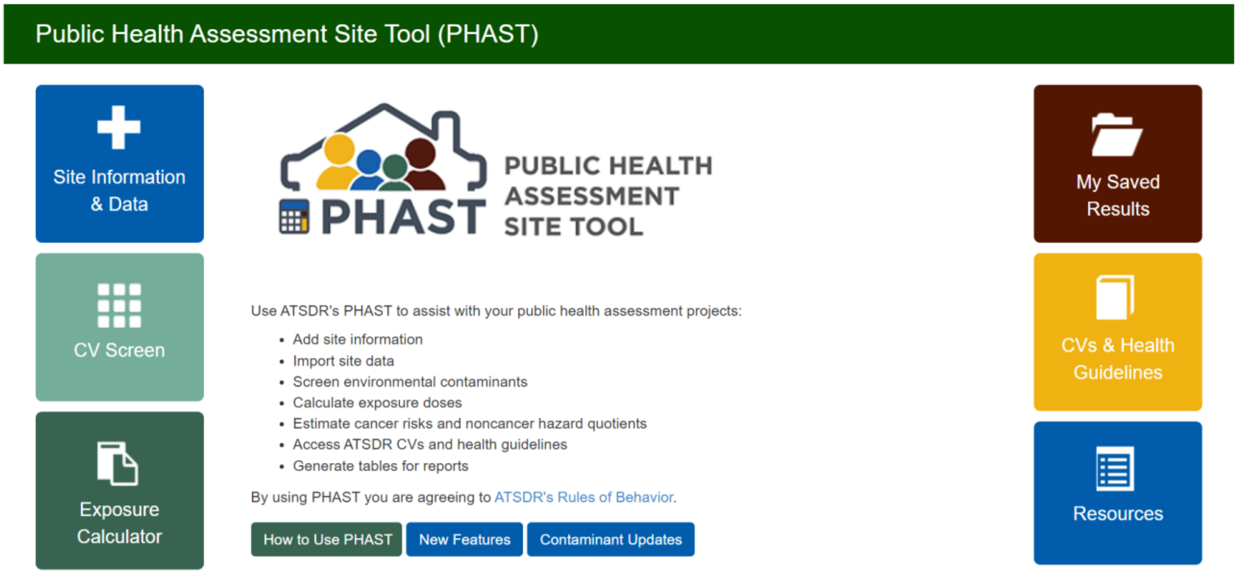
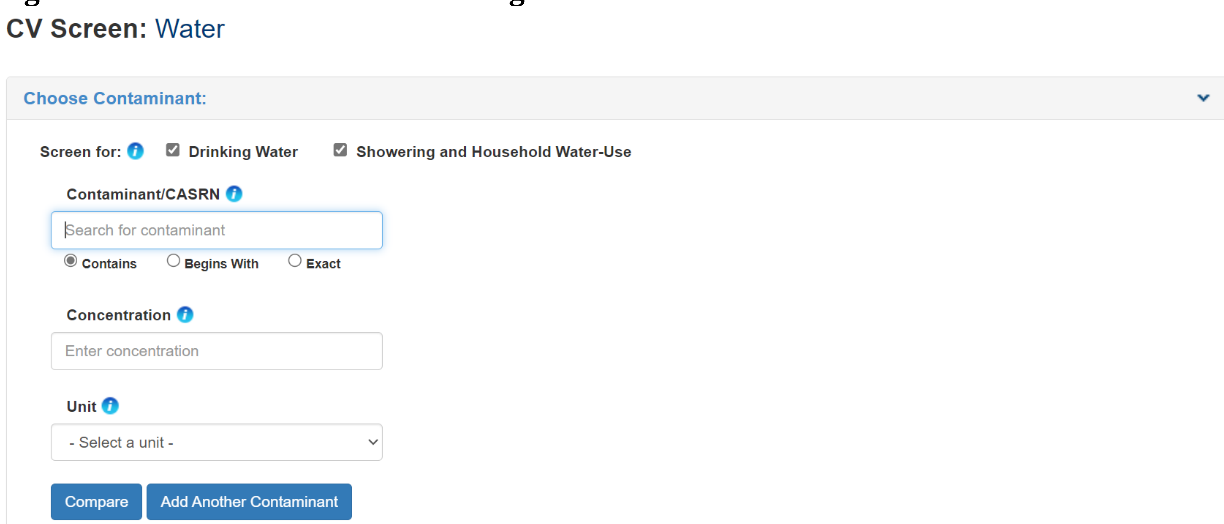


Figure 3. PHAST Water CV Screening module



To screen a contaminant for inhalation and dermal exposures, leave the **Showering and Household Water-Use** check box selected. If persons exposed at the site are also drinking the water, leave the **Drinking Water** check box selected to screen for ingestion exposures as well. Stated another way, if residents are bathing in but not drinking the water, un-check the drinking water box. Enter the contaminant name or CASRN in the **Contaminant/CASRN** field and select the contaminant from the dropdown list that appears to load the contaminant. In the **Concentration** field, enter the numeric value of the maximum detected concentration of the contaminant in water at the site, and enter the units associated with the maximum detected concentration in the **Unit** field. Use the **Add Another Contaminant** button to screen more than one contaminant at the same time. When you have entered information for all potential contaminants of concern at your site, click the **Compare** button to screen them against CVs.

Figure 4 shows inhalation and dermal screening results for a single contaminant, tetrachloroethylene (PCE), that had a maximum water concentration of 100 parts per billion (ppb) among several houses tested. The **ATSDR Screening Values** table identifies the screening results for the inhalation and dermal exposure routes. The **Above or Equal to Rec ATSDR CV?** column indicates whether the water concentration exceeded ATSDR's recommended CV for the exposure route, which in this case was the ATSDR Cancer Risk Evaluation Guide (CREG) for both routes. The **Contaminant(s) for Further Evaluation in SHOWER Model** table indicates whether or not the contaminant requires further evaluation. Any contaminants with a "Yes" recorded in the **Recommended for Further Evaluation** field should be evaluated using the SHOWER model. Any contaminants with a "No" in that field have concentrations below CVs and do not pose a health concern.

Figure 4. Inhalation and dermal screening results for tetrachloroethylene at a water concentration of 100 ppb.

Results: Showering and Household Water-Use

ATSDR Screening Values

Contaminant Name / CASRN	Conc	Unit	Pathway	Above or Equal to Rec ATSDR CV?	Above or Equal to Other CV?	CREG	Chronic EMEG Child	Chronic EMEG Adult	Int EMEG Child	Int EMEG Adult	RMEG Child	RMEG Adult	Acute EMEG Child	Acute EMEG Adult
Tetrachloroethylene 127-18-4	100	ppb	Inhalation	Yes [1]	Yes [2]	5.2 [1]	56 [2]	56 [2]	56 [2]	56 [2]	54 [2]	54 [2]	56 [2]	56 [2]
Tetrachloroethylene 127-18-4	100	ppb	Dermal	Yes [1]	No	38 [1]	330	690	330	690	240	520	330	690

[1] Recommended ATSDR CV for the pathway met or exceeded.
[2] Additional ATSDR CV met or exceeded.
[3] Acute ATSDR CV met or exceeded.
Show More

Contaminant(s) for Further Evaluation in SHOWER Model

Please use the SHOWER Model to evaluate exposure for contaminants that have "Yes" in the "Recommended for Further Evaluation" column.

Contaminant Name	Exposure Medium	Maximum Site Conc	Unit	ATSDR Recom-mended CV	ATSDR CV Type	Pathway for Recommended CV	Recommended for Further Evaluation	Notes
Tetrachloroethylene	Shower	100	ppb	5.2	CREG	Inhalation	Yes	

In some cases, contaminants will be recommended for further evaluation even if they did not exceed a CV. PHAST will recommend for further evaluation any chemicals without SHOWER CVs because they cannot be screened out. If a contaminant has neither inhalation nor dermal parameters for a contaminant, however, the contaminant will not be recommended for further evaluation because it cannot be evaluated in the SHOWER model.

If a contaminant has drinking water CV exceedances but is not recommended for further evaluation in the SHOWER model, use the Drinking Water Exposure Calculator in PHAST to evaluate ingestion exposures for that contaminant. More information on evaluating the drinking water pathway can be found in ATSDR's *Exposure Dose Guidance for Water Ingestion* (ATSDR 2023a).

4. Calculate an EPC

For any chemicals recommended for further evaluation, the next step in the evaluation process is to determine the chemical's EPC. For sites where acute, intermediate, and chronic duration exposures are being evaluated, health assessors will need to determine an EPC for each exposure duration. The EPC for each exposure duration will be either the contaminant's maximum detected concentration or its 95UCL. For acute exposures, health assessors should use the statistic (maximum or 95UCL) that best aligns with the contaminant's applicable toxicity data. For intermediate and chronic exposures, health assessors should use the output of the ATSDR EPC Tool, which selects the appropriate statistic for each EPC based on the sample size, number of detects, and underlying distribution of the contaminant's measured concentration data.

The ATSDR EPC Tool is available through the CDC SAMS portal at the link (https://amdportal-sams.cdc.gov/epctool/). If you do not have access to the ATSDR EPC Tool, contact phast@cdc.gov for assistance. Detailed instructions for using the EPC Tool are provided in the EPC Tool User's Guide (ATSDR 2022b). Figure 5 shows the EPC Tool home screen.

Figure 5. The ATSDR EPC Tool home screen.

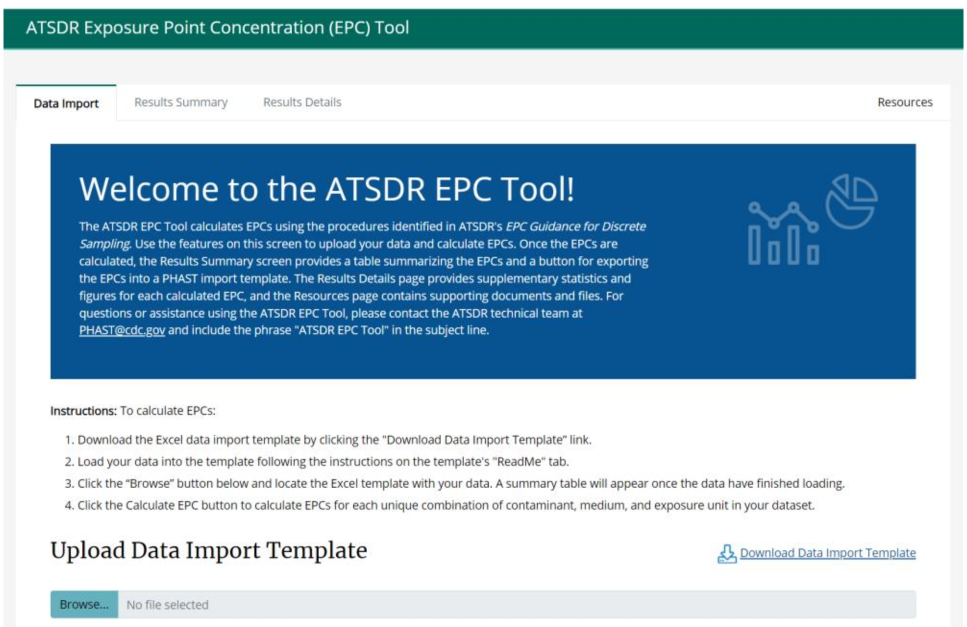


Figure 6 shows summary data generated by the EPC Tool for a sample dataset of 25 PCE water concentrations. The concentrations had a maximum detected value of 100 ppb and included three nondetect values, which each had a reporting limit of 10 ppb. The remaining 21 records had detected concentrations between 10 ppb and 100 ppb. For this dataset, the EPC value calculated by the EPC Tool was a 95UCL equal to 58.16 ppb. For intermediate and chronic evaluations at this site, health assessors would enter this value into the SHOWER model as the site water concentration. For acute evaluations, health assessors would also use the calculated 95UCL as the EPC because ATSDR's acute inhalation and oral MRLs for PCE were both based on long-term studies (ATSDR 2019b).

Figure 6. ATSDR EPC Tool summary table for a sample dataset of 25 PCE records

Exposure Unit	Media	Contaminant	Units	EPC Value	EPC Type	EPC Quality Control Flags	R Warnings and Error Flags	Number of Detected Observations	Result Details
House A	Water	Tetrachloroethylene	ppb	58.16	95% UCL of the mean			22	Details

CASRN	000127-18-4
Number of Observations	25
Maximum Detected Value	100
Notes	This dataset contained 20 or more records. The data are either singly censored or have multiple censoring limits with no interspersed levels, so the EPC was calculated using bootstrap sampling of a lognormal distribution with regression on order statistics.

Showing 1 to 1 of 1 entries Previous 1 Next

5. Run a SHOWER Model Scenario

After calculating the appropriate EPCs, health assessors will run the SHOWER model using those EPCs as the input water concentration. Sections 5.1 and 5.2 describe the SHOWER model residential scenarios and communal shower and bathroom scenarios, respectively, and identify how to use the SHOWER model to set up and run each scenario type.

5.1. Residential Scenarios

The default SHOWER model residential scenario divides the home into three compartments:

- a shower stall,
- a bathroom (excluding the shower stall), and
- the main house (excluding bathroom and shower stall).

Figure 7 shows the three-compartment layout in the default SHOWER model scenario. In the figure, air flow between compartments and from the house to the outdoors is represented by blue lines, and contaminant releases from water-using appliances (sources) are represented by yellow dots. The model accounts for contaminant releases from numerous sources, such as showers, toilets, bathtubs, sinks, clothes washers, and dishwashers. Anytime a source is used, contaminants are released from the source appliance to the air. The model simulates contaminant movement in air between compartments and between the main house and the outdoors, and can simulate venting of contaminants directly to outdoor air via exhaust fans in the bathroom or shower. The model keeps track of the contaminant mass in each compartment over time and calculates the contaminant concentration in each compartment at each second of the day. A full description of the mathematics used in the model can be found in the SHOWER model technical document (ATSDR 2024b). A user's guide also is available that provides step-by-step instructions on using the model (ATSDR 2024a).

Figure 7. A schematic of the SHOWER model house layout

In a SHOWER model simulation, each person in the house is assigned a human activity pattern, which specifies the compartment in the house where the person is located (main house, shower, bathroom, or away from home) at each second of the day and the appliances they use in each compartment. Using the person's activity pattern, the model tracks the contaminant air concentration in the compartment where the person is located throughout the day and calculates the average daily exposure concentration for each person as a time-weighted average (TWA). The model then uses the average daily exposure concentrations calculated for each person to identify the most highly exposed person in each scenario. Time spent outside the home is included in the TWA, but any exposures that may occur outside the home (e.g., breathing contaminated outdoor air) are not accounted for in the average daily exposure concentration.

The default SHOWER model scenario simulates a 4-person household in which four people take consecutive morning showers. The default scenario is an RME scenario in which the first three people take 10-minute showers and the fourth person takes a 15-minute shower. In the default scenario, the fourth person is the most highly exposed person and is referred to as the target person. This person can be male or female and from any of ATSDR's standard age groups, since the exposure concentration estimated by the model in the default scenario is the same for children and adults. The SHOWER model reports the TWA daily air exposure concentration for the most highly exposed person as its primary output. Air concentrations generated by the model can be reported in micrograms per cubic meter (µg/m^3) or parts per billion (ppb).

In addition to predicting the TWA daily exposure concentration, the model also predicts the daily dermal dose for the most highly exposed person. Dermal doses include skin contact from bathing and from hands contacting faucet water. These doses are provided in micrograms per kilogram per day (µg/kg/day) for ATSDR's standard age groups and are based on dermal equations and parameters from USEPA's RAGS Part E (USEPA 2004). The SHOWER model technical document describes these equations in more detail (ATSDR 2024b).

Custom SHOWER model residential scenarios can simulate houses with one to eight people. Running a custom scenario is optional and typically is not used to decide whether a site with contaminated household water is a hazard. Instead, the custom scenario allows users (1) to conduct sensitivity analyses by changing model parameters and (2) to answer specific questions from the community, such as, could harmful effects occur from taking a long shower or could harmful effects occur should a family have more than four members. Activities and parameters that can be modified when running a custom scenario include the following:

- Varying the showering schedule (e.g., changing from consecutive morning showers to different showering and bathing patterns in the morning and evening).
- Evaluating exposure for children who take a bath and for a parent who helps children take a bath.
- Taking a long shower and spending a long time in the bathroom after a shower.
- Taking two showers daily or a combination of a shower and a bath.
- Turning a bathroom fan on while showering.
- Having a house with two bathrooms instead of one.
- Changing the size of the shower stall, the bathroom, or the main house.
- Being away from the house during the day.

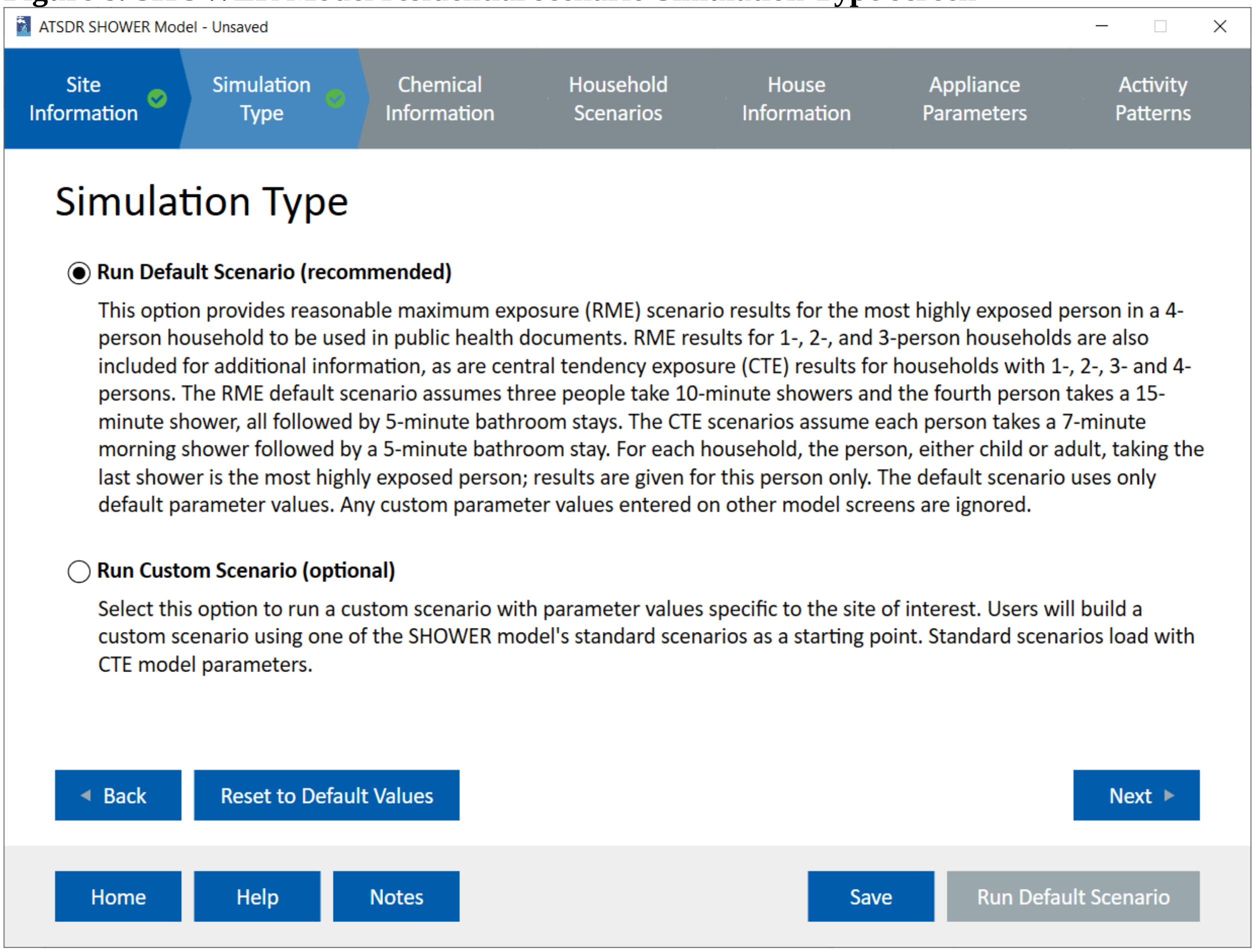
Additional model options are available for health assessors who want to evaluate other exposure scenarios based on site-specific information, such as site-specific building, appliance, and chemical parameters. The SHOWER model user's guide provides more information on the parameters that can be customized (ATSDR 2024a).

