Appendix A. Glossary

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health. This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-422-8737).

General Terms

Absorption
The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acute
Occurring over a short time [compare with chronic].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Additive effect
A biologic response to exposure to multiple substances that equals the sum of responses of all the individual substances added together [compare with antagonistic effect and synergistic effect].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems

Aerobic
Requiring oxygen [compare with anaerobic].

Ambient
Surrounding (for example, ambient air).

Anaerobic
Requiring the absence of oxygen [compare with aerobic].

Analyte
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

Analytic epidemiologic study
A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

Antagonistic effect
A biologic response to exposure to multiple substances that is less than would be expected if the known effects of the individual substances were added together [compare with additive effect and synergistic effect].

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biodegradation
Decomposition or breakdown of a substance through the action of microorganisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).

Biologic indicators of exposure study
A study that uses (a) biomedical testing or (b) the measurement of a substance [an analyte], its metabolite, or another marker of exposure in human body fluids or tissues to confirm human exposure to a hazardous substance [also see exposure investigation].

Biologic monitoring
Measuring hazardous substances in biologic materials (such as blood, hair, urine, or breath) to determine whether exposure has occurred. A blood test for lead is an example of biologic monitoring.

Biologic uptake
The transfer of substances from the environment to plants, animals, and humans.

Biomedical testing
Testing of persons to find out whether a change in a body function might have occurred because of exposure to a hazardous substance.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Body burden
The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

CAP [see Community Assistance Panel.]

Cancer
Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

Case study
A medical or epidemiologic evaluation of one person or a small group of people to gather information about specific health conditions and past exposures.

Case-control study
A study that compares exposures of people who have a disease or condition (cases) with people who do not have the disease or condition (controls). Exposures that are more common among the cases may be considered as possible risk factors for the disease.

CAS registry number
A unique number assigned to a substance or mixture by the American Chemical Society Abstracts Service.

Central nervous system
The part of the nervous system that consists of the brain and the spinal cord.

CERCLA [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980]

Chronic
Occurring over a long time [compare with acute].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Cluster investigation
A review of an unusual number, real or perceived, of health events (for example, reports of cancer) grouped together in time and location. Cluster investigations are designed to confirm case reports; determine whether they represent an unusual disease occurrence; and, if possible, explore possible causes and contributing environmental factors.

Community Assistance Panel (CAP)
A group of people from a community and from health and environmental agencies who work with ATSDR to resolve issues and problems related to hazardous substances in the community. CAP members work with ATSDR to gather and review community health concerns, provide information on how people might have been or might now be exposed to hazardous substances, and inform ATSDR on ways to involve the community in its activities.

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see exposure pathway].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances. This law was later amended by the Superfund Amendments and Reauthorization Act (SARA).

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Delayed health effect
A disease or an injury that happens as a result of exposures that might have occurred in the past.

Dermal
Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see route of exposure].

Descriptive epidemiology
The study of the amount and distribution of a disease in a specified population by person, place, and time.

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease prevention
Measures used to prevent a disease or reduce its severity.

Disease registry
A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

DOD
United States Department of Defense.

DOE
United States Department of Energy.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose (for radioactive chemicals)
The radiation dose is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

Dose-response relationship
The relationship between the amount of exposure [dose] to a substance and the resulting changes in body function or health (response).

Environmental media
Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism
Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

EPA
United States Environmental Protection Agency.

Epidemiologic surveillance [see Public health surveillance].

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction
A method of estimating the amount of people's past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure investigation
The collection and analysis of site-specific information and biologic tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Exposure registry
A system of ongoing followup of people who have had documented environmental exposures.

Feasibility study
A study by EPA to determine the best way to clean up environmental contamination. A number of factors are considered, including health risk, costs, and what methods will work well.

Geographic information system (GIS)
A mapping system that uses computers to collect, store, manipulate, analyze, and display data. For example, GIS can show the concentration of a contaminant within a community in relation to points of reference such as streets and homes.

Grand rounds
Training sessions for physicians and other health care providers about health topics.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Half-life ($t_{½}$)
The time it takes for half the original amount of a substance to disappear. In the environment, the half-life is the time it takes for half the original amount of a substance to disappear when it is changed to another chemical by bacteria, fungi, sunlight, or other chemical processes. In the human body, the half-life is the time it takes for half the original amount of the substance to disappear, either by being changed to another substance or by leaving the body. In the case of radioactive material, the half life is the amount of time necessary for one half the initial number of radioactive atoms to change or transform into another atom (that is normally not radioactive). After two half lives, 25% of the original number of radioactive atoms remain.

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous Substance Release and Health Effects Database (HazDat)
The scientific and administrative database system developed by ATSDR to manage data collection, retrieval, and analysis of site-specific information on hazardous substances, community health concerns, and public health activities.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

Health education
Programs designed with a community to help it know about health risks and how to reduce these risks.

Health investigation
The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to evaluate the possible association between the occurrence and exposure to hazardous substances.

Health promotion
The process of enabling people to increase control over, and to improve, their health.

Health statistics review
The analysis of existing health information (i.e., from death certificates, birth defects registries, and cancer registries) to determine if there is excess disease in a specific population, geographic area, and time period. A health statistics review is a descriptive epidemiologic study.

Indeterminate public health hazard
The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

In vitro
In an artificial environment outside a living organism or body. For example, some toxicity testing is done on cell cultures or slices of tissue grown in the laboratory, rather than on a living animal [compare with in vivo].

In vivo
Within a living organism or body. For example, some toxicity testing is done on whole animals, such as rats or mice [compare with in vitro].

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Medical monitoring
A set of medical tests and physical exams specifically designed to evaluate whether an individual's exposure could negatively affect that person's health.

Metabolism
The conversion or breakdown of a substance from one form to another by a living organism.

Metabolite
Any product of metabolism.

mg/kg
Milligram per kilogram.

mg/cm2
Milligram per square centimeter (of a surface).

mg/m3
Milligram per cubic meter; a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

Morbidity
State of being ill or diseased. Morbidity is the occurrence of a disease or condition that alters health and quality of life.

Mortality
Death. Usually the cause (a specific disease, a condition, or an injury) is stated.

Mutagen
A substance that causes mutations (genetic damage).

Mutation
A change (damage) to the DNA, genes, or chromosomes of living organisms.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

National Toxicology Program (NTP)
Part of the Department of Health and Human Services. NTP develops and carries out tests to predict whether a chemical will cause harm to humans.

No apparent public health hazard
A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

No-observed-adverse-effect level (NOAEL)
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard
A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

NPL [see National Priorities List for Uncontrolled Hazardous Waste Sites]

Physiologically based pharmacokinetic model (PBPK model)
A computer model that describes what happens to a chemical in the body. This model describes how the chemical gets into the body, where it goes in the body, how it is changed by the body, and how it leaves the body.

Pica
A craving to eat nonfood items, such as dirt, paint chips, and clay. Some children exhibit pica-related behavior.

Plume
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Potentially responsible party (PRP)
A company, government, or person legally responsible for cleaning up the pollution at a hazardous waste site under Superfund. There may be more than one PRP for a particular site.

ppb
Parts per billion.

ppm
Parts per million.

Prevalence
The number of existing disease cases in a defined population during a specific time period [contrast with incidence].

Prevalence survey
The measure of the current level of disease(s) or symptoms and exposures through a questionnaire that collects self-reported information from a defined population.

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public availability session
An informal, drop-by meeting at which community members can meet one-on-one with ATSDR staff members to discuss health and site-related concerns.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action
A list of steps to protect public health.

Public health advisory
A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public health hazard categories
Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

Public health statement
The first chapter of an ATSDR toxicological profile. The public health statement is a summary written in words that are easy to understand. The public health statement explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public health surveillance
The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the data and use for public health programs.

Public meeting
A public forum with community members for communication about a site.

Radioisotope
An unstable or radioactive isotope (form) of an element that can change into another element by giving off radiation.