5.1.1. Scenario Setup

To start a residential scenario, open the SHOWER model and on the home page, click the **Run New Scenario** button. The program will give you the option of choosing either a new residential scenario or a new communal shower and bathroom scenario. Click the **Residential Scenario** button to evaluate a residential scenario, and then enter information about the site on the Site Information screen. Once finished, click the **Next** button to move to the Simulation Type screen (Figure 8).

On the Simulation Type screen, select the **Run Default Scenario (recommended)** button to evaluate a default scenario, or select the **Run Custom Scenario (optional)** button to evaluate a custom scenario. Once finished, click the **Next** button to move to the Chemical Information screen.

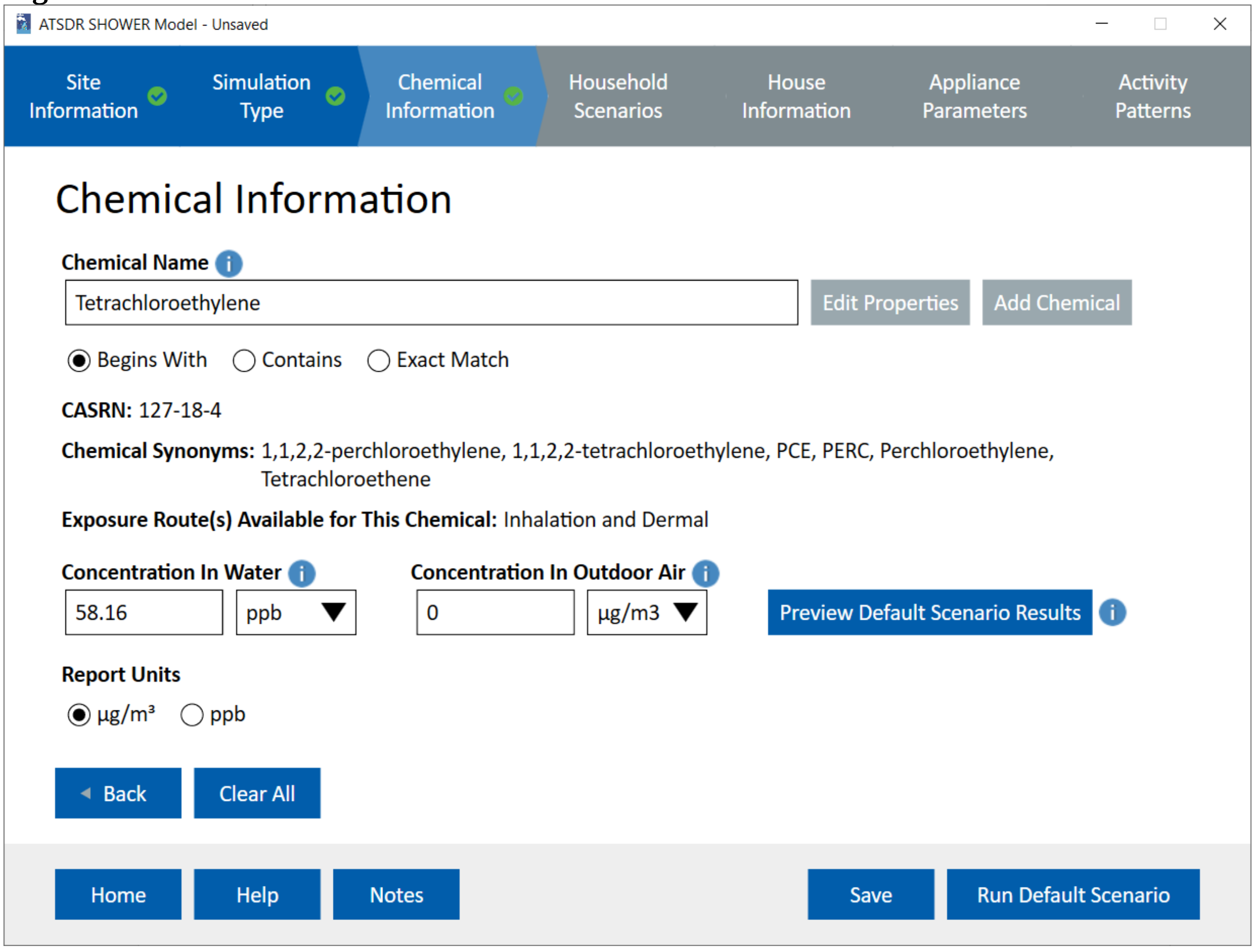
Figure 8. SHOWER Model residential scenario Simulation Type screen



5.1.2. Default Scenario

To run a default scenario, the only additional required inputs are the chemical name and concentration in water. Figure 9 shows the residential scenario Chemical Information screen filled in with the PCE EPC calculated in Section 4. The **Chemical Name** is tetrachloroethylene, and the chemical **Concentration in Water** is 58.16 ppb. The **Concentration in Outdoor Air** has a default value of 0 µg/m^3, but if a value is known, it can be entered into that field. If the **Report Units** are left as µg/m^3, air concentrations in the output report will be displayed in µg/m^3. You have the option, though, of changing the report units to ppb. Clicking the **Preview Default Scenario Results** button allows you to see the average daily air exposure concentration calculated for the target person in the default scenario in both sets of units. To run the SHOWER model default scenario, click the **Run Default Scenario** button.

Figure 9. SHOWER model residential scenario Chemical Information screen



Concentration in Outdoor Air

USEPA maintains the Air Toxics Ambient Monitoring Archive (AMA), a historical collection of data on hazardous air pollutants (HAPs) in outdoor air (USEPA 2023) which can be found at https://www.epa.gov/amtic/amtic-ambient-monitoring-archive-haps. The Clean Air Act Amendments in 1990 defined a list of 189 HAPs requiring regulation to reduce public health risk (Kelly et al. 1994). At the time of this writing, the most recent version of the AMA was released in October 2023 and included HAP air toxics monitoring data collected by federal, state, local, and tribal agencies during 1990–2021. If site-specific outdoor air concentration data are not available, outdoor air concentration data may be available from a nearby site reported in the AMA.

The primary default residential scenario results generated by the SHOWER model are presented in Table S1 (Figure 10) and Table S2 (Figure 11) in the SHOWER model report. Table S1 and Table S2 give the daily air exposure concentration and administered dermal dose for the target person in the default scenario, respectively. The daily exposure concentration is calculated based on a TWA of the concentrations in the compartments (shower, bathroom, and main house) where the target person is located throughout the day. Dermal doses are calculated using age-specific dermal factors (e.g., skin surface area, body weight) based on the target person's contact with water while showering and while using sinks.

The concentration in Table S1 should be used to evaluate inhalation exposures for all simulated exposure groups, and the dermal doses in Table S2 should be used to evaluate dermal exposures. The information in these two tables will form the basis of the public health evaluations at most sites, and results from these two tables should be included in public health documents.

Figure 10. Table S1 in the default residential scenario report

Table S1. RME daily exposure concentration in µg/m³ for the target person (person 4) in the 4-person household

RME Daily Exposure Concentration
43

Abbreviations: µg/m³ = micrograms chemical per cubic meter air; RME = reasonable maximum exposure

Figure 11. Table S2 in the default residential scenario report

Table S2. RME daily administered dermal dose in µg/kg/day for the target person (person 4) in the 4-person household

Exposure Group	RME Administered Dermal Dose
Birth to < 1 year	1.4
1 to < 2 years	1.3
2 to < 6 years	1.1
6 to < 11 years	0.92
11 to < 16 years	0.75
16 to < 21 years	0.69
Adult	0.68
Pregnant & breastfeeding women	0.68

Abbreviations: µg/kg/day = micrograms chemical per kilograms body weight per day

Some contaminants in the SHOWER model do not have inhalation or dermal parameters. For contaminants that do not have inhalation parameters, Table S1 will display "NC" for the RME daily exposure concentration. For contaminants without dermal parameters, Table S2 will display "NC" for the RME administered dermal dose for all exposure groups.

Table S3 (Figure 12) and Table S4 (Figure 13) in the report provide inhalation concentrations and dermal doses for other scenarios run along with the default 4-person scenario. These include a CTE 4-person household scenario and CTE and RME 1-, 2-, and 3-person household scenarios. These additional scenarios add context to the default 4-person RME scenario and may help you decide whether health effects might occur in households with fewer than four members or when answering questions from the community. Results from these scenarios are not required in public health documents but can be included for discussion purposes at the discretion of the author. The highlighted cell in Table S3 corresponds with the default scenario value reported in Table S1, and the highlighted cells in Table S4 correspond with the default scenario values reported in Table S2.

Figure 12. Table S3 in the default residential scenario report

Table S3. Daily exposure concentration in µg/m³ in each scenario

Scenario Type	1-Person Household	2-Person Household	3-Person Household	4-Person Household
RME	12	23	33	43
CTE	4.9	9.9	15	19

Abbreviations: CTE = central tendency exposure; µg/m³ = micrograms chemical per cubic meter air; RME = reasonable maximum exposure

Figure 13. Table S4 in the default residential scenario report

Table S4. Daily administered dermal dose in µg/kg/day in each scenario

Exposure Group	RME 1-P	RME 2-P	RME 3-P	RME 4-P	CTE 1-P	CTE 2-P	CTE 3-P	CTE 4-P
Birth to < 1 year	NC	1.4	1.4	1.4	NC	0.95	0.95	0.96
1 to < 2 years	NC	1.3	1.3	1.3	NC	0.88	0.88	0.88
2 to < 6 years	NC	1.1	1.1	1.1	NC	0.75	0.75	0.76
6 to < 11 years	NC	0.91	0.92	0.92	NC	0.61	0.61	0.62
11 to < 16 years	NC	0.75	0.75	0.75	NC	0.50	0.50	0.50
16 to < 21 years	NC	0.68	0.69	0.69	NC	0.46	0.46	0.46
Adult	0.67	0.67	0.67	0.68	0.45	0.45	0.45	0.45
Pregnant & breastfeeding women	0.67	0.68	0.68	0.68	0.45	0.45	0.45	0.46

Abbreviations: -P = person; CTE = central tendency exposure; µg/kg/day = micrograms chemical per kilograms body weight per day; NC = not calculated; RME = reasonable maximum exposure

The remaining tables and figures in the default scenario report provide additional information about the default 4-person RME scenario. These are included for information purposes only and are not required in your public health documents.

Table 1 (Figure 14) gives the average daily exposure concentration for each person in the house in the units selected on the Chemical Information screen. The target person is identified with an "X" in the table's Target Person column, and will always be person 4 in a default scenario because person 4 has the highest average daily exposure concentration. The table also identifies each person's main activities, which in a default scenario are a morning shower for each person.

Figure 14. Table 1 in the default residential scenario report

Table 1. RME daily exposure concentration in µg/m³ for each person in the house

Person	Target Person	Main Activities	RME Daily Exposure Concentration
1	—	Showering in Shower #1 at 6:05 a.m.	14
2	—	Showering in Shower #1 at 6:21 a.m.	21
3	—	Showering in Shower #1 at 6:37 a.m.	26
4	X	Showering in Shower #1 at 6:53 a.m.	43

Abbreviations: µg/m³ = micrograms chemical per cubic meter air

Table 2 (Figure 15) identifies the target person's administered dermal dose and their average daily inhalation dose for ATSDR's standard exposure groups. The dermal doses calculated are absorbed doses through the skin.

- For most organic chemicals, the dermal absorbed dose is the same as the oral administered dose because 100% of the chemical is assumed to be absorbed through the GI tract (ATSDR 2018; USEPA 2004). Therefore, no adjustment from dermal absorbed dose to administered oral dose is needed, and the absorbed dose calculated from dermal uptake is also an administered dose.
- For inorganic chemicals, the SHOWER model accounts for chemical absorption through the GI tract in the reported administered dermal dose. The average daily inhalation doses are derived from age-specific breathing rates and the average daily exposure concentration for the most highly exposed person in Table 1. The dermal doses are the same as those in Table S2.

For sites where residents are drinking and showering in contaminated water, it may be appropriate to combine doses from ingestion, inhalation, and dermal contact to get a total exposure dose. See Section 2.3 for more information.

Figure 15. Table 2 in the default residential scenario report

Table 2. RME daily inhalation dose in µg/kg/day and administered dermal dose for the target person

Exposure Group	Inhalation	Dermal
Birth to < 1 year	56	1.4
1 to < 2 years	61	1.3
2 to < 6 years	38	1.1
6 to < 11 years	21	0.92
11 to < 16 years	14	0.75
16 to < 21 years	10	0.69
Adult	9.3	0.68
Pregnant & breastfeeding women	13	0.68

Abbreviations: µg/kg/day = micrograms chemical per kilograms body weight per day; NC = not calculated

Table 3 in the report (Figure 16) shows that residents could be exposed to high concentrations for a brief period while showering. The 15-minute average exposure concentration from a shower and 5-minute average exposure concentration from afterwards in the bathroom are much higher, but for shorter periods, than the exposure in the main house or the average daily exposure. Knowledge of this brief exposure to high levels in the shower and bathroom could be useful when evaluating whether harmful effects might be possible from acute exposure to very high levels. Health assessors should consider a chemical-specific toxicity review by reviewing the acute inhalation studies in ATSDR's toxicological profiles.

Figure 16. Table 3 in the default residential scenario report

Table 3. Exposure time and average human exposure concentration by location for the target person

Location	Exposure Time (min)	Average Human Exposure Concentration (µg/m³)
Shower	15	2,862
Bathroom after shower	5	350
Main house with additional bathroom visits	1,420	12
Away from house	0	0
Average daily exposure	1,440	43
Main house (all day)	1,440	5.7

Abbreviations: µg/m³ = micrograms chemical per cubic meter air; min = minute

Table 4 in the report (Figure 17) shows the percent exposure that results from taking a shower and being in the bathroom immediately after the shower compared to being in the house the rest of the day. This information is provided to help answer questions from the community about how much exposure comes from taking a shower versus how much exposure comes from being in the house. In this example, about 70% of someone's exposure comes from taking a shower and being in the bathroom afterwards, while about 28% comes from being in the house the rest of the day. For comparison, in a 1-person household 1-morning shower scenario with the same PCE water concentration, about 35% of the person's exposure comes from taking a shower and being in the bathroom afterward while 65% of their exposure comes from being in the house. Note that the percent exposures in each compartment may not sum to 100% due to rounding applied to the reported percentages.

Figure 17. Table 4 in the default residential scenario report

Table 4. Exposure time and percent of total exposure by location for the target person

Location	Exposure Time (min)	Percent Exposure (%)
Shower	15	70
Bathroom after shower	5	2.8
Main house with additional bathroom visits	1,420	28
Away from house	0	0
Average daily exposure	1,440	100
Main house (all day)	1,440	100

Abbreviations: min = minute; % = percent

The SHOWER model default scenario report includes two figures. Figure 1 in the report (Figure 18) shows the air concentration of the chemical in the shower stall, the bathroom, and the main house throughout the day. In Figure 1, shower concentrations rise quickly at 6:05 AM, when the first person in the house takes their shower. They continue to rise as each person takes their morning shower, and then gradually fall after the fourth person showers. Bathroom concentrations rise along with the shower stall concentrations. Increases in the bathroom concentrations around 10 AM, 2 PM, 6 PM, and 9 PM reflect additional bathroom visits from all members of the house. For the main house concentration, increases at 7 PM reflect the clothes washer use. Although not apparent in the figure, the default scenario also includes a dishwasher use at 9 PM. The figure shows the air concentrations in log scale to provide more detail for the low levels in the main house.

Figure 2 in the report (Figure 19) shows the concentrations that the target person is exposed to as they move within the home throughout the day. Figure 2 shows the shower stall air concentration from 7:00 AM to 7:15 AM when the person is taking a shower, and the bathroom air concentration for the 5 minutes immediately after the shower when the person moves from the shower stall to the bathroom. The other bathroom concentrations shown represent the exposure concentrations when the target person visits the bathroom to use the toilet and bathroom sink. Throughout the rest of the day, the target person is in the main house. Like Figure 1, Figure 2 also uses a log scale so that all concentrations can be clearly seen.

The remaining tables in the default scenario model report identify the input parameters used to run the default scenario. More information about these tables can be found in the report itself and in the SHOWER model user's guide (ATSDR 2024a).

Figure 18. Figure 1 in the default residential scenario report

Figure 1. Calculated air concentrations in the shower, bathroom, and main house compartments for a 4-person household

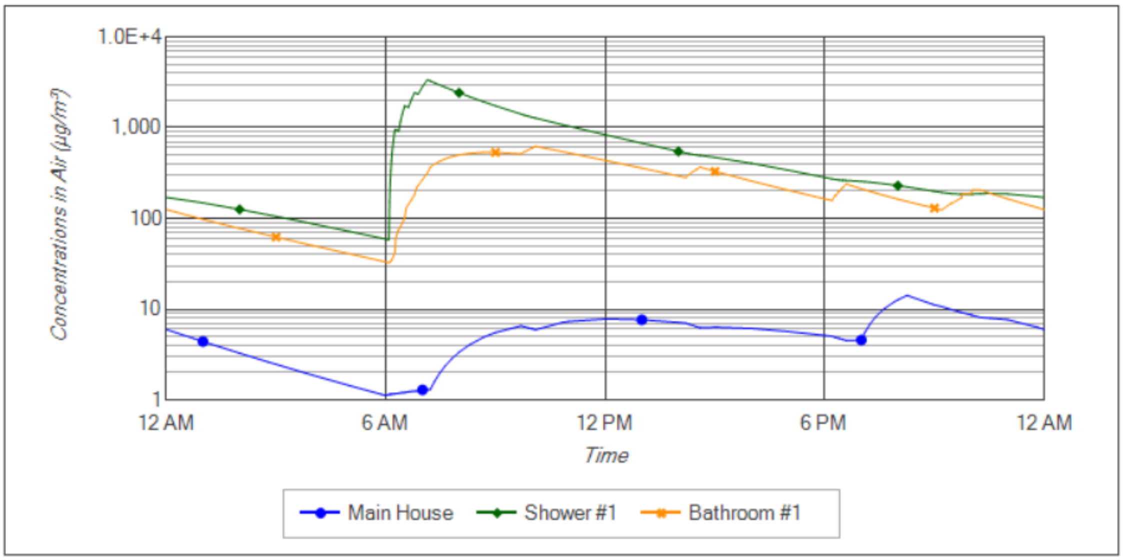
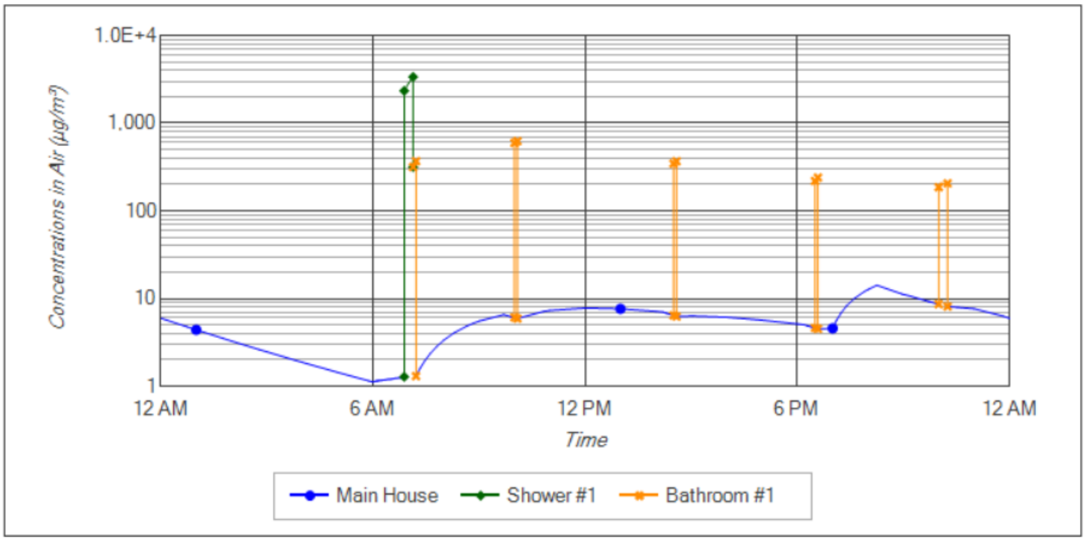


Figure 19. Figure 2 in the default residential scenario report

Figure 2. Calculated exposure air concentrations in different compartments throughout the day for the target person selected in this scenario (person 4)



5.1.3. Custom Scenario

If you select the option to run a custom scenario on the Simulation Type screen, you will need to enter the same inputs on the Chemical Information screen as those in a default scenario (Section 5.1.2). Once you have entered a chemical name, you can click the **Edit Properties** button to edit the default inhalation and dermal chemical properties for that chemical. In addition, you can enter data for a new chemical by clicking on the **Add Chemical** button. The SHOWER model technical document (ATSDR 2024b) provides more information about the chemical properties used within the SHOWER model.

Once all the fields on the Chemical Information screen are filled in, click the **Next** button to proceed to the Household Scenarios screen (Figure 20). Use the **Select number of persons in household** dropdown to identify the number of persons in the household you are evaluating, and then select one of the standard scenarios included in the SHOWER model to serve as the basis for your custom scenario.

Figure 20. SHOWER Model Household Scenarios screen

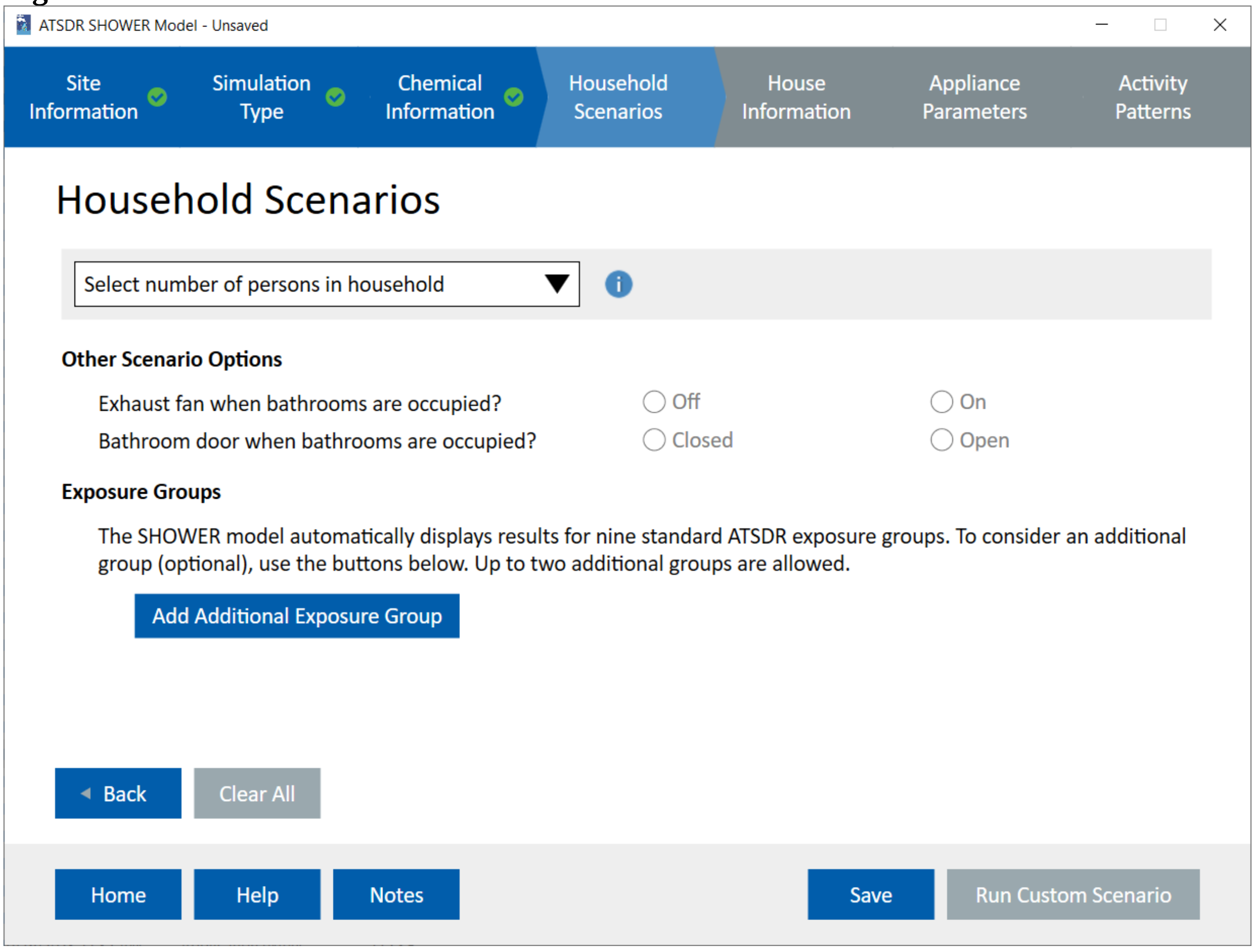
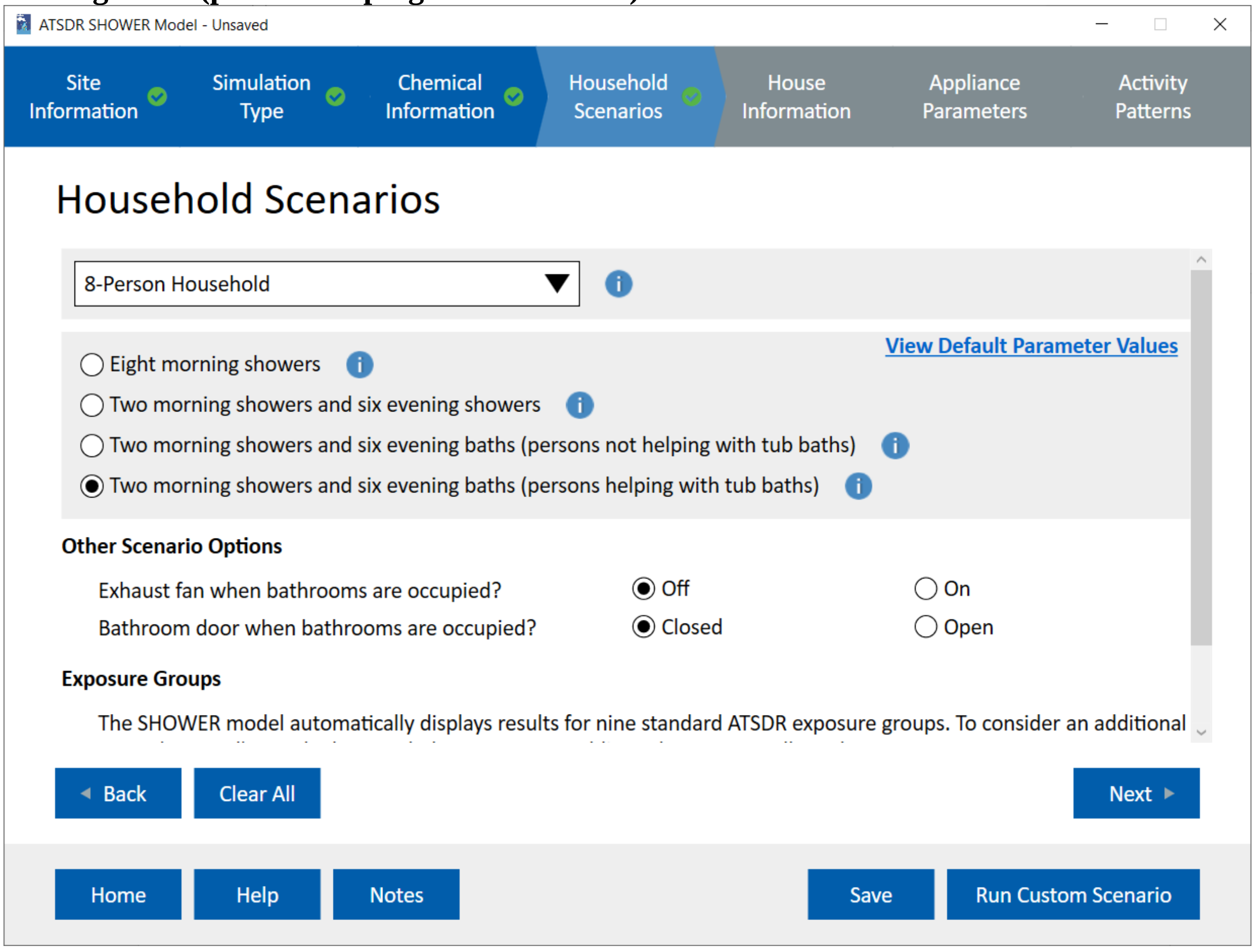


Figure 21 shows an example of the Household Scenarios screen for a custom 8-person household scenario in which the two morning showers and six evening baths (persons helping with tub baths) option was selected as the custom scenario basis. Once you have selected a standard scenario, the SHOWER model will populate the remaining screens (House Information, Appliance Parameters, and Activity Patterns) with information for that scenario.

Figure 21. Household Scenarios screen with the standard two morning showers and six evening baths (persons helping with tub baths) scenario selected



After selecting a standard scenario, health assessors can do all of the following:

- Add custom exposure groups on the Household Scenarios screen
- Modify the layout of the simulated house and change the house volume and air exchange rate parameters on the House Information screen.
- Replace the standard appliance water-use parameters with site-specific values on the Appliance Parameters screen.
- Enter custom shower and bathroom usage schedules on the Activity Patterns screen.
- Choose to have certain household members be away from home for part of the day.

In the standard custom scenarios, the standard time assigned for showers is 7 minutes and the standard time assigned for tub baths is 20 minutes. These activity durations can be changed on the Activity Patterns screen. See the SHOWER model user's guide (ATSDR 2024a) for more information about other parameters that can be changed on each screen and the SHOWER model technical document (ATSDR 2024b) for more information on how the parameters are used in the SHOWER model governing equations.

Reproducing the Default 4-Person RME Scenario as a Custom Scenario

The default 4-person RME scenario is not one of the standard custom scenarios. To reproduce the default 4-person RME scenario as a custom scenario, do the following:

- On the Household Scenarios screen, select a 4-person household four morning showers scenario.
- On the Appliance Parameters screen, change the kitchen sink and bathroom sink durations per use from 0.64 min to 1.0 min.
- On the Activity Patterns screen:
  - Change the morning shower duration for Person 1, 2, and 3 from 7 minutes to 10 minutes.
  - Change the morning shower duration for the fourth person from 7 minutes to 15 minutes.
  - Change the number of kitchen sink uses from 15 to 20.

You should now be able to run this scenario and get the same results as running the default 4-person household. More importantly, you can now perform a sensitivity analysis by changing parameters to see how those changes affect the default 4-person result.

Once you have made any desired customizations to the standard scenario parameters, click the **Run Custom Scenario** button to run the custom scenario. The custom report will contain tables and figures based on the custom exposure parameters selected. Using results from custom reports in your public health documents is optional.

The primary output result tables for a custom scenario report are similar to Tables S1–S4 in a default scenario report. Table 1 in the custom report will display the average daily exposure concentration for each person in the house and will identify the target person, which will be the most highly exposed person unless a different target person was selected on the Activity Patterns screen. Table 1 will also identify each person’s main activities, which can include showering, taking tub baths, or helping other persons in the house with tub baths.

Depending on the target person’s main activities, some of ATSDR’s standard exposure groups will not have dermal or inhalation doses reported in Table 2.

- If the target person takes a shower, custom scenarios will not report results in Table 2 for the birth to <1 year age group because infants do not take showers.

- If the target person helps with a tub bath, custom scenarios will not report results in Table 2 for age groups <11 years old, since persons in those age groups are unlikely to help with tub baths.

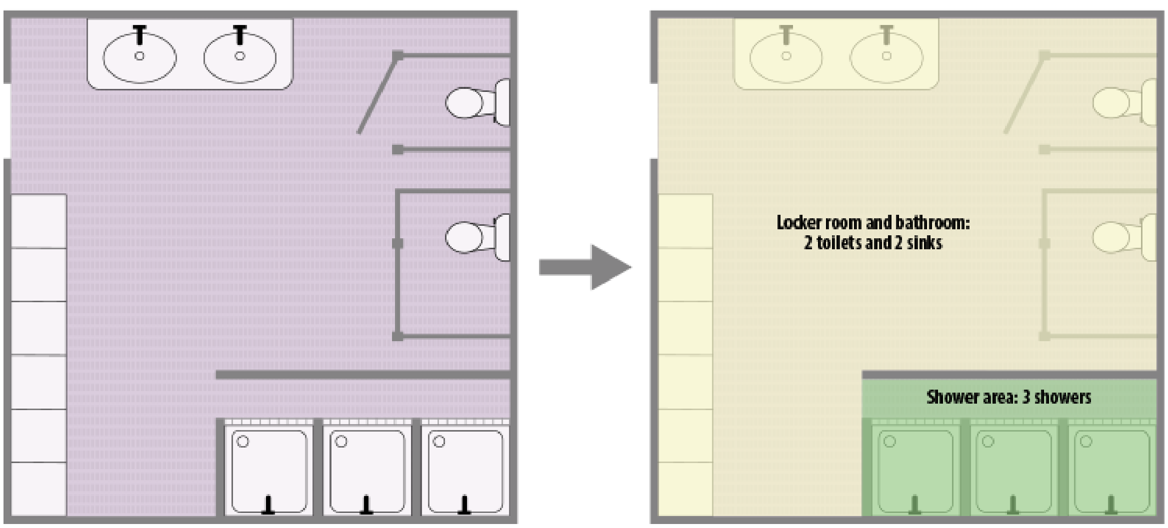
The average daily exposure concentration reported in Table 1 does not apply to any exposure groups that do not have results reported in Table 2.

The remaining tables and figures in the custom scenario report provide additional information about the custom scenario and site-specific parameters you entered. These are included for information purposes only and are not required in your public health documents. More information about these tables and figures is provided in the report itself, and in the SHOWER model user's guide (ATSDR 2024a).

5.2. Communal Shower and Bathroom Scenarios

Communal shower and bathroom scenarios allow for evaluation of two facility types in a building. The first type are communal shower and locker room facilities where multiple people can shower simultaneously, such as in shower facilities attached to a commercial or school gym. Figure 22 shows an example layout schematic for a small communal shower and locker room facility with three showers, two toilets, two bathroom sinks, and six lockers. The left side of the image shows the facility layout, and the right side shows how it is conceptualized within the SHOWER model.

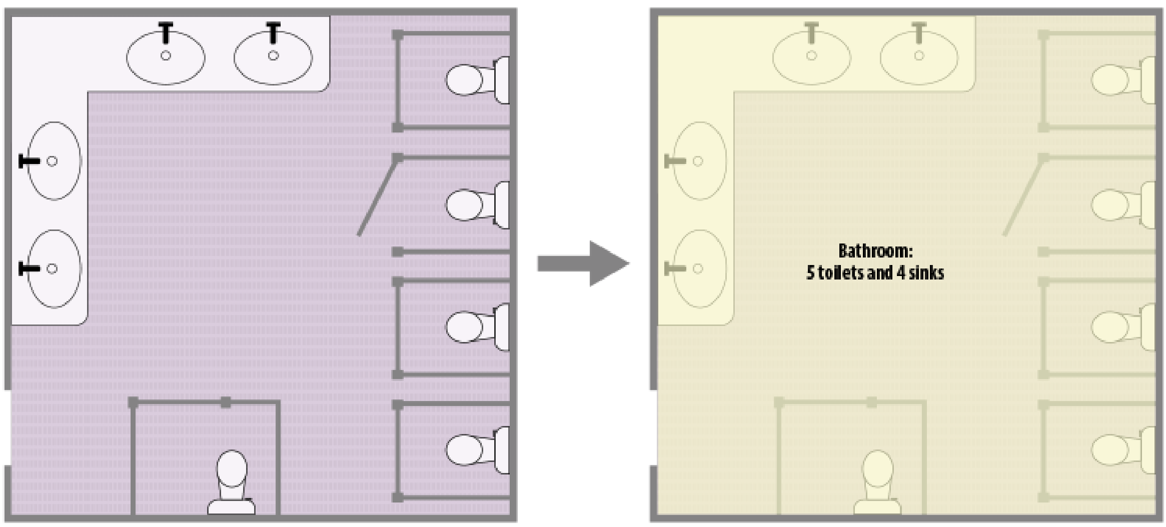
Figure 22. Example layout schematic for a communal shower and locker room facility



The SHOWER model simulates the facility as a two-compartment model in which the showers are in one compartment, and the toilets, bathroom sinks, and lockers are in another compartment. The shower area includes the shower space and adjoining space for people to enter and exit the showers, and the locker room and bathroom area includes the remaining space in the facility. Contaminant releases occur from the showers, toilets, and bathroom sinks, and air exchange moves contaminated air between the shower area and the bathroom area and between the bathroom area and the main building. The shower area and the bathroom area are both assumed to have supply vents that provide fresh air from the outdoors via the building's heating, ventilation, and air conditioning (HVAC) system, and exhaust fans that vent moisture-laden air from the shower and bathroom areas to the outdoors.

The second type of facility that can be modeled in a communal shower and bathroom scenario is a communal bathroom facility, such as a public restroom in an office building. Figure 23 shows an example layout for a communal bathroom facility with five toilets and four sinks. The left side of the image shows the facility layout and the right side shows how the space is conceptualized in the SHOWER model.

Figure 23. Example layout schematic for a communal bathroom facility



The SHOWER model uses a one-compartment model to simulate communal bathroom facilities. In the image, the five toilets and four bathroom sinks are all included in the bathroom compartment. Air exchange occurs between the bathroom and the main building, outdoor air is supplied to the bathroom by the building's HVAC system, and air from the bathroom is vented to the outdoors via exhaust fans.

Communal shower and bathroom scenarios simulate contaminant air concentrations in the shower (if applicable) and bathroom compartments over a 24-hour period. Contaminant releases from water occur anytime someone enters the facility and uses a shower, a toilet, or a bathroom sink. In facilities that are open 24 hours a day (e.g., dorm showers), people can take showers and use the toilets and sinks at any time of day. In facilities that are closed for part of the day (e.g., commercial office bathrooms), people can use the facility only when it is open, and no contaminant releases occur while the facility is closed. The building HVAC system is assumed to be off when the facility is closed, such that fresh air is not supplied directly to the facility nor is exhaust air vented to the outdoors during those hours. Unlike in residential scenarios, in which the main building's contaminant air concentration is variable, the main building concentration in communal shower and bathroom scenarios is assumed to be a fixed constant that does not change throughout the day.