Radionuclide
Any radioactive isotope (form) of any element.

RCRA [see Resource Conservation and Recovery Act (1976, 1984)]

Receptor population
People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Registry
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see exposure registry and disease registry].

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Resource Conservation and Recovery Act (1976, 1984) (RCRA)
This Act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RFA
RCRA Facility Assessment. An assessment required by RCRA to identify potential and actual releases of hazardous chemicals.

RfD [see reference dose]

Risk
The probability that something will cause injury or harm.

Risk reduction
Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

Risk communication
The exchange of information to increase understanding of health risks.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Safety factor [see uncertainty factor]

SARA [see Superfund Amendments and Reauthorization Act]

Sample
A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample size
The number of units chosen from a population or an environment.

Solvent
A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Special populations
People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Stakeholder
A person, group, or community who has an interest in activities at a hazardous waste site.

Statistics
A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Substance
A chemical.

Substance-specific applied research
A program of research designed to fill important data needs for specific hazardous substances identified in ATSDR's toxicological profiles. Filling these data needs would allow more accurate assessment of human risks from specific substances contaminating the environment. This research might include human studies or laboratory experiments to determine health effects resulting from exposure to a given hazardous substance.

Superfund [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)

Superfund Amendments and Reauthorization Act (SARA)
In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Surveillance [see public health surveillance]

Survey
A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people [see prevalence survey].

Synergistic effect
A biologic response to multiple substances where one substance worsens the effect of another substance. The combined effect of the substances acting together is greater than the sum of the effects of the substances acting by themselves [see additive effect and antagonistic effect].

Teratogen
A substance that causes defects in development between conception and birth. A teratogen is a substance that causes a structural or functional birth defect.

Toxic agent
Chemical or physical (for example, radiation, heat, cold, microwaves) agents that, under certain circumstances of exposure, can cause harmful effects to living organisms.

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Tumor

An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

Uncertainty factor
Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

Urgent public health hazard
A category used in ATSDR's public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Volatile organic compounds (VOCs)
Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:
Environmental Protection Agency (http://www.epa.gov/OCEPAterms/)

National Center for Environmental Health (CDC)
(http://www.cdc.gov/nceh/dls/report/glossary.htm)

National Library of Medicine (NIH)
(http://www.nlm.nih.gov/medlineplus/mplusdictionary.html)

For more information on the work of ATSDR, please contact:
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Appendix B. Comparison Values

ATSDR health assessors use comparison values (CVs) as screening tools to evaluate environmental data that are relevant to the exposure pathways. CVs represent media-specific contaminant concentrations that are much lower than exposure concentrations observed to cause adverse health effects. This means that CVs are protective of public health in essentially all exposure situations. If the concentrations in the exposure medium are less than the CV, the exposures are not of health concern and no further analysis of the pathway is required. However, while concentrations below the CV are not expected to lead to any observable health effect, it should not be inferred that a concentration greater than the CV will necessarily lead to adverse effects. Depending on site-specific environmental exposure factors (for example, duration of exposure) and activities of people that result in exposure (time spent in area of contamination), exposure to levels above the CV may or may not lead to a health effect. Therefore, ATSDR's CVs are not used to predict the occurrence of adverse health effects. Rather, they are used by ATSDR to select contaminants for further evaluation to determine the possibility of adverse health effects.

CVs used in this PHA include:

Cancer Risk Evaluation Guide (CREG)

Estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10^{-6}) persons exposed over a 70-year life span. ATSDR's CREGs are calculated from EPA's cancer slope factors (CSFs).

Environmental Media Evaluation Guide (EMEG)

EMEGs are based on ATSDR minimal risk levels (MRLs) and factor in body weight and ingestion rates. An EMEG is an estimate of daily human exposure to a chemical (in mg/kg/day) that is likely to be without noncarcinogenic health effects over a specified duration of exposure to include acute, intermediate, and chronic exposures.