For shower and locker room facilities, each facility user's daily activity pattern may include one shower and one or more toilet and bathroom sink uses. The model assumes that each person takes no more than one shower daily at the facility, but that they may visit the facility multiple times to use the toilets and sinks. In addition, the model allows facility users not to take showers and instead to visit the facility just to use the bathroom. Whenever a facility user showers, the model assumes they use the toilet and wash their hands in the sink afterwards. For bathroom facilities, each facility user's daily activity pattern includes one or more toilet and bathroom sink uses. Along with time spent in the facility, the model also simulates the time that each person spends outside the facility in the main building to account for contaminant inhalation exposures in the main building. Dermal exposures in the main building are not considered in communal shower and bathroom scenarios, nor are outdoor inhalation or dermal exposures.

Communal Shower and Bathroom Scenario "Facilities"

The term "facility" in the SHOWER model communal shower and bathroom scenarios refers to either a single communal shower area with adjoining locker room or a single communal bathroom area. If a building has separate facilities by gender, family status, accessibility, or other trait, the model must be run separately for each facility. For example, in a commercial gym with separate shower facilities for men and women, the model should be run twice—once for the men's facility and once for the women's facility.

Unlike residential scenarios, which predefine 24-hour activity patterns for each person in the house, communal shower and bathroom scenarios do not predefine activity patterns for facility users. Instead, the SHOWER model uses Monte Carlo methods to randomly generate activity patterns for facility users based on input parameter distributions. Monte Carlo methods are computational techniques that involve running a large number of iterations of a model to better understand its output. In a single Monte Carlo iteration, a set of values is sampled at random from input parameter distributions and is used to calculate a set of output values. After multiple iterations, distributions of the output values can be constructed and analyzed for relevant statistics, such as the range of possible outcomes and the likelihood of different results. In communal shower and bathroom scenarios, the following parameters are defined by distributions which are used to randomly generate activity patterns for facility users:

- Shower duration
- Bathroom sink use duration
- Average time in the locker room before and after a shower
- Average time in the bathroom for bathroom-only visits
- Time each person spends in the building

More information on the default values for these parameters can be found in Appendix C, and further information on how they are used to randomly generate activity patterns can be found in the SHOWER model technical document (ATSDR 2024b).

Each Monte Carlo iteration from a communal shower and bathroom scenario returns simulated average daily exposure concentrations and administered dermal doses for all facility users. Once all Monte Carlo iterations are complete, the SHOWER model uses the simulated concentrations and doses to derive CTE and RME results for each scenario. The CTE results are the 50th percentile average daily exposure concentration and dermal doses across all Monte Carlo iterations and exposure groups, and the RME results are the 95th percentile average daily exposure concentration and dermal doses across all Monte Carlo iterations and exposure groups. For shower and locker room facilities, the SHOWER model reports separate results for persons who shower from those who do not shower in the facility.

Like the residential scenarios, the SHOWER model includes both default and custom communal shower and bathroom scenarios. Default scenarios are available for facilities in commercial gyms, commercial daycares (bathroom facilities only), dorms or barracks, offices, and schools. The communal shower and bathroom scenario conceptual model does not change based on the building type—the only differences between building types are in the standard values assigned to some of the model parameters. Custom scenarios can be used to make the parameter values site-specific. For more information on the default parameter values associated with facilities in each building type, see Appendix C.

Percent of Facility Users Taking Showers

Most of the default shower and locker room facility scenarios assume that only a fraction of the facility users take showers. The default percent of people taking showers for each building type is:

- Commercial gym: 25%
- Dorm or barracks: 100%
- Office: 5%
- School: 10%
- Other: 100% (initial value used in custom scenarios)

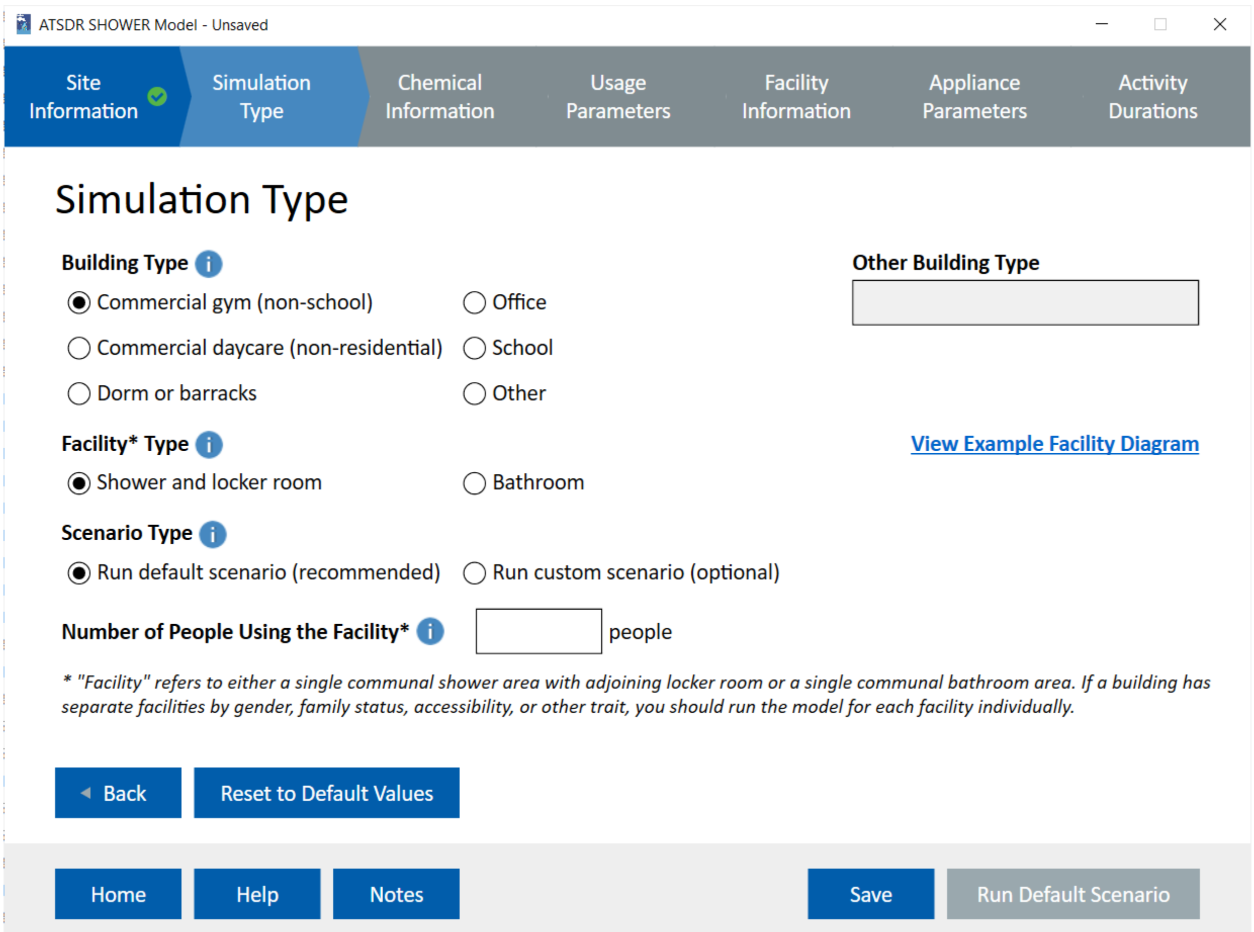
5.2.1. Scenario Setup

To initialize a communal shower and bathroom scenario, open the SHOWER model and click the **Run New Scenario** button. The program will give you the option of choosing either a new residential scenario or a new communal shower or bathroom scenario. Click the **Communal Shower or Bathroom Scenario** button and then enter information about the site on the Site Information screen. Once finished, click the **Next** button to move to the Simulation Type screen (Figure 24).

On the Simulation Type screen, use the **Building Type** radio button to identify the type of building where the facility is located. The options are non-school commercial gyms, non-residential commercial daycares, dorms or barracks, offices, and schools. You also have the option of selecting an "Other" building type and entering a description for the building type in the **Other Building Type** field.

Use the **Facility Type** radio button to identify the type of facility in the building. Select the **Shower and locker room** facility type to model a communal shower facility with adjoining locker room and select the **Bathroom** facility type to model a communal bathroom facility without showers. Bathroom facilities can be simulated for all building types, and shower and locker room facilities can be simulated for all building types except commercial daycares, since those are unlikely to have showers. After selecting the facility type, select the **Run default scenario (recommended)** button to evaluate a default scenario, or select the **Run custom scenario (optional)** button to evaluate a custom scenario.

Figure 24. SHOWER model communal shower and bathroom scenario Simulation Type screen



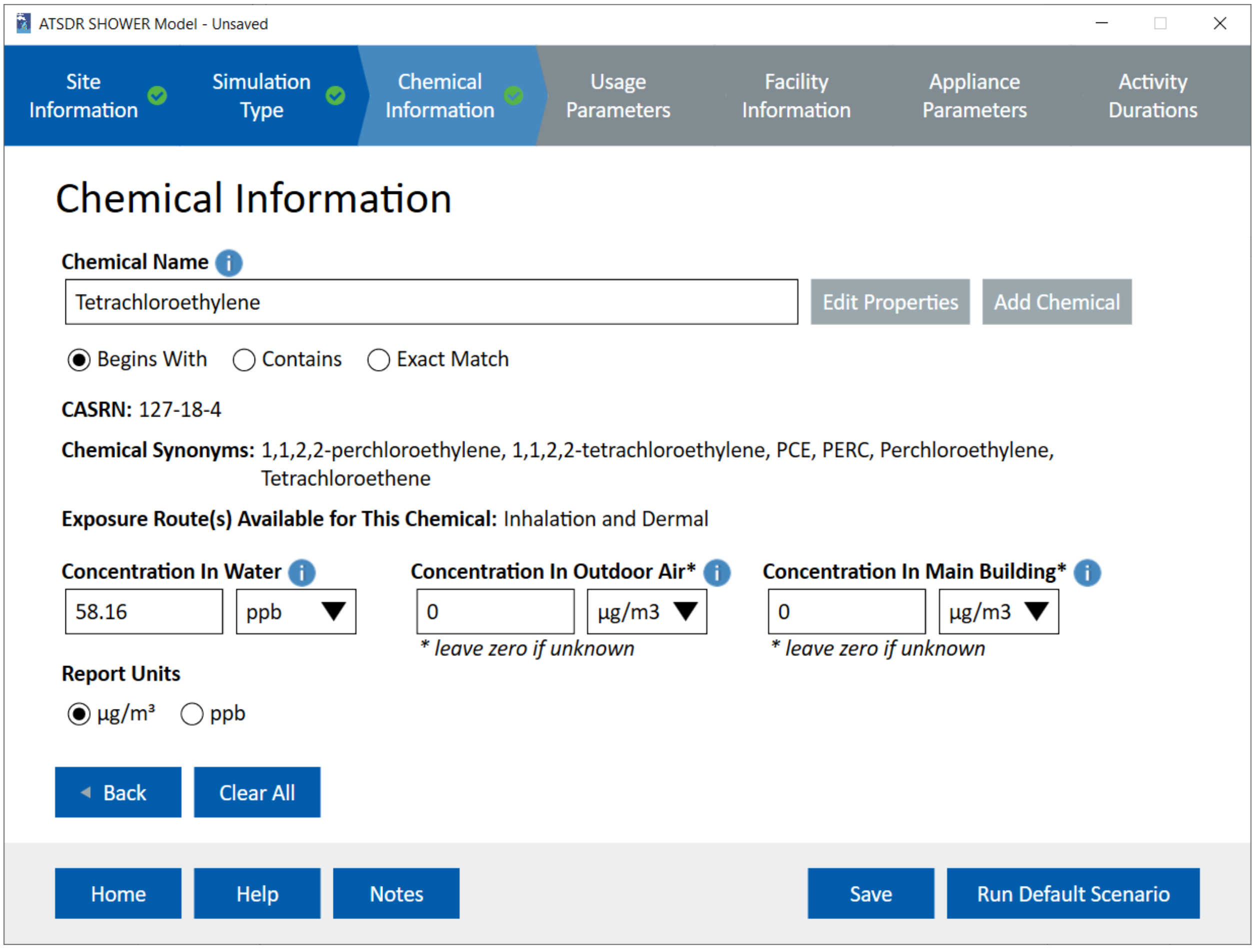
The final parameter that must be entered is the **Number of People Using the Facility**. The SHOWER model supports simulations of up to 1,000 facility users. The entered number represents the number of people that use the facility in a typical day. For buildings with only one facility, such as a small office with only one bathroom, the number of facility users would likely be the total number of people in the office. For larger buildings with multiple facilities, the entered number will be less than the total number of people in the building and should reflect just the number of people that use the facility being evaluated. For example, if you were evaluating a gym with one shower facility for men and another for women, you would run two scenarios: one for the men's facility and another for the women's. For the men's facility, the number of people using the facility would equal the number of men that visit the gym each day. Similarly, for the women's facility, the number of people using the facility would equal the number of women that visit the gym each day.

In the sections that follow (Section 5.2.2 and Section 5.2.3), the example results shown are for a commercial gym shower and locker room facility where 100 people use the facility each day. Once all the parameters on the Simulation Type screen have been assigned, click the **Next** button to move to the Chemical Information screen.

5.2.2. Default Scenario

To run a default scenario, the only additional required inputs are the chemical name and concentration in water. Figure 25 shows the communal shower and bathroom scenario Chemical Information screen filled in with the PCE EPC calculated in Section 4. The **Chemical Name** is tetrachloroethylene, and the chemical **Concentration in Water** is 58.16 ppb. The **Concentration in Outdoor Air** and **Concentration in Main Building** both have default values of 0 $\mu g/m^3$, but if a value for either parameter is known, they can be entered into the appropriate field. The **Report Units** are left as $\mu g/m^3$ so that air concentrations in the output report will be displayed in $\mu g/m^3$ instead of ppb. To run the SHOWER model default scenario, click the **Run Default Scenario** button.

Figure 25. SHOWER model communal shower and bathroom scenario Chemical Information screen



Concentration in Outdoor Air and Main Building

If site-specific outdoor air concentrations are not available, measurements from a nearby site may be available from USEPA's AMA database (USEPA 2023)—see Section 5.1.2 for more information. A similar nationwide database of indoor air building concentrations does not exist, but representative values may be available in the literature for buildings similar to the one you are modeling. For example, in 2011, USEPA compiled statistical data from numerous studies of background VOC concentrations in indoor air from thousands of North American residences (USEPA 2012). For offices, as part of USEPA's Building Assessment Survey and Evaluation study, VOCs were measured in indoor and outdoor air at 56 public and private office buildings across the United States between the summer of 1995 and winter of 1997 and 1998 (Girman et al. 1999). Similar studies may exist for schools and other building types. When using indoor air concentrations reported in the literature to characterize typical background concentrations, be sure that they do not include buildings near known hazardous waste sites, since buildings near these sites may have elevated background contaminant concentrations.

The primary results generated by the SHOWER model are presented in Table S1 (Figure 26) and Table S2 (Figure 27) in the SHOWER model report. Table S1 and Table S2 give the CTE and RME daily air exposure concentrations and administered dermal doses for all exposure groups evaluated in the default scenario, respectively. For shower and locker room facilities, Table S1 and Table S2 present statistics for people who shower in the facility. For scenarios with only bathroom facilities, they present statistics for all facility users.

- The CTE and RME daily exposure concentrations reported in Table S1 are the 50th and 95th percentile values, respectively, of the daily exposure concentrations for all persons simulated across all Monte Carlo iterations. Each person's ***daily*** exposure concentration is calculated based on a TWA of the concentrations in the compartments (shower area, bathroom, and main building) where they are located throughout their time at the facility and building.
- The CTE and RME dermal doses reported in Table S2 are the 50th and 95th percentile values, respectively, of the dermal doses calculated for each simulated exposure group for all persons simulated across all Monte Carlo iterations. Dermal doses are calculated using age-specific dermal factors (e.g., skin surface area, body weight) and are based on each person's contact with water while showering and while using sinks.

The RME concentration in Table S1 should be used to evaluate inhalation exposures for all simulated exposure groups, and the RME dermal doses in Table S2 should be used to evaluate dermal exposures. The information in these two tables will form the basis of the public health evaluations at most sites, and results from these two tables should be included in public health documents.

Figure 26. Table S1 in the communal shower and bathroom scenario report

Table S1. CTE and RME daily exposure concentrations for persons who shower in the facility

Exposure Type	Percentile Exposure	Daily Exposure Concentration (µg/m^3)
CTE	50th	0.16
RME	95th	0.61

Abbreviations: CTE = central tendency exposure; µg/m^3 = micrograms chemical per cubic meter air; RME = reasonable maximum exposure

Figure 27. Table S2 in the communal shower and bathroom scenario report

Table S2. CTE and RME daily administered dermal dose for persons who shower in the facility

Exposure Group	CTE Dermal Dose (µg/kg/day)	RME Dermal Dose (µg/kg/day)
Birth to < 1 year	0.69	1.1
1 to < 2 years	0.62	1.0
2 to < 6 years	0.56	0.90
6 to < 11 years	0.45	0.74
11 to < 16 years	0.37	0.61
16 to < 21 years	0.34	0.56
Adult	0.33	0.53
Pregnant & breastfeeding women	0.33	0.54

Abbreviations: CTE = central tendency exposure; µg/kg/day = micrograms chemical per kilograms body weight per day; RME = reasonable maximum exposure

In most of the default shower and locker room facility scenarios, not all facility users take showers. Facility users that do not take showers just use the facility toilets and bathroom sinks. In these scenarios, Table S3 (Figure 28) and Table S4 (Figure 29) give the CTE and RME daily air exposure concentrations and administered dermal doses for persons who do not shower in the facility. Exposures for these people are typically much lower than those for facility users who shower. As a result, public health evaluations will typically focus on results for persons who shower in the facility, which are provided in Table S1 and Table S2.

Figure 28. Table S3 in the communal shower and bathroom scenario report

Table S3. CTE and RME daily exposure concentrations for persons who do not shower in the facility

Exposure Type	Percentile Exposure	Daily Exposure Concentration (µg/m³)
CTE	50th	0.0058
RME	95th	0.014

Abbreviations: CTE = central tendency exposure; µg/m³ = micrograms chemical per cubic meter air; RME = reasonable maximum exposure

Figure 29. Table S4 in the communal shower and bathroom scenario report

Table S4. CTE and RME daily administered dermal dose for persons who do not shower in the facility

Exposure Group	CTE Dermal Dose (µg/kg/day)	RME Dermal Dose (µg/kg/day)
Birth to < 1 year	0.011	0.021
1 to < 2 years	0.010	0.021
2 to < 6 years	0.0079	0.016
6 to < 11 years	0.0064	0.013
11 to < 16 years	0.0050	0.0099
16 to < 21 years	0.0046	0.0090
Adult	0.0049	0.0096
Pregnant & breastfeeding women	0.0048	0.0095

Abbreviations: CTE = central tendency exposure; µg/kg/day = micrograms chemical per kilograms body weight per day; RME = reasonable maximum exposure

The remaining tables and figures in the report provide additional information about the input parameters and output distributions for your scenario. These are included for information purposes only and are not required in your public health documents. For shower and locker room facilities, Table 1, 2, and 3 in the reports are typically subdivided into “a” and “b” tables that present results for persons who do and do not shower in the facilities. Similarly, Figures 1 and 2 are subdivided into “a” and “b” figures that present results for persons who do and do not shower. The one exception is when 100% of the facility users take showers, as in the default dorm or barracks scenario. In that case, the tables and figures are not subdivided since all facility users are showering. Similarly, tables and figures are not subdivided for bathroom facility scenarios.

Table 1a (Figure 30) and Table 1b (Figure 31) in the report provide summary statistics on the activity patterns generated for facility users across all Monte Carlo iterations. The table identifies the mean value calculated for certain parameters, as well as the 50th and 95th percentile values. All statistics in this table and in other tables in the report are derived independently and therefore are not the values that went into deriving the CTE and RME results shown in Tables S1 and S2. Table 1a shows the values for people who shower while Table 1b shows the values for people who do not shower.

Figure 30. Table 1a in the communal shower and bathroom scenario report

Table 1a. Facility usage summary statistics for persons who shower in the facility

Parameter	Mean	50th percentile	95th percentile
Shower duration	7.9 min	6.6 min	18 min
Time in shower and locker room	24 min	23 min	34 min
Time using bathroom sink	0.64 min	0.46 min	1.7 min
Time in building	2.3 hr	1.9 hr	5.6 hr

Abbreviations: hr = hours; min = minute

Figure 31. Table 1b in the communal shower and bathroom scenario report

Table 1b. Facility usage summary statistics for persons who do not shower in the facility

Parameter	Mean	50th percentile	95th percentile
Time in locker room	5.2 min	5.0 min	7.0 min
Time using bathroom sink	0.60 min	0.45 min	1.6 min
Time in building	2.2 hr	1.8 hr	5.4 hr

Abbreviations: hr = hours; min = minute

Figures 1a and 1b (Figure 32 and Figure 33) in the report are histograms of the simulated inhalation concentrations across all Monte Carlo iterations for people who shower and for people who do not shower. The figures identify the CTE and RME concentrations from Table S1 and Table S3 using blue and red flags.

Figure 32. Figure 1a in the communal shower and bathroom scenario report

Figure 1a. Histogram of inhalation exposure concentrations for persons who shower in the facility

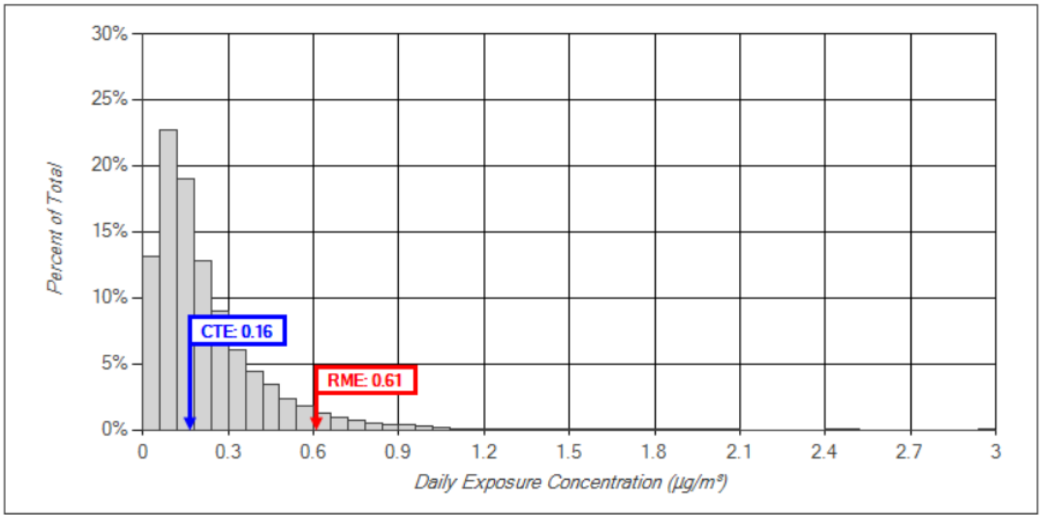
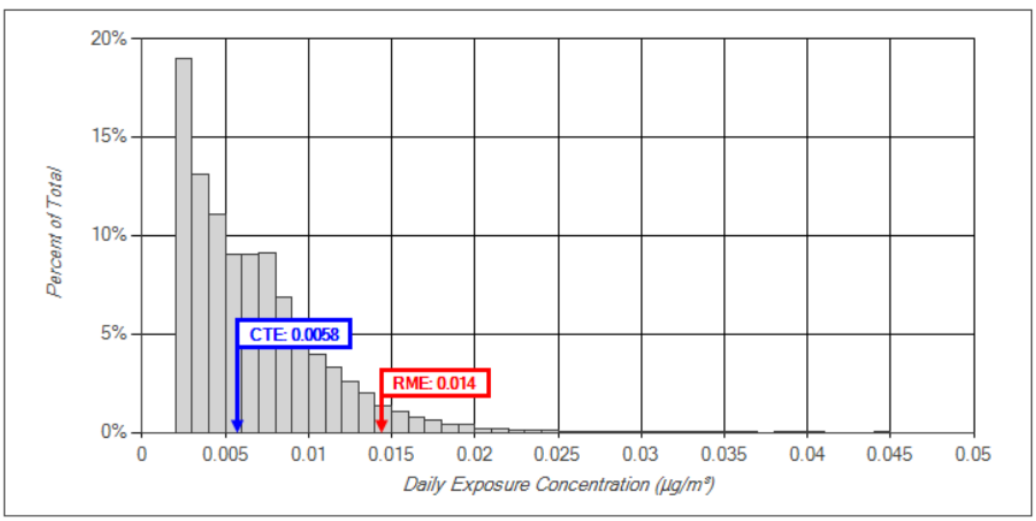


Figure 33. Figure 1b in the communal shower and bathroom scenario report

Figure 1b. Histogram of inhalation exposure concentrations for persons who do not shower in the facility



Figures 2a and 2b (Figure 34 and Figure 35) in the report show histograms of the maximum daily dermal doses simulated across all Monte Carlo iterations for people who shower and for people who do not shower. Multiple doses were calculated for each person based on the exposure groups in the scenario, but the histogram shows only the highest dose calculated for each person. In scenarios that use ATSDR's standard exposure groups, the highest dose is the dose calculated for the birth to <1 year age group. The CTE and RME flags in the figure report the CTE and RME maximum daily dermal doses and correspond with the highest CTE and RME doses reported in Table S2 and Table S4.

Figure 34. Figure 2a in the communal shower and bathroom scenario report

Figure 2a. Histogram of administered dermal doses for persons who shower in the facility

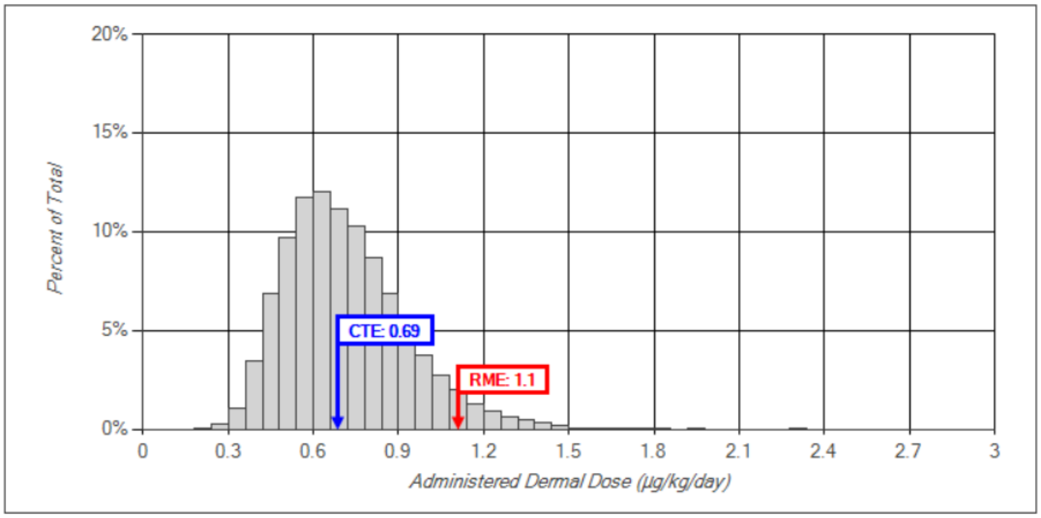
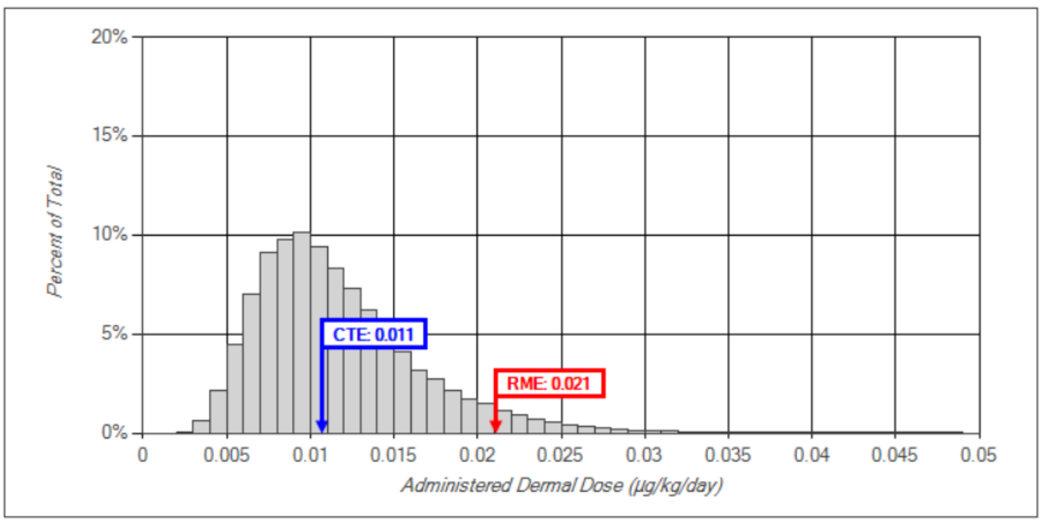


Figure 35. Figure 2b in the communal shower and bathroom scenario report

Figure 2b. Histogram of administered dermal doses for persons who do not shower in the facility



Tables 2a and 2b (Figure 36 and Figure 37) in the report show 50th and 95th percentile statistics on the time that facility users spend in the shower area, the locker room, and the main building. Table 2a provides statistics for people who shower, and Table 2b provides statistics for people who do not shower. The tables also show the concentrations to which they are exposed in those locations. The exposure from being in the shower and bathroom can be much higher (but for shorter periods) than the exposure from being in the main building. Knowledge of this brief exposure to high levels in these areas might be useful when evaluating whether harmful effects might be possible from acute exposure to high concentrations. This acute exposure to high levels might be particularly important for irritant chemicals, such as formaldehyde, chloroform, 2-butanone, and acetone. Some irritants, however, cannot be evaluated using the SHOWER model because required chemical parameters are lacking. Health assessors should evaluate acute inhalation exposures if the reported 95th percentile average human exposure concentration in any location exceeds the contaminant's acute inhalation CV, and if needed conduct a chemical-specific toxicity review by examining acute inhalation studies in ATSDR's toxicological profiles. Health assessors should consult with the ADS when evaluating brief exposure to high levels.

Figure 36. Table 2a in the communal shower and bathroom scenario report

Table 2a. 50th and 95th percentile exposure time and time-weighted average exposure concentration by location for persons who shower in the facility

Location	50th Percentile Exposure Time (min)	50th Percentile Time-weighted Average Exposure Concentration (µg/m³)	95th Percentile Exposure Time (min)	95th Percentile Time-weighted Average Exposure Concentration (µg/m³)
Shower area	7.0	31	18.0	66
Locker room	15.0	1.1	19.0	2.5
Main building	91.0	0	314.0	0

Abbreviations: µg/m³ = micrograms chemical per cubic meter air; min = minute

Figure 37. Table 2b in the communal shower and bathroom scenario report

Table 2b. 50th and 95th percentile exposure time and time-weighted average exposure concentration by location for persons who do not shower in the facility

Location	50th Percentile Exposure Time (min)	50th Percentile Time-weighted Average Exposure Concentration (µg/m³)	95th Percentile Exposure Time (min)	95th Percentile Time-weighted Average Exposure Concentration (µg/m³)
Locker room	5.0	1.7	7.0	3.9
Main building	109.0	0	324.0	0

Abbreviations: µg/m³ = micrograms chemical per cubic meter air; min = minute

Tables 3a and 3b (Figure 38 and Figure 39) in the report show the CTE and RME daily inhalation doses for people who shower and for people who do not shower. These doses are derived from age-specific breathing rates and the average daily exposure concentrations calculated for each person in each Monte Carlo iteration. For sites where facility users are drinking the water and using it for other purposes, it may be appropriate to combine doses from ingestion, inhalation, and dermal contact to get a total exposure dose. See Section 2.3 for more information.

Figure 38. Table 3a in the communal shower and bathroom scenario report

Table 3a. CTE and RME daily inhalation doses for persons who shower in the facility

Exposure Group	CTE Inhalation Dose (µg/kg/day)	RME Inhalation Dose (µg/kg/day)
Birth to < 1 year	0.23	0.86
1 to < 2 years	0.25	0.93
2 to < 6 years	0.15	0.57
6 to < 11 years	0.081	0.30
11 to < 16 years	0.054	0.20
16 to < 21 years	0.039	0.15
Adult	0.036	0.14
Pregnant & breastfeeding women	0.050	0.19

Abbreviations: CTE = central tendency exposure; µg/kg/day = micrograms chemical per kilograms body weight per day; RME = reasonable maximum exposure

Figure 39. Table 3b in the communal shower and bathroom scenario report

Table 3b. CTE and RME daily inhalation doses for persons who do not shower in the facility

Exposure Group	CTE Inhalation Dose (µg/kg/day)	RME Inhalation Dose (µg/kg/day)
Birth to < 1 year	0.0081	0.020
1 to < 2 years	0.0087	0.022
2 to < 6 years	0.0054	0.013
6 to < 11 years	0.0029	0.0072
11 to < 16 years	0.0019	0.0047
16 to < 21 years	0.0014	0.0035
Adult	0.0013	0.0032
Pregnant & breastfeeding women	0.0018	0.0044

Abbreviations: CTE = central tendency exposure; µg/kg/day = micrograms chemical per kilograms body weight per day; RME = reasonable maximum exposure

The remaining tables in the report identify the input parameters used to run the scenario. More information about these tables can be found in the report itself and in the SHOWER model user's guide (ATSDR 2024a).

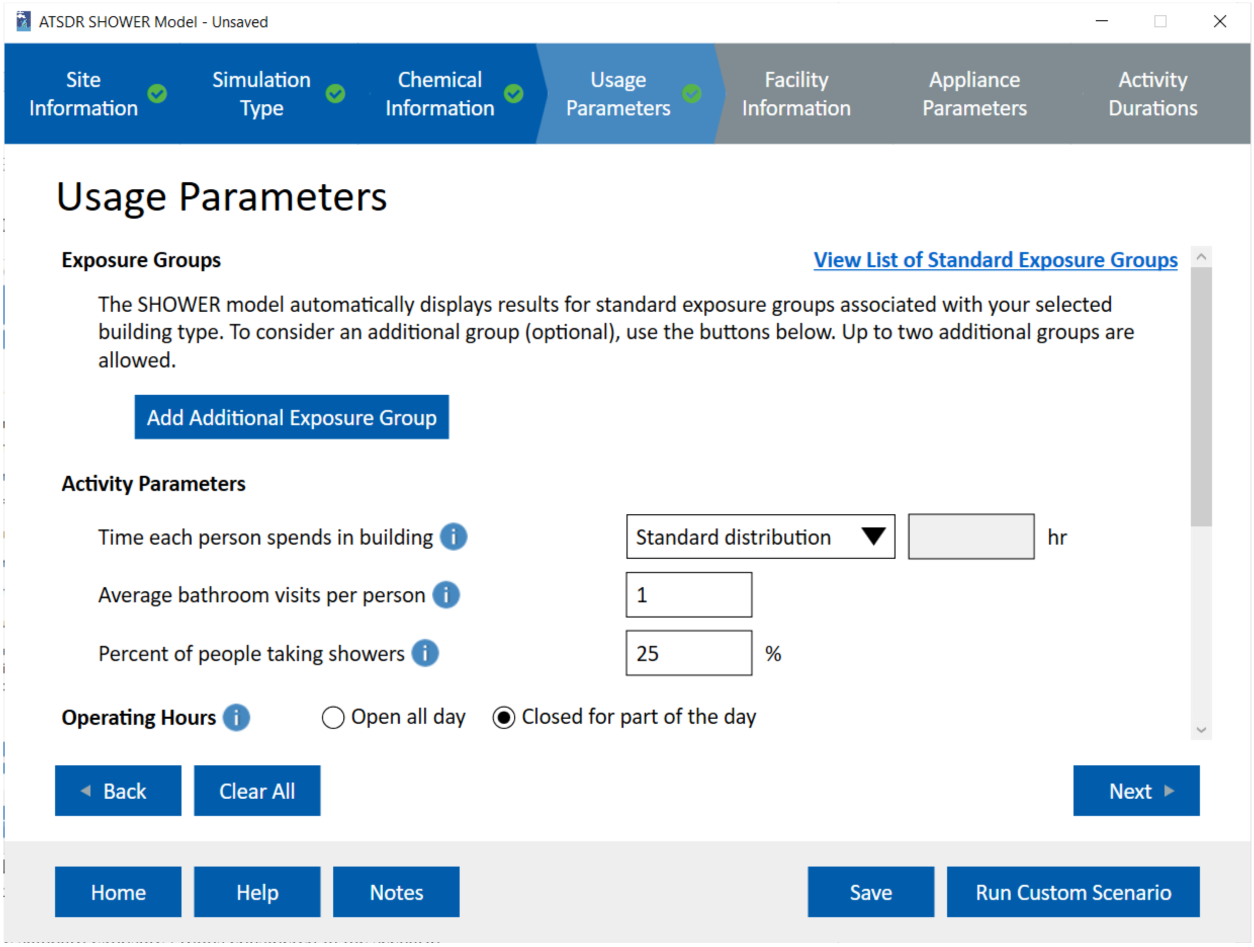
5.2.3. Custom Scenario

If you select the option to run a custom scenario, you will need to fill out the same inputs on the Chemical Information screen as those required in a default scenario (Section 5.2.2). Once you have entered a chemical name, you can click the **Edit Properties** button to edit the default inhalation and dermal properties for that chemical. In addition, you can also enter data for a new chemical by clicking on the **Add Chemical** button. The SHOWER model technical document

(ATSDR 2024b) provides more information about the chemical properties used within the SHOWER model.

Once all the fields on the Chemical Information screen are filled in, you can run the scenario at any time by clicking the **Run Custom Scenario** button at the bottom of the screen. To customize your scenario and enter site-specific information, click the **Next** button to proceed to the Usage Parameters screen (Figure 40).

Figure 40. SHOWER model communal shower and bathroom scenario Usage Parameters screen



The building type selected on the Simulation Type screen controls the standard values of the other parameters on the Usage Parameters screen, which are:

- the standard exposure groups considered in the scenario,
- the distribution of times that each person spends in the building,
- the average number of bathroom visits per person,
- the percent of people taking showers (shower and locker room facilities only), and

- the standard operating hours of the facility.

More information on the standard values of these parameters for each building type can be found in Appendix C, and more information on customizations that can be made to these parameters and to the other options available on the Usage Parameters screen is available in the SHOWER model user's guide (ATSDR 2024a).

Once you have reviewed the information on the Usage Parameters screen and made any site-specific edits needed, you can run your scenario by clicking the **Run Custom Scenario** button. If desired, you can also visit the final three screens to apply additional site-specific customizations. Making edits to the parameters on these screens is not required, but can be performed when additional site-specific data are available.