Reference Media Evaluation Guide (RMEG)

ATSDR derives RMEGs from EPA's oral reference doses (RfDs). The RMEG represents the concentration in water or soil at which daily human exposure is unlikely to result in adverse noncarcinogenic effects.

EPA's Region III Risk-Based Concentration (RBC)

EPA combines RfDs and CSF with "standard" exposure scenarios to calculate RBCs, which are chemical concentrations corresponding to fixed levels of risk (i.e., a hazard quotient of 1, or lifetime cancer risk of 10^{-6}, whichever occurs at a lower concentration) in water, air, fish tissue, and soil.

EPA's Maximum Contaminant Level (MCL)

The MCL is the drinking water standard established by EPA. It is the maximum permissible level of a contaminant in water that is delivered to a free-flowing outlet. MCLs are considered protective of human health over a lifetime (70 years) for individuals consuming 2 liters of water per day.

CVs are derived from available health guidelines, such as ATSDR's MRLs, EPA's RfDs, and EPA's CSFs. These guidelines are based on the no-observed-adverse-effect levels (NOAELs), lowest-observed-adverse-effect levels (LOAELs), or cancer effect levels (CELs) reported for a contaminant in the toxicological literature. A description of these terms is provided:

Minimal Risk Level (MRL)

MRLs are estimates of daily human exposure to a chemical (i.e., doses expressed in mg/kg/day) that are unlikely to be associated with any appreciable risk of deleterious noncancer effects over a specified duration of exposure. MRLs are calculated using data from human and animal studies and are reported for acute ($\leq$ 14 days), intermediate (15 to 364 days), and chronic ($\geq$ 365 days) exposures.

Reference Dose (RfD)

The RfD is an estimate, with safety factors built in, of the daily, lifetime exposure of human populations to a possible hazard that is *not* likely to cause them harm.

Cancer Slope Factor (CSF)

Usually derived from dose-response models and expressed in milligrams per kilogram per day, CSFs describe the inherent potency of carcinogens and estimate an upper limit on the likelihood that lifetime exposure to a particular chemical could lead to excess cancer deaths.

Lowest-Observed-Adverse-Effect Level (LOAEL)

The lowest dose of a chemical that produced an adverse effect when it was administered to animals in a toxicity study or following human exposure.

No-Observed-Adverse-Effect Level (NOAEL)

The highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

Cancer Effect Level (CEL)

The CEL is the lowest dose of a chemical in a study, or group of studies, that was found to produce increased incidences of cancer (or tumors).

Appendix C. ATSDR's Methods for Determining Whether a Health Hazard Exists

I. Overview of ATSDR's Methodology for Evaluating Potential Public Health Hazards

The health hazards that could plausibly result from exposures to contaminants detected in the vicinity of NWIRP Bedford are discussed in further detail in this appendix. It is important to note that public health hazards from environmental contamination happen only when (1) people are exposed to the contaminated media and (2) the exposure is at high enough doses to result in an effect.

Selecting Exposure Situations for Further Evaluation

As an initial screen, ATSDR evaluated available data to determine whether contaminants were accessible to the public or were above ATSDR's comparison values (CVs). The majority of detected contaminants were either not accessible to the public or fell at or below comparison values and were not evaluated further. Exposure situations with contaminants above comparison values or that had insufficient environmental data were deemed worthy of further evaluation. These exposure situations are:

- Past exposure of Bedford residents to VOCs and dissolved iron in municipal water from the Hartwell Road well field between 1983 and 1984.

- Possible past hazards from breathing in vapors that seeped into on-site buildings situated above groundwater plumes. ATSDR evaluated this pathway using the Johnson Ettinger Indoor Air Model (EPA 2003a).