- The Facility Information screen identifies the number of showers, toilets, and bathroom sinks in the facility; the volume of the shower and bathroom area; and the facility air exchange rates when the facility is open or closed. Standard values for the number of showers, toilets, and bathroom sinks are based on the number of people that use the facility each day, which is set on the Simulation Type screen. The standard area volumes are derived from the number of each appliance type in the facility, and the standard air exchange rates are determined by the building type.
- The Appliance Parameters screen identifies the volume of water used in each toilet flush, the shower flow rate, and the bathroom sink flow rate. It also specifies the supply flow rate of outdoor air to the bathroom, and the flow rates of exhaust air from the shower and bathroom to the outdoors. The supply and exhaust air flow rates apply only when the facility is open and the building's HVAC system is on. The standard values of the supply and exhaust air flow rates depend on the number of showers and toilets in the facility and on the volume of the shower and bathroom areas. The **View Airflow Diagram** link shows the air flow rate values that will be applied in your simulation when the facility is open and closed, based on the parameter values entered on the Facility Information and Appliance Parameters screens.
- The Activity Durations screen identifies the parameters used to characterize the distributions of how long people spend in the facility performing various activities, including taking showers and using the bathroom sink. The standard values of the parameters on the Activity Durations screen are the same for all building types.

See Appendix C for more information on the standard values of the parameters on these screens, and see the SHOWER model technical document (ATSDR 2024b) for more information about how they are used in the SHOWER model.

The communal shower and bathroom custom scenario reports contain the same tables and figures as those in the default reports. See Section 5.2.2 for more information.

6. Perform Exposure Calculations in PHAST

After running the SHOWER model with the appropriate EPC, the next step is to use the PHAST SHOWER Model Exposure Calculator to compare the simulated average daily exposure concentrations and administered dermal doses to the appropriate health guidelines and cancer risk values. As discussed in Section 2.4, if any exposure group has an HQ greater than 1 or a CR greater than 1.0 x 10^{-6}, a detailed toxicological evaluation is required for that contaminant. More information on performing cancer and noncancer toxicological evaluations can be found in ATSDR's PHAGM (ATSDR 2023b).

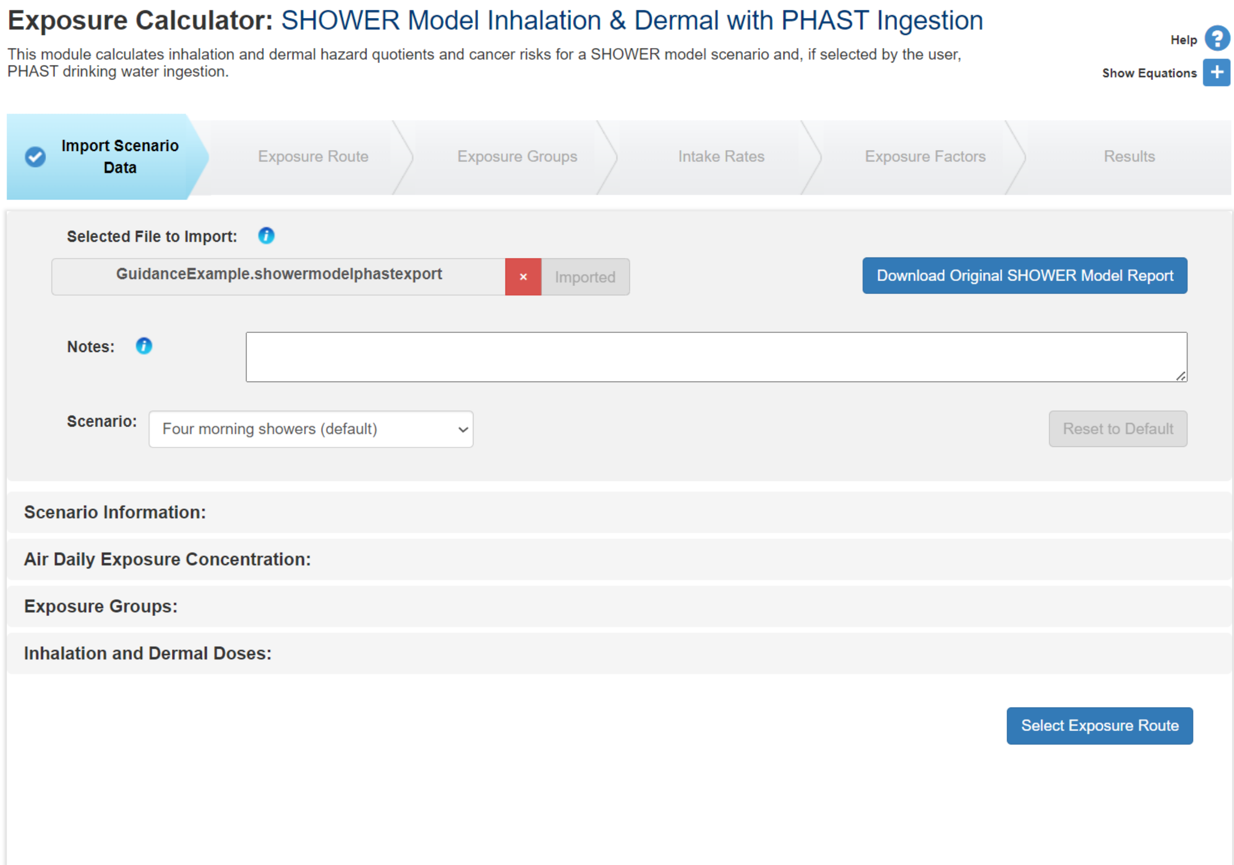
6.1. Data Import

The PHAST SHOWER Model Exposure Calculator uses a custom data file exported from the SHOWER model to complete exposure calculations. To export data from any SHOWER model scenario, click the **Export to PHAST** button on the SHOWER model Results screen. The SHOWER model will generate a .showermodelphastexport file which can be imported into PHAST for additional analysis.

To access PHAST, log into SAMS (https://sams.cdc.gov) and access the link https://csams.cdc.gov/PHAST/Home/Index. On the PHAST Home screen, click the **Exposure Calculator** button, and select the **SHOWER Model Inhalation, Ingestion & Dermal** option that appears in the popup. PHAST will load the SHOWER Model Exposure Calculator to the Import Scenario Data screen. To import your data, click the **Choose File** button and find the saved .showermodelphastexport file that you exported from the SHOWER model. If you do not have access to SAMS or PHAST, email phast@cdc.gov for assistance.

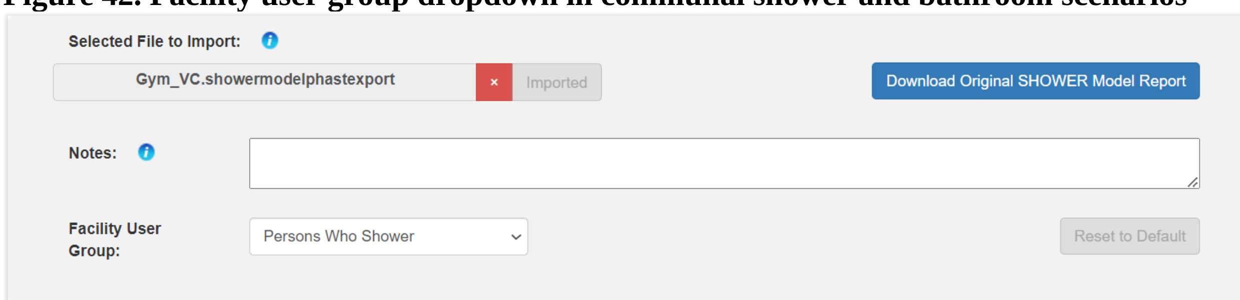
Figure 41 shows an example of the PHAST Import Scenario Data screen with data loaded from a default residential scenario. You can use the **Scenario** dropdown to switch between the 1-, 2-, 3-, and 4-person household scenarios evaluated in the default simulation. To analyze the default 4-person household RME scenario, leave the dropdown set to "Four morning showers (default)".

Figure 41. PHAST SHOWER Model Exposure Calculator Import Scenario Data screen



The **Scenario** dropdown will only be present in default residential scenarios. For custom residential scenarios, the **Scenario** dropdown will not be present, but all other elements shown in Figure 41 will be there. For communal shower and bathroom scenarios where results are presented separately for persons who do and do not shower in the facility, the dropdown is replaced by a **Facility User Group** dropdown (Figure 42) that lets you select between persons who shower and persons who do not shower in the facility. Hazard quotients and cancer risks can be generated for only one facility user group at a time. For bathroom facility scenarios and shower and locker room facility scenarios where 100% of people take showers (e.g., barracks scenarios), the **Facility User Group** scenario will not appear and the results generated apply to all facility users.

Figure 42. Facility user group dropdown in communal shower and bathroom scenarios



You can click on the accordions beneath the import data menu to see the data imported from the SHOWER model for your scenario, and you can click on the **Download Original SHOWER Model Report** button to view the original report created within the SHOWER model for your scenario. Click the **Select Exposure Route** button when you are ready to proceed with completing exposure calculations in PHAST.

On the Exposure Route screen, you have the option of analyzing two exposure scenarios. You can choose either a scenario where people are both drinking the water and using it for other purposes (showering, hand-washing, etc.), or a scenario where people are using the water but are not drinking it. Selecting the option where people are drinking the water means that PHAST will perform ingestion exposure calculations for your scenario along with inhalation and dermal calculations, and selecting the option where people are not drinking the water means that PHAST will not perform ingestion calculations. Once you have selected one of the options, you can click on the **Run Quick Summary** button to perform exposure calculations using default exposure parameters, or you can click on the **Enter Site-Specific Parameters** button to perform calculations using site-specific exposure parameters. For a custom scenario, the quick summary results are not available, and the only option is to use site-specific exposure parameters.

6.2. Default (Quick Summary) Scenarios

Clicking on the **Run Quick Summary** button brings up the quick summary results for your scenario. Quick summary results are calculated using all default SHOWER Model and PHAST exposure parameters and provide a rapid indication of whether noncancer or cancer health effects may be of concern for any exposure groups evaluated at your site.

Figure 43 shows quick summary results for the example PCE default residential scenario from Section 5.1.2 for a site where residents are both drinking the water and using it for other purposes. The **Quick Summary: Inhalation Only** table provides summaries of the HQs and CRs calculated using the average daily exposure concentration from the SHOWER model report. The **Quick Summary: Combining Doses for Ingestion & Dermal** table provides summaries of the HQs and CRs calculated based on the sum of the dermal doses from the SHOWER model report and the ingestion doses calculated within PHAST. The ingestion only and dermal only tables are initially collapsed but can be opened to view summaries of the HQs and CRs calculated separately for each exposure route.

Figure 43. PHAST SHOWER Model Exposure Calculator quick summary results

Quick Summary: Inhalation Only

Results for the Highest Exposed Group	Value	Notes
− Tetrachloroethylene		
Chronic Hazard Quotient	1.0	Concentrations for at least one of the standard age groups exceed the chronic health guideline. Review concentrations and HQs for each age group.
Intermediate Hazard Quotient	1.0	Concentrations for at least one of the standard age groups exceed the intermediate health guideline. Review concentrations and HQs for each age group.
Acute Hazard Quotient	1.0	Concentrations for at least one of the standard age groups exceed the acute health guideline. Review concentrations and HQs for each age group.
Cancer Risk	> 1.0E-6	Review cancer risks for adults and children; See CVs and Health Guidelines Module for additional cancer class information.

Quick Summary: Combining Doses for Ingestion & Dermal

Results for the Highest Exposed Group	Value	Notes
− Tetrachloroethylene		
Chronic Hazard Quotient	1.2	Doses for at least one of the standard age groups exceed the chronic health guideline. Review doses and HQs for each age group.
Intermediate Hazard Quotient	1.2	Doses for at least one of the standard age groups exceed the intermediate health guideline. Review doses and HQs for each age group.
Acute Hazard Quotient	1.2	Doses for at least one of the standard age groups exceed the acute health guideline. Review doses and HQs for each age group.
Cancer Risk	> 1.0E-6	Review cancer risks for adults and children; See CVs and Health Guidelines Module for additional cancer class information.

Quick Summary: Ingestion Only

Quick Summary: Dermal Only

Each quick summary table reports the maximum chronic HQ, intermediate HQ, and acute HQ calculated for any of the exposure groups considered in the scenario, and it reports the maximum cancer risk calculated across all exposure groups. Any HQs greater than 1 indicate the need for a detailed noncancer toxicological evaluation to determine if noncancer harmful effects might be possible, and any CRs greater than 1.0 x 10^{-6} indicate the need for a detailed cancer toxicological evaluation. The "Value" column for any records that meet these criteria will be shaded yellow.

In Figure 43, all the quick summary HQs and CRs meet these criteria, such that a detailed noncancer and cancer toxicological evaluation will be needed for this scenario. For the inhalation HQs, even though the rounded values reported in the table are all equal to 1.0, the unrounded values are slightly greater than 1.0, and therefore they are shaded yellow. In this example, because the acute HQ was greater than 1.0 and the EPC used in the SHOWER model was a 95UCL (Section 4), the SHOWER model should be run again using the maximum water concentration to obtain inhalation concentration and dermal dose estimates based on the maximum value for use in the acute noncancer toxicological evaluation.

The inhalation, dermal, and combined ingestion and dermal quick summary tables will have calculated results only for SHOWER model contaminants that have both inhalation and dermal parameter values. If a contaminant has only inhalation parameters in the SHOWER model, the dermal and combined tables will not appear. Similarly, if a contaminant has only dermal parameters, the inhalation table will not appear.

Clicking on the **Show Results for SHOWER Model Exposure Groups Based on PHAST Exposure Parameters** button will bring up tables showing the chronic, intermediate, and acute exposure calculations for each exposure group evaluated. Default scenario tables will include both CTE and RME results—health assessors should base their conclusions on the RME results. The detailed result tables can be used to identify the specific exposure groups with HQs greater than 1.0 and CRs greater than 1.0 x 10^{-6}. For example, Figure 44 shows the detail results table for chronic combined ingestion and dermal exposures. In this case, only the birth to <1 year exposure group had an RME HQ greater than 1.0, and the RME CRs calculated for all exposure groups were above 1.0 x 10^{-6}.

Figure 44. Combining doses for ingestion & dermal chronic exposure detail result table

Result Tables: Combining Doses for Ingestion & Dermal

Chronic Combined Exposure

Exposure Group	Default SHOWER Model Data with PHAST Exposure Parameters							
	Chronic Dose (mg/kg/day)		Chronic Hazard Quotient		Cancer Risk §			
	CTE	RME	CTE	RME	CTE	ED (yrs)	RME	ED (yrs)
Tetrachloroethylene (Chronic MRL: 0.008 mg/kg/day; CSF: 0.0021 (mg/kg/day)$^{-1}$)								
Birth to < 1 year	0.0047	0.0097	0.59	1.2 †	6.5E-7	1	2.1E-6 ‡	1
1 to < 2 years	0.0025	0.0059	0.31	0.73		1		1
2 to < 6 years	0.0020	0.0044	0.25	0.55		4		4
6 to < 11 years	0.0016	0.0035	0.19	0.44		5		5
11 to < 16 years	0.0012	0.0028	0.14	0.35		1		5
16 to < 21 years	0.0011	0.0027	0.14	0.33		0		5
Total exposure duration for child cancer risk						12		21
Adult	0.0013	0.0029	0.17	0.37	4.3E-7	12	2.6E-6 ‡	33
Pregnant Women	0.0011	0.0027	0.14	0.34	NC Ω			
Breastfeeding Women	0.0018	0.0035	0.22	0.44	NC Ω			
Birth to < 21 years + 12 years during adulthood	*Use this cancer risk if you have a scenario where children are likely to continue to live in their childhood home as adults.*						3.0E-6 ‡	33

At the bottom of the screen, clicking on the **Download Results** button and selecting the **508-Compliant** report option will generate a report with 508-compliant result tables that can be included in your public health documents. The default inhalation and dermal exposure parameters are described in the inhalation and dermal exposure dose guidance documents, respectively (ATSDR 2018, 2020).

6.3. Site-Specific Scenarios

If you have site-specific exposure parameters available, you can perform exposure calculations based on those parameters by clicking the **Enter Site-Specific Parameters** button on the Exposure Route screen. The next three screens allow you to customize the exposure groups, drinking water intake rates, and exposure factors evaluated in your scenario. Each screen also includes options for selecting default parameters when site-specific data are not available.

- The Exposure Groups screen allows you to select the exposure groups that apply at your site. Data exported from the SHOWER model for residential scenarios and communal shower and bathroom scenarios for commercial gyms, dorms or barracks, and “other” buildings will include results for ATSDR’s standard exposure groups. Data exported for communal shower and bathroom scenarios for offices, schools, and commercial daycares will include exposure groups for full- and part-time workers. In addition, daycares and schools will include other exposure groups typically associated with those buildings. On the Exposure Groups screen, you can choose to either calculate results for all the groups exported from the SHOWER model, or you can select a subset of them for further evaluation. For example, in an evaluation of a high school shower and locker room facility, you would select only the exposure groups corresponding to high school students, since they are the only groups that would be using the facilities. If you entered a custom exposure group in the SHOWER model, you will need to identify that group’s exposure duration in years on this screen.

- The Intake Rates screen allows you to set drinking water intake rates for all exposure groups selected on the Exposure Groups screen. The Intake Rates screen will be active only for scenarios where people are drinking the water. On this screen, you can either choose to use default CTE and RME drinking water intake rates for all standard exposure groups or to enter custom drinking water intake rates. Custom drinking water intake rates must be entered for any custom exposure groups imported from the SHOWER model.

- The Exposure Factors screen allows you to set exposure factors for the exposure groups at your site. Because the concentrations and doses calculated within the SHOWER model represent exposures over a 24-hour period, the only exposure factors that can be set in PHAST are the days per week, weeks per year, and years per lifetime over which exposure occurred. For residential scenarios and for communal shower and bathroom scenarios in commercial gyms, dorms or barracks, and “other” buildings, PHAST allows you to apply one site-specific value for days per week, weeks per year, and years per lifetime to all exposure groups evaluated. For offices, schools, and commercial daycares, PHAST provides more granular control and allows you to apply different values for each exposure group. In addition, PHAST allows you to determine whether results will be generated for acute, intermediate, and chronic exposures, or for just a subset of the three.

See the SHOWER Model Exposure Calculator section of the PHAST user’s guide (ATSDR 2024a) for more information on options available on these screens. Once you have finished entering site-specific parameter data, click the **Calculate Results** button to generate HQs and CRs for the exposure groups in your scenario.

The results reported in PHAST for site-specific scenarios are similar to those reported in the quick summary detail tables for default scenarios. If all three exposure routes (inhalation, ingestion, and dermal) and all three exposure durations (acute, intermediate, and chronic) are evaluated, the results will include the same 12 tables as those in the quick summary detail result tables. The site-specific tables will include HQs and CRs calculated based on the site-specific exposure parameters entered on the Exposure Groups, Intake Rates, and Exposure Factors screens. For site-specific scenarios with both CTE and RME results available, health assessors should base their conclusions on the RME results. For default residential scenarios, the result tables will also show HQs and CRs calculated using default exposure factors for comparison with the site-specific values.

Figure 45 shows an example of a site-specific chronic inhalation exposure table for the example PCE default residential scenario from Section 5.1.2. In this case, only the exposure groups aged 11 and older were selected for further analysis on the Exposure Groups screen. On the Exposure Factors screen, the exposure parameters were set at 4 days per week, 20 weeks per year, for a period of 5 years. In the figure, the site-specific results are shown under the blue “Default SHOWER Model Data with Site-Specific PHAST Exposure Parameters” heading, and the default results for comparison are shown under the brown “Default SHOWER Model Data with PHAST Exposure Parameters” heading. With the site-specific parameters used in this scenario, none of the chronic HQs exceeded 1.0 for any age group, nor were any of the cancer risks greater than 1.0 x 10^{-6}. By comparison, the default scenario chronic RME HQs exceeded one for all exposure groups, and the RME cancer risks exceeded 1.0 x 10^{-6} for all groups for which cancer risks were calculated.

As with the quick summary results, clicking on the **Download Results** button and selecting the **508-Compliant** report option will generate a report with 508-compliant result tables that can be included in your public health documents.

Additional Questions

If you have questions about how to set up the SHOWER model to simulate a site-specific scenario or questions about how to interpret SHOWER model results, contact showermodel@cdc.gov. A SHOWER model subject matter expert from ATSDR will reach out to you.

Figure 45. Chronic inhalation exposure site-specific results table

Result Tables: Inhalation Only:

Display results in: (●) µg/m³ ( ) ppb

Collapse All

Chronic Inhalation Exposure

Exposure Group	Default SHOWER Model Data with Site-Specific PHAST Exposure Parameters							Default SHOWER Model Data with PHAST Exposure Parameters							
	Chronic Adjusted EPC (µg/m³)		Chronic Hazard Quotient		Cancer Risk			Chronic Adjusted EPC (µg/m³)		Chronic Hazard Quotient		Cancer Risk §			
	CTE	RME	CTE	RME	CTE	RME	ED (yrs)	CTE	RME	CTE	RME	CTE	ED (yrs)	RME	ED (yrs)
− Tetrachloroethylene (Chronic MRL: 41 µg/m³; IUR: 2.6E-07 (µg/m³)⁻¹)															
Birth to < 1 year								19	43	0.47	1.0 †	7.7E-7	1	3.0E-6 ‡	1
1 to < 2 years								19	43	0.47	1.0 †		1		1
2 to < 6 years								19	43	0.47	1.0 †		4		4
6 to < 11 years								19	43	0.47	1.0 †		5		5
11 to < 16 years	4.2	9.4	0.10	0.23	7.0E-8	1.6E-7	5	19	43	0.47	1.0 †		1		5
16 to < 21 years	4.2	9.4	0.10	0.23			0	19	43	0.47	1.0 †		0		5
Total exposure duration for child cancer risk							5						12		21
Adult	4.2	9.4	0.10	0.23	7.0E-8	1.6E-7	5	19	43	0.47	1.0 †	7.7E-7	12	4.7E-6 ‡	33
Pregnant Women	4.2	9.4	0.10	0.23	NC Ω			19	43	0.47	1.0 †	NC Ω			
Breastfeeding Women	4.2	9.4	0.10	0.23	NC Ω			19	43	0.47	1.0 †	NC Ω			
Birth to < 21 years + 12 years during adulthood								*Use this cancer risk if you have a scenario where children are likely to continue to live in their childhood home as adults.*						4.7E-6 ‡	33

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Appendix A: Definitions of Common Terms

Appendix A provides definitions for standard terms used throughout this and other SHOWER model documents, including the user's guide (ATSDR 2024a) and technical document (ATSDR 2024b).

Administered Dermal Dose (ADD): A dermal absorbed dose that has been adjusted using a GI absorption factor. The ADD can be combined with doses from other routes (e.g., oral drinking water doses) and compared directly to oral MRLs and RfDs.

Air Exchange Rate: The SHOWER model calculates the flowrate of air into and out of a compartment as a function of the compartment's volume and air exchange rate. A compartment's air exchange rate is defined as the number of times that the volume of air in the compartment is replaced within a given time period. For example, in a shower compartment that has an air exchange rate of 0.45 air changes per hour (ACH), approximately half of the air in the shower is replaced each hour. The units used for air exchange rate in the SHOWER model are ACH. However, within the program, users can also calculate air exchange rates using compartment residence times.

Cancer Slope Factor (CSF): The CSF is a plausible upper-bound estimate of the probability that an individual will develop cancer if exposed to a chemical for a lifetime. The cancer slope factor is expressed as risk per milligram per kilogram per day (mg/kg/day).

Communal Bathroom Facility: A facility where one or more people can use the bathroom simultaneously. Examples include office, school, and commercial daycare restrooms. Communal bathroom facilities have at least one toilet and bathroom sink.

Comparison Value (CV): CVs are substance and media-specific concentrations that health assessors use during the initial phase of ATSDR's PHA process to select environmental contaminants that require further evaluation. ATSDR derives CVs from health guidelines, such as MRLs, RfDs, RfCs, and CSFs. These health guidelines are developed by ATSDR and USEPA and are based on epidemiological or toxicological data for which uncertainty factors have been applied to ensure that they are adequately protective of public health. Therefore, contaminants present at concentrations less than CVs are unlikely to pose a health threat. Contaminant concentrations that exceed their respective CVs require additional evaluation as part of ATSDR's PHA process to determine their potential health impact. Media-specific CVs incorporate ATSDR standard default exposure assumptions and are not site-specific. They may be based on carcinogenic or non-carcinogenic health effects.

Communal Shower and Locker Room Facility: A facility where one or more people can take a shower simultaneously. Examples include showers in commercial gyms, dorms, barracks, and schools. Communal shower and locker room facilities have a communal shower area and a communal bathroom and locker room area. Communal shower and locker room facilities have at least one shower, toilet, and bathroom sink.

Compartment: Compartments are areas in a building where the SHOWER model assumes air is perfectly mixed, such that contaminant air concentrations can be modeled as a single value within the area. Residential scenarios include three compartment types: shower stalls, bathrooms, and the main house. Communal shower and bathroom scenarios also consider three compartment types: shower areas, locker room and bathroom areas, and the main building.

Dermal Exposure: Dermal exposure refers to chemical uptake through the skin from contact with contaminated water while showering/bathing and hand contact with water from a faucet.

Dermal Absorbed Dose (DAD): The amount of chemical absorbed through the skin. The dermal absorbed dose needs to be converted to an administered dose before comparing the dose to health guidelines, such as MRLs and RfDs, or before using a CSF to estimate cancer risk. This conversion is done using an ABS_{GI} to convert the dermal absorbed dose to an administered dose.

Exposure Point Concentration (EPC): A representative contaminant concentration in a medium, such as water, soil, or air, within an exposure unit or area in an exposure pathway to which receptors are exposed for acute, intermediate, or chronic durations during the past, present, or future.

Exposure Point Concentration (EPC) Tool: ATSDR's EPC Tool is an R Shiny web-based application that calculates EPCs using discrete environmental data. It automates the EPC calculation algorithm from ATSDR's *Exposure Point Concentration Guidance for Discrete Sampling* and also includes additional calculation steps for special-case contaminants like dioxins and polycyclic aromatic hydrocarbons.

f Value: The f value, or fractional release value, refers to the fraction (as a percentage) of a chemical in water that volatilizes from water to air when water is being used in the house. The f value for a chemical depends upon many factors, including water temperature and physical-chemical properties of the chemical, such as Henry's Law Constant and diffusivity in water and air. The SHOWER model has chemical-specific f values for water used in showers, bathtubs, dishwashers, clothes washers, faucets, and toilets.

Facility: In communal shower and bathroom scenarios, the term facility refers to either a single communal shower area with adjoining locker room or a single communal bathroom area. One building can have multiple facilities. If a building has separate facilities by gender, family status, accessibility, or other trait, each facility should be treated as a distinct exposure unit and modeled separately using the SHOWER model.

Gastrointestinal Absorption Factor (ABS_{GI}): The fraction of a contaminant absorbed by the gastrointestinal (GI) tract. Used to convert an absorbed dermal dose to an equivalent administered oral dose, which allows health assessors to combine doses from the ingestion and dermal exposure pathways for the same medium to create a total dose and compare the combined dose to health guidelines or oral CSFs. For most contaminants, ATSDR assumes 100% of the contaminant is absorbed through the GI tract, thus using an ABS_{GI} of 1. For some inorganic compounds, however, ATSDR adjusts the dermal dose using specific absorption factors.

Human Activity Pattern: The human activity pattern refers to the time, location, and activity of the person whose exposure is being assessed. In residential scenarios with multiple showers in series, each person's activity pattern is established at the start of the simulation and determines when they move to and from the shower stall, the bathroom, and the main house throughout the day. The activity pattern also can include movement outside the house for some scenarios. For communal shower and bathroom scenarios, the activity patterns are randomly generated based on values sampled from input parameter distributions.

Indoor Water Use: Indoor water use includes all water use in the home or facility and includes shower water use, bathroom water use (e.g., bathtub, bathroom faucet, and toilet), and for residential scenarios, water use in other areas of the home (e.g., kitchen faucet, dishwasher, clothes washer). In communal shower and bathroom scenarios, the SHOWER model does not simulate indoor water use in the main building.

Inhalation Unit Risk (IUR): The IUR is an estimate of the increased cancer risk from inhalation exposure to a concentration of 1 microgram per cubic meter (µg/m^3) for a lifetime. The IUR can be multiplied by an estimate of lifetime exposure (in µg/m^3) to estimate the lifetime cancer risk.

Minimal Risk Level (MRL): An MRL is an estimate of someone's daily exposure to a hazardous substance that is likely to be without appreciable risk to their health. MRLs protect against noncancer health effects only. MRLs are derived for different exposure periods, including acute (1–14 days), intermediate (15–364 days), and chronic (365 days and longer) exposures. Exposure above the MRL does not mean that health problems will occur. MRLs are used as a screening tool to help identify exposures that require further toxicological evaluation to decide whether harmful effects might be possible.

Monte Carlo Method: Monte Carlo methods are computational techniques that involve running a large number of iterations of a model to better understand its output. In a single Monte Carlo iteration, a set of values is sampled at random from input parameter distributions and is used to calculate a set of output values. After completing multiple iterations, distributions of the output values can be constructed and analyzed for relevant statistics, such as the range of possible outcomes and the likelihood of different results.

Public Health Assessment (PHA): A PHA is a document that evaluates a site for hazardous substances, health outcomes, and community concerns. A PHA also looks at whether people could be harmed by coming into contact with site-related substances. Public health assessments are often the evaluation tool of choice when a site contains multiple contaminants and multiple potential pathways of chemical exposure. ATSDR and other agencies use PHAs to identify whether a health study is appropriate or whether some other public health action is warranted, such as community health education.

Public Health Assessment (PHA) Process: The PHA process refers to ATSDR's work to reduce people's exposures to toxic substances in the environment. ATSDR staff members:

- Evaluate environmental exposures, determine the possibility of harmful effects, and recommend ways to protect people's health.

- Prepare environmental reports based on agency findings.
- Get communities involved in public health activities and supply health education materials to those communities.
- Give technical help to communities, states, tribes, and other agencies.
- Work with ATSDR tribal programs and help with environmental justice activities.

Public Health Assessment Guidance Manual (PHAGM): ATSDR's online PHAGM provides guidance to new and experienced health assessors when performing tasks associated with the PHA process. The manual presents specific approaches, methods, and resources to:

- Evaluate environmental exposures associated with a hazardous waste site.
- Assess the potential for adverse health effects resulting from environmental exposures at a site.
- Recommend public health actions based on scientific evaluation of health and environmental data.
- Involve communities near a site and respond to their health concerns.
- Organize and write a PHA document to convey the findings of an assessment.

Because the science of risk assessment continues to evolve, ATSDR's online PHAGM is supplemented by ATSDR's exposure guidance documents, which focus on recent advances in risk assessment methods pertaining to exposure assessment and dose calculations.

Public Health Assessment Site Tool (PHAST): PHAST is a multi-purpose website developed by ATSDR that staff can use when evaluating exposure to environmental contamination. Health assessors can use PHAST to screen environmental contaminants, calculate exposure doses, estimate cancer risks and noncancer hazard quotients, and access current ATSDR CVs and health guidelines.

Reference Dose (RfD): An RfD is an estimate, with uncertainty spanning perhaps an order of magnitude, of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a No Observed Adverse Effect Level (NOAEL), a Lowest Observed Adverse Effect Level (LOAEL), or a benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used. RfDs are typically used in USEPA's noncancer risk assessments.

Reference Concentration (RfC): An RfC is an estimate, with uncertainty spanning perhaps an order of magnitude, of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a No Observed Adverse Effect Level (NOAEL), a Lowest Observed Adverse Effect Level (LOAEL), or a benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used. RfCs are typically used in USEPA's noncancer risk assessments.

Residence Time: Residence time is defined as the average amount of time that a parcel of air stays within a compartment. Within the SHOWER model, users can either enter compartment air exchange rates directly or calculate them based on compartment residence times. Residence times provided in minutes (min) can be converted to air exchange rates in units of air changes per hour (ACH) by the following formula:

$$air\ exchange\ rate\ (\text{ACH}) = \frac{60}{air\ residence\ time\ (\text{min})}$$

Per this formula, a shower compartment with an air exchange rate of 0.45 ACH would have a residence time of 133.3 min. An ACH of 0.45 means that 45% of the air in the compartment is replaced with air from outside the compartment every hour, or that the entire volume of air in the compartment is replaced with air from outside the compartment approximately once every 2.2 hours (133.3 min). The equations for calculating flow rate of air based on air exchange rate/residence time are specific to each compartment and scenario.

Shower and Household Water-Use Exposure (SHOWER) Model: The ATSDR SHOWER model predicts indoor air concentrations and dermal uptake from indoor use of contaminated water. ATSDR and state health assessors can use the SHOWER model to evaluate the inhalation and dermal exposure pathways from contaminated water in residences and in buildings with communal shower and bathroom facilities. The model does not include oral exposure from drinking household water, but oral drinking water doses can be calculated using the SHOWER Model Exposure Calculator in PHAST.

Sources: In the SHOWER model, sources refer to a household appliance or device (e.g., clothes washer, dishwasher, faucet, toilet, or showerhead) that uses water and contributes contaminants to indoor air.

Appendix B: Residential Scenario Standard Parameters

Appendix B contains a brief explanation of the sources of standard parameter values in the SHOWER model residential scenarios. Default residential scenarios use all standard parameter values. Custom scenarios are initialized with the standard parameter values, but users have the option to change them using the SHOWER model data input screens.

Household Composition

To select the number of persons in the household for the default scenario, ATSDR reviewed statistics from the 2011 American Community Survey conducted by the U.S. Census Bureau (ACS 2011). The typical household (50^{th} percentile) has 2 persons and the 90^{th}, 95^{th}, and 98^{th} percentile households have 4, 5, and 6 persons, respectively. The average number of persons per household is 2.6. ATSDR chose a 4-person household for the default scenario because it is protective of nearly all (90%) households in the U.S.

Activity Patterns

Residential activity patterns define the timing, frequency, and duration of appliance uses for all household members. The most comprehensive sources of information related to these parameters that ATSDR identified were the two *Residential End Uses of Water Surveys* (REUWS) conducted by the Water Research Foundation, which compiled information on water use in hundreds of households nationwide. Based on flow monitoring data, survey results, and other information collected for each household, the REUWS reports provided statistics on the duration of activities such as showering and sink uses, along with estimates of the volume of water used during those activities (DeOreo et al. 2016; Mayer et al. 1999). For the households examined, the first REUWS (Mayer et al. 1999) reported an average shower duration of 8.2 minutes, and the second (DeOreo et al. 2016) reported an average shower duration of 7.8 minutes and a 97^{th} percentile shower duration of 14 minutes. In 2017, the Alliance for Water Efficiency and USEPA's WaterSense program also reported 8 minutes as an average shower duration (AWE 2017; USEPA 2017).

For the default scenario, ATSDR chose to have showers take place in the morning, be consecutive, and be in the same shower stall. This pattern is health-protective because it gives increasing exposure to each consecutive person taking a morning shower, such that the last person to take a morning shower has the highest exposure. The CTE and RME shower durations and other activity pattern parameters in the default 4-person household simulation are based on Monte Carlo simulations that ATSDR conducted using activity data from the REUWS reports and USEPA's *Exposure Factors Handbook* (USEPA 2011a). Using a series of consecutive morning showers for a 4-person household, the output from deterministic scenarios with the following parameters reasonably approximated the 50^{th} and 95^{th} percentile output from the Monte Carlo simulations:

- CTE scenario (50^{th} percentile):
    - 7-minute showers for all four people in the household

  - 0.64-minute kitchen and bathroom sink use durations
  - 15 kitchen sink uses per person
- RME scenario (95^{th} percentile):
  - 10-minute showers for the first three people to shower
  - 15-minute shower for the last person to shower only
  - 1-minute kitchen and bathroom sink use durations
  - 20 kitchen sink uses per person

All other CTE and RME activity pattern parameters in the default residential simulation are the same. More information about the derivation of the CTE and RME scenarios using Monte Carlo simulation data is provided in the SHOWER model technical document (ATSDR 2024b).

The standard activity pattern parameters in custom residential scenarios are the same as those in the default residential CTE scenario. For custom scenarios in which residents take tub baths, the standard tub bath duration is 20 minutes, which is the median value for all exposure groups for time spent giving and taking a bath reported in Table 16-34 of USEPA's *Exposure Factors Handbook* (USEPA 2011b). For all residential scenarios (both default and custom), the standard value for time spent in the bathroom after a shower is 5 minutes, which is the 50^{th}-percentile value for all exposure groups reported in Table 16-32 of USEPA's *Exposure Factors Handbook* (USEPA 2011b).

Compartment Layout

The typical size of houses, including showers and bathrooms, has increased throughout the years. In older homes, which are more likely to have private wells, bathroom dimensions are typically 5 ft x 8 ft (40 ft^2) and shower stalls are typically 3 ft x 3 ft (9 ft^2) (DOJ 2010; TOH 2017). The median house size in the U.S. is 1,500 ft^2 (AHS 2015), and 8 ft ceilings are common in homes. ATSDR chose to use a standard small shower stall (3 ft x 3 ft x 8 ft), a standard small bathroom (5 ft x 8 ft x 8 ft), and an average house size (1,500 ft^2 x 8 ft) to characterize the default scenario. Larger shower stalls and bathrooms tend to reduce exposure because the compartment volumes are larger, which makes contaminant air concentrations lower. Similarly, larger houses make contaminant air concentrations in the main house lower, and smaller houses make air concentrations in the main house higher.

In custom scenarios, because six to eight consecutive morning showers in the same bathroom seemed unlikely, the standard house layout for scenarios with six or more persons assumes the house has two bathrooms instead of one. The standard bathroom layout in custom scenarios assumes that the bathtub is part of the shower compartment. If the bathtub is moved to the bathroom compartment so that the bathroom includes a separate bathtub and shower stall, the standard floor area assumed for the bathroom compartment is increased by 10 ft^2 to accommodate the extra space for the bathtub. Similarly, if the clothes washer is moved from the main house to the bathroom, the standard bathroom floor area is increased by another 10 ft^2 to accommodate the clothes washer.

Air Exchange Rates

The standard air exchange rate for all compartments in the residential scenarios is 0.45 air changes per hour (ACH). This value comes from Table 19-1 in USEPA's *Exposure Factors Handbook* (USEPA 2011c), which reported a median air exchange rate of 0.45 ACH for U.S. residential buildings from all regions. For a building, an air exchange rate of 0.45 means that 45% of the air in the building is replaced with outdoor air every hour. In a compartment, an air exchange rate of 0.45 also means that 45% of the air in the compartment is replaced every hour, either by air from the outdoors (for the main house compartment) or by air from another compartment (for the shower and bathroom compartments).