Estimating Exposure Doses

ATSDR derived exposure doses for those contaminants that were detected above ATSDR's CVs or did not have a CV for each of the two exposure situations. Exposure doses are expressed in milligrams per kilogram of body weight per day (mg/kg/day). This represents the amount of contaminant mass that an individual is assumed to inhale, ingest, or touch (in milligrams), divided by the body weight of the individual (in kilograms) each day. When estimating exposure doses, health assessors evaluate chemical concentrations to which people could be exposed, together with the length of time and the frequency of exposure. Variables considered when estimating exposure doses include the contaminant concentration, the exposure amount (how much), the exposure frequency (how often), and the exposure duration (how long). There is often considerable uncertainty about the true level of exposure to environmental contamination, because we do not know exactly how long someone could have been exposed or to what concentration exposure occurred over time. To account for the uncertainty and to be protective of public health, ATSDR scientists typically use worst-case exposure level estimates as the basis for

determining whether adverse health effects are *possible*. These estimated exposure levels usually are much higher than the levels that people are really exposed to.

Using Exposure Doses To Evaluate Potential Health Hazards

ATSDR analyzes the available toxicological, medical, and epidemiologic data to determine whether exposures might be associated with harmful health effects (noncancer and cancer).As a first step in evaluating noncancer effects, ATSDR compares estimated exposure doses to conservative health guideline values, including ATSDR's minimal risk levels (MRLs) and EPA's reference doses (RfDs). The MRLs and RfDs are estimates of daily human exposure to a substance that are unlikely to result in noncancer effects over a specified duration. *Estimated exposure doses that are less than these values are not considered to be of health concern.* To maximize human health protection, MRLs and RfDs have built-in uncertainty or safety factors, making them considerably lower than levels at which health effects have been observed. The result is that even if an exposure dose is higher than the MRL or RfD, it does not necessarily follow that harmful health effects will occur.

For carcinogens, ATSDR also calculates a theoretical increase of cancer cases in a population (for example, 1 in 1,000,000 or 10^{-6}) using EPA's cancer slope factors (CSFs), which represent the relative potency of carcinogens. This is accomplished by multiplying the calculated exposure dose by a chemical-specific CSF. Because they are derived using mathematical models which apply a number of uncertainties and conservative assumptions, risk estimates generated by using CSFs tend to be overestimated.

If health guideline values are exceeded, ATSDR examines the health effects levels discussed in the scientific literature and more fully reviews exposure potential. ATSDR reviews available human studies as well as experimental animal studies. This information is used to describe the disease-causing potential of a particular chemical and to compare site-specific dose estimates with doses shown in applicable studies to result in illness (known as the margin of exposure). For cancer effects, ATSDR compares an estimated lifetime exposure dose to available cancer effect levels (CELs), which are doses that produce significant increases in the incidence of cancer or tumors, and reviews genotoxicity studies to understand further the extent to which a chemical might be associated with cancer outcomes. This process enables ATSDR to weigh the available evidence in light of uncertainties and offer perspective on the plausibility of harmful health outcomes under site-specific conditions.

Sources for Health-Based Guidelines

By Congressional mandate, ATSDR prepares toxicological profiles for hazardous substances found at contaminated sites. These toxicological profiles were used to evaluate potential health effects from contamination at NWIRP Bedford. ATSDR's toxicological profiles are available on the Internet at http://www.atsdr.cdc.gov/toxpro2.html or by contacting the National Technical Information Service at 1-800-553-6847. EPA also develops health effects guidelines; in some cases, ATSDR relied on EPA's guidelines to evaluate potential health effects. These guidelines

are found in EPA's Integrated Risk Information System (IRIS)—a database of human health effects that could result from exposure to various substances found in the environment. IRIS is available on the Internet at http://www.epa.gov/iris. For more information about IRIS, please call EPA's IRIS hotline at 1-301-345-2870 or e-mail at Hotline.IRIS@epamail.epa.gov.

II. Evaluation of Exposure to Contaminants in the Hartwell Road Well Field in the Past

The contaminants benzene, trichloroethylene (TCE), and dissolved iron were detected in the Hartwell Road well field in 1983 and 1984 at concentrations greater than health guidance levels for drinking water. The wells contained other VOCs, but at lower concentrations. The primary exposure pathway of concern was past exposure through consumption of the well water or inhalation of volatilized VOCs during household use. No exposures are occurring now because the wells are not being used for drinking water or domestic use. Because residents of the town used the water drawn from the wells in the past, ATSDR evaluated the health effects from past ingestion to benzene, TCE, and dissolved iron in drinking water and inhalation exposure to benzene and TCE vapors from household use.