ATSDR conducted a literature search for additional air exchange rate data but was unable to find room-specific information—nearly all available values were whole-house air exchange rates. Of the studies that investigated room-specific air exchange rates, Wallace et al. (2002) examined air exchange rates in 10 rooms in an unoccupied three-story townhome for one year. Nine of the rooms were connected to the house's central air system and the remaining room (the attic) was not. Air exchange rates among the nine rooms connected to the central air system were very consistent and ranged from 0.62 ACH in a second floor office to 0.67 ACH in the kitchen, with an average air exchange rate of 0.65 ACH among all nine rooms. The bathroom air exchange rate was the same as the average air exchange rate. Since this study demonstrated that air exchange rates do not vary significantly from room to room in houses with central air systems, ATSDR used the median whole-house air exchange rate reported in USEPA's *Exposure Factors Handbook* as the standard air exchange rate of all compartments (shower, bathroom, and main house).

Appliance Parameters

Table B1 identifies the standard values of appliance parameters used in the residential scenarios. Most of the values were based on central tendency statistics reported in the 2016 REUWS (DeOreo et al. 2016). Of those from other sources, the average dishwasher and clothes washer cycle durations came from data provided by *Consumer Reports* (CR 2019a, 2019b), and the exhaust fan flow rate is based on the Home Ventilating Institute's recommendation of a 50 cubic feet per minute exhaust fan for bathrooms smaller than 50 square feet (HVI 2017).

Table B1. Standard residential scenario appliance parameters

Appliance	Parameter	Value	Reference
Bathtub	Volume	76.47 L	(DeOreo et al. 2016)
Bathroom sink	Flow rate	3.347 L/min	(DeOreo et al. 2016)
Clothes washer	Average cycle duration	75 min	(CR 2019b)
Clothes washer	Volume per cycle	117 L/load	(DeOreo et al. 2016)
Dishwasher	Average cycle duration	145 min	(CR 2019a)
Dishwasher	Volume per cycle	23.1 L/load	(DeOreo et al. 2016)
Exhaust fan	Flow rate	1,416 L/min	(HVI 2017)
Kitchen sink	Flow rate	3.347 L/min	(DeOreo et al. 2016)
Shower	Flow rate	7.6 L/min	(DeOreo et al. 2016)
Toilet	Volume per flush	8.7 L/flush	(DeOreo et al. 2016)

Appliance	Parameter	Value	Reference
Utility sink	Maximum volume use per person	8.544 L/person/day	(DeOreo et al. 2016)

Abbreviations: L/min = liters air breathed per minute; L = liters water; L/flush = liters water per flush; L/load = liters water per load; L/person/day = liters water used per person per day; min = minute

Volatilization Factors

A chemical volatilization factor (or f value) is the fraction of the chemical that escapes from water to air from appliances that use water. F values are both chemical- and appliance-specific. The SHOWER model includes chemical f values for showers, bathtubs, dishwashers, clothes washers, sinks, and toilets. More information on the derivation of the f values used in the SHOWER model can be found in the SHOWER model technical document (ATSDR 2024b).

Appendix C: Communal Shower and Bathroom Scenario Standard Parameters

Appendix C contains a brief explanation of the sources of standard parameter values in the SHOWER model communal shower and bathroom scenarios. With the exception of the input contaminant concentrations, the parameter values in default scenarios are all standard values that are described in this appendix. Custom scenarios are also initialized with standard parameter values, but users have the option to change them using the SHOWER model data input screens.

The subsections in Appendix C are organized by SHOWER model data input screen—the parameters discussed in the Usage Parameters section are set on the Usage Parameters screen, those discussed in the Facility Information section are set on the Facility Information screen, and so on.

Chemical Information

The standard chemical parameter values applied in communal shower and bathroom scenarios are the same as those applied in residential scenarios. Although chemical volatilization factors (f values) for commercial showers, toilets, and bathroom sinks may be different from those for residential appliances, ATSDR assumed that f values for commercial and residential appliances would be comparable. More information on the derivation of chemical f values can be found in the SHOWER model technical document (ATSDR 2024b).

Usage Parameters

The standard values for the facility usage parameters in communal shower and bathroom scenarios depend on the scenario's building type. Table C1 identifies the standard values associated with each building type for the building's operating hours, average number of bathroom visits per person, and percent of people taking showers.

Table C1. Standard commercial shower and bathroom scenario usage parameters for all building types

Building Type	Opening Time	Closing Time	Average Bathroom Visits Per Person	Percent of People Taking Showers
Commercial gym	6:00 AM	10:00 PM	1	25%
Commercial daycare	6:00 AM	7:00 PM	2	Not applicable
Dorm or barracks	Open all day	Open all day	5	100%
Office	6:00 AM	10:00 PM	2	5%
Other building	Open all day	Open all day	1	100%
School	6:00 AM	7:00 PM	2	10%

The standard opening and closing time for each building type and the average number of bathroom visits per person were established based on professional judgment. Dorms and barracks are open all day, and the other buildings are assumed to open at 6 AM. The school and commercial daycare closing time (7:00 PM) was based on an assumed time by which most children will have been picked up from schools and daycares, and the office and commercial gym closing time (10:00 PM) was based on an assumed time by which most people will have left those facilities. The average bathroom visits per person assumes approximately one bathroom visit per person every few hours.

The percent of people taking showers applies only for shower and locker room facilities. Limited data were available on shower frequency in communal shower settings, but according to one survey of 1,000 gym goers that was reported in various publications (e.g., MC (2023)), 73% of people do not shower after visiting the gym. For schools, ATSDR found articles indicating that many students prefer not to use school communal shower facilities, and that they are not widely used even among athletes (e.g., NYT (2023)). Because the articles did not include quantitative estimates of the percent of people taking showers in schools, ATSDR established the standard value of the parameter for schools based on professional judgment. For dorms and barracks, ATSDR assumed all residents shower once per day, and in offices with showers, ATSDR assumed only 5% of workers use the showers.

The default exposure groups for each building type match those identified in ATSDR's Exposure Dose Guidance for Inhalation Exposures (ATSDR 2020). Commercial gyms, dorms, barracks, and "other" buildings use ATSDR's standard exposure groups. Offices, schools, and commercial daycares use ATSDR's exposure groups for full- and part-time workers. Schools and commercial daycares also include additional exposure groups for children, and schools also include exposure groups for full- and part-time educators.

Table C2 identifies the standard distribution percentiles used to establish the time in the main building for each facility user. The reported percentiles come from the following data in Chapter 16 of USEPA's *Exposure Factors Handbook* (USEPA 2011b).

- **Commercial Gym:** Used percentile values reported for the "All" category in Table 16-18 for time spent indoors at a gym/health club (doers only).
- **Commercial Daycare:** Used percentile values reported in Table 16-17 for children aged 3 to <6 years for time spent indoors in schools (doers only). Of the child age groups applicable to daycare scenarios, the sample size for the 3 to <6 year age group was the largest in that table (*N* = 71), and the 50th and 95th percentile values for the 3 to <6 year age group appeared comparable to what might be expected for adult workers (418 minutes and 590 minutes, respectively).
- **Dorm or Barracks:** Used percentile values reported for the "All" category in Table 16-16 for time spent indoors in a residence (doers only).
- **Office:** Used percentile values reported for the "All" category in Table 16-18 for time spent indoors at an office or factory (doers only).
- **Other building:** Did not use percentile values; health assessors must enter a constant value for the time in building that applies to all facility users.
- **School:** Used percentile values reported for the "All" category in Table 16-18 for time spent indoors at a school (doers only).

Table C2. Distribution percentiles for time in the main building, in minutes

Percentile	Commercial Gym	Daycare	Dorm or Barracks	Office	School
Min	5	5	8	1	1
1	Not available	23	Not available	Not available	Not available
2	Not available	34	Not available	Not available	Not available
5	30	110	575	9	10
10	Not available	160	Not available	Not available	Not available
25	60	228	795	180	210
50	110	418	985	485	395
75	155	540	1,235	550	454
90	240	570	1,395	630	540
95	320	590	1,440	675	585
98	525	615	1,440	765	660
99	600	627	1,440	818	723
Max	686	630	1,440	1,440	995

In the PHAST SHOWER Model Exposure Calculator, ATSDR used standard values for the days per week, weeks per year, and years per lifetime established in ATSDR's *Exposure Dose Guidance for Inhalation Exposures* (ATSDR 2020) for offices, schools, and daycares. For dorms or barracks, ATSDR assumed exposure factors of 7 days per week, 52.14 weeks per year, for 4 years in CTE scenarios and for 6 years in RME scenarios. "Other" buildings do not have default exposure factors in PHAST.

ATSDR established the commercial gym CTE and RME days per week and weeks per year exposure factors based on data reported by Milkman et al. (2021). They conducted a study examining gym attendance habits using data collected in partnership with 24 Hour Fitness, a commercial gym chain that had over 4 million members and 450 locations in 14 states at the time of their study. Of those members, 61,923 participated in the study. Of the participants with relevant data, the median number of visits was 41 per year, and the 95th percentile was 206 per year. Assuming that gymgoers visited the gym no more than once per day, ATSDR used the median value to establish CTE exposure factors of 1 gym visit per week, 41 weeks per year, and RME exposure factors of 4 gym visits per week, 52 weeks per year. For years per lifetime, ATSDR established a CTE exposure factor of 5 years based on the average U.S health club membership tenure of 4.7 years reported in IHRSA (2022). ATSDR assumed an RME exposure factor of 20 years.

Facility Information

Three parameter types are set on the Facility Information screen: the number of showers, toilets, and bathroom sinks; the volume of the communal shower and bathroom areas; and the facility air exchange rates when the facility is open and closed.

The standard numbers of showers and toilets in the facility are based on requirements in OSHA Standard 29 CFR 1910.141 (OSHA 1974), which establishes sanitation standards for places of employment.

- For showers, the standard specifies that a workplace provide 1 shower for every 10 employees required to shower at the workplace in the same shift. As a result, ATSDR assumed a standard value of 1 shower for every 10 facility users.
- For toilets, the standard specifies that workplaces provide a certain number of water closets according to the number of employees expected to use the facility, as identified in Table C3. The SHOWER model uses the guidelines in Table C3 to establish the standard number of toilets in the facility based on the number of facility users.

Table C3. Requirements on number of water closets per number of employees in OSHA Standard 29 CFR 1910.141

Number of employees	Minimum number of water closets
1 to 15	1
16 to 35	2
36 to 55	3
56 to 80	4
81 to 110	5
111 to 150	6
Over 150	6 + 1 per 40 additional employees

OSHA Standard 29 CFR 1910.141 does not establish a required number of bathroom sinks per number of employees. As a result, ATSDR established the standard number of bathroom sinks using guidelines from the 2018 International Building Code (ICC 2018). Section 2902 of the code recommends that bathrooms include 1 sink for the first 40 people expected to use the facility and 2 sinks for the first 80 people. For bathrooms used by more than 80 people, the code recommends 2 sinks plus an additional sink for every additional 80 users after the first 80.

For the compartment area volumes, ATSDR established the standard sizes assuming 8-foot ceilings and floor areas based on the number of each appliance in the facility. For the shower area, ATSDR assumed a floor area of two meters by one meter for each facility shower, which aligned with typical values that ATSDR observed in materials from shower stall manufacturers (e.g., (CW 2021)). For the bathroom area, ATSDR assumed that the first bathroom stall has a floor area of 56 inches by 60 inches, which meets requirements established in the Americans with Disabilities Act (ADA 1990), and that all remaining stalls have a floor area of 56 inches by 30 inches, per recommendations in the 2021 International Building Code (ICC 2021). To account for space outside of stalls and for bathroom sinks, ATSDR multiplied the floor area of all bathroom stalls by a factor of 2.4, which reflects typical values that ATSDR observed in floor plans for public restrooms (HCS 2016).

Similar to the residential scenarios, the SHOWER model uses values reported for building-wide air exchange rates as the standard air exchange rates in the facility compartments. The model uses different air exchange rates for hours when the facility is open and closed, since the building HVAC system is assumed to be on when the facility is open and off when it is closed. The standard air exchange rates for when the facility is open come from Table 19-30 in USEPA's *Exposure Factors Handbook* (USEPA 2011a), which identifies mean air exchange rates in commercial buildings by building type. The SHOWER model assumes a standard air exchange rate of 1.9 ACH for schools, 1.5 ACH for offices (based on the table's entry for offices < 100,000 ft^2), and 1.4 ACH for all other buildings (based on the table's entry for multiuse buildings) when the facility is open. When the facility is closed, the standard air exchange rate of 0.4 ACH comes from Table 19-31 of USEPA (2011a) and is the median additional (non-mechanical) ventilation rate when the doors are shut from a sample of 37 commercial buildings.

Appliance Parameters

Table C4 provides the standard appliance parameters used in communal shower and bathroom scenarios. The appliance parameters are flowrates for the shower and bathroom sink, the volume of water used per toilet flush, and the total flowrates of air supplied from and vented to the outdoors for each facility compartment. All appliances of the same type (shower heads, toilets, and bathroom sinks) are assumed to have the same parameter values in the facility.

Table C4. Appliance parameter values in the communal shower and bathroom scenarios

Parameter	Standard Value
Shower flowrate	7.6 L/min
Toilet volume of water per flush	8.7 L
Bathroom sink flowrate	3.347 L/min
Bathroom compartment total outdoor air supply rate	1.2 L/s-m^2
Shower compartment total exhaust rate	10 L/s per shower
Bathroom compartment total exhaust rate in bathroom facilities with one toilet	12.5 L/s
Bathroom compartment total exhaust rate in bathroom facilities with multiple toilets	25 L/s per toilet
Bathroom compartment total exhaust rate in shower and locker room facilities with one toilet	12.5 L/s or 2.5 L/s-m^2, whichever is greater
Bathroom compartment total exhaust rate in shower and locker room facilities with multiple toilets	25 L/s or 2.5 L/s-m^2, whichever is greater

Abbreviations: L = liters, m = meters, min = minutes, s = seconds

The standard values for the shower flowrate, toilet volume of water per flush, and bathroom sink flowrate are the same as those used in residential scenarios, which come from the 2016 *Residential End Uses of Water Survey*, or REUWS (DeOreo et al. 2016). The standard value for the flowrate of outdoor air supplied to the bathroom compartment comes from Table 19-31 of USEPA (2011a) and is the mean outdoor air delivery rate by HVAC units per unit floor area. To get the total flowrate of outdoor supply air, the SHOWER model multiplies the outdoor air supply rate per unit area by the facility's total floor area. The total floor area is calculated by taking the sum of the shower and bathroom compartment volumes and dividing by an assumed height of 8 ft.

The SHOWER model also includes standard values for the shower and bathroom compartment total exhaust rates. ATSDR established standard exhaust rates based on the American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE) *Ventilation for Acceptable Indoor Air Quality Standard 62.1* (ASHRAE 2019). The ASHRAE standard specifies that exhaust air from showers and bathrooms be vented directly outside without recirculating within the building, and it provides minimum exhaust rates based on the facility area and number of appliances. Wherever the standard provided different values for exhaust systems that operated continuously or intermittently, ATSDR used the value associated with continuous operation to reflect the communal shower and bathroom scenario conceptual model assumption of continuous HVAC system operation when the facility is open.

- For the shower compartment, ASHRAE (2019) specifies a minimum exhaust rate of 10 L/s-unit for showers. The SHOWER model assigns a standard exhaust rate of 10 L/s per shower in the facility.
- For the bathroom compartment, ASHRAE (2019) specifies a minimum exhaust rate of 2.5 L/s-m^2 for locker rooms associated with athletic, industrial, or healthcare facilities. It also specifies a minimum exhaust rate of 25 L/s-unit for public toilets and 12.5 L/s-unit for private toilets.
    - For bathroom facilities, the SHOWER model bases the standard exhaust rate on the number of toilets in the facility. If the facility has only one toilet, the SHOWER model uses the lower rate for private toilets (12.5 L/s-unit) as the total exhaust rate. Otherwise, it uses the higher rate for public toilets (25 L/s-unit) to calculate the total exhaust rate.
    - For shower and locker room facilities, the SHOWER model uses the higher of the total exhaust rate based on the number of toilets (12.5 L/s for one toilet or 25 L/s-toilet for multiple toilets) or the total exhaust rate based on the locker room floor area (2.5 L/s-m^2). For example, if a shower and locker room facility contains 5 toilets and has a bathroom compartment area of 20 m^2, the minimum exhaust rate based on the bathroom compartment area would be 50 L/s (20 m^2 * 2.5 L/s-m^2 = 50 L/s), and the minimum exhaust rate based on the number of toilets would be 125 L/s (5 toilets * 25 L/s per toilet = 125 L/s). In this case, the default total exhaust rate for the bathroom compartment would be 125 L/s, since 125 L/s is the higher of the two values evaluated.

In default scenarios, when the facility is open, air flows from the main building into the locker room (or bathroom) and from the locker room into the shower area, but does not flow in the other direction. As a result, if default parameters are used, contaminants released in the facility do not flow into the main building when the facility is open. When the facility is closed, however, the facility exhaust fans are off and air exchange occurs with the main building. Because the main building contaminant concentration is modeled as a constant, any change in the main building contaminant concentration resulting from contaminated air flowing out of the facility is ignored.

Activity Durations

Table C5 identifies the parameter values and distributions used to randomly generate facility user activity patterns in the Monte Carlo simulations. ATSDR derived the shower and bathroom sink use duration parameters from data reported in the 2016 REUWS. The REUWS compiled water-usage information from single-family residences in the U.S. and Canada based on data obtained from residential flow monitors and other sources (DeOreo et al. 2016). The study included a database that reported use durations for different appliance types, including showers, dishwashers, clothes washers, and faucets. The 2016 REUWS database included 17,079 shower duration records and 495,931 faucet duration records. The database did not report data for different types of sinks, but instead reported results only for “faucets”.

After analyzing the REUWS data, ATSDR characterized the standard shower and bathroom sink use durations as lognormal distributions and obtained distribution parameters using the *fitdistplus* package in R. For shower duration, in natural space, the arithmetic mean of the lognormal distribution that best fit the data was 8.0 minutes and the arithmetic standard deviation was 5.3 minutes. For bathroom sink use duration, in natural space, the arithmetic mean of the lognormal distribution that best fit the data was 0.61 minutes and the arithmetic standard deviation was 0.57 minutes.

ATSDR used professional judgment to determine the standard distributions and values for the other three parameters in Table C5. The standard distributions and values associated with each parameter reflect ATSDR’s estimate of the time required to do the following activities:

- **Time in locker room before shower**: Enter the facility, get undressed, store belongings in a locker, and enter the shower compartment.
- **Time in locker room after shower**: Exit the shower compartment, retrieve belongings, get dressed, use the toilet, wash hands in the bathroom sink, and exit the facility.
- **Time in bathroom for bathroom-only visits**: Enter the facility, use the toilet, wash hands in the bathroom sink, and exit the facility.

The SHOWER model custom scenarios allow users to change the arithmetic means of these three parameters, but not the arithmetic standard deviations. Instead, the arithmetic standard deviations are automatically calculated as 1/5 of the entered arithmetic mean values, based on ATSDR’s professional judgment. For example, if a user enters a value of 20 minutes for the arithmetic mean of the time in locker room after a shower, the arithmetic standard deviation will equal 4 minutes.

Table C5. Parameters used to characterize activity duration distributions, in minutes

Parameter	Distribution Type	Arithmetic Mean	Arithmetic Standard Deviation
Shower duration	Lognormal	8.0	5.3
Time in locker room before shower	Normal	5	1
Time in locker room after shower	Normal	10	2
Time in bathroom for bathroom-only visits	Normal	5	1
Bathroom sink use duration	Lognormal	0.61	0.57