II.A. Exposure to Contaminants via Consumption of Drinking Water

ATSDR used the following equation and default assumptions to estimate the exposure doses from drinking water contaminated with benzene, TCE, and dissolved iron*****.

$$\text{Estimated dose} = \frac{C \times CF \times IR \times EF \times ED}{BW \times AT}$$

where:

C: Maximum concentration in parts per billion (ppb)
CF Conversion factor to convert ppb to milligrams per liter (mg/L)
IR: Ingestion rate: adult = 2 liters per day; child = 1 liters per day (EPA 1997)
EF: Exposure frequency, or number of exposure events per year of exposure: 365 days/year
ED: Exposure duration, or the duration over which exposure occurs: For Bedford water supply: adult and child = 1 year
BW: Body weight: adult = 70 kg (or 154 pounds), child = 10 kg (or 22 pounds)
AT = Averaging time, or period over which cumulative exposure are averaged (6 years or 30 years x 365 days/year for noncancer effects, 70 years x 365 days/year for cancer effects)

* Iron doses were estimated by multiplying the iron concentration in water (ppm or mg/kg) by the ingestion rate (liters/day) to derive doses expressed in mg/day for comparison to the U.S. Food and Drug Administration Daily Values (mg/day).

ATSDR applied this equation to the maximum concentrations of benzene, TCE, and dissolved iron. ATSDR then compared the estimated doses to health guidance levels and information in the toxicological literature to assess whether health effects were likely to occur at the detected concentration. The results are discussed below.

Benzene

Noncancer: Benzene was detected at a maximum concentration of 30 ppb in the Hartwell Road productions wells. Health effects in humans exposed to benzene in drinking water are not known (ATSDR 1997a). EPA recently set an RfD of 0.004 (mg/kg/day) for benzene based on route-to-route extrapolation of the results of benchmark dose modeling (BMD) of the absolute lymphocyte count data from an occupational study conducted by Rothman et al. (1996) (EPA 2003b). In this study, workers were exposed to benzene by inhalation. In comparison, the ATSDR's estimated doses for an adult of 0.0008 mg/kg/day and a child of 0.003 mg/kg/day are below the RfD of 0.004 mg/kg/day (Table C-1). The RfD is based on a benzene dose to workers of 1.2 mg/kg/day, which is 400 to 1,500 times greater the doses estimated for exposure to benzene levels detected in the Hartwell Road wells.

Cancer: Though inhaled benzene is classified as a known human carcinogen, there is little information available about the human cancer effects of ingesting benzene. The EPA determined that ingesting benzene causes cancer in people based on studies of people who inhaled benzene and on studies of laboratory animals that ingested benzene. Cancer studies in animals link benzene to leukemia in rodents and various organ carcinomas in rats. The cancer effect level (CEL) for benzene ranges from 25 to 500 mg/kg/day based on findings of animals studies and are more than a million times greater than the estimated doses from drinking water containing the detected level of benzene in the municipal well field (Table C-2). People drinking water in the past contaminated with a benzene level of 30 ppb face no apparent increase risk of cancer.

TCE

Noncancer: TCE was detected in water collected from the Hartwell Road production wells at levels up to 33 ppb. Using this maximum concentration, ATSDR derived exposure doses to TCE in the well water of 0.0009 mg/kg/day for an adult and 0.003 mg/kg/day for a child (Table C-1). While these doses are slightly greater than the provisional chronic oral RfD for TCE of 0.0003 mg/kg/day, they are well below the levels at which no harmful health effects have been observed in animals orally exposed to TCE for less than 1 year (doses ranging from 18 mg/kg/day to 3,200 mg/kg/day; ATSDR 1997b). Although intermediate doses less than these have been observed to cause developmental health effects (0.18 mg/kg/day caused 5% increased fetal heart abnormalities in rats; Dawson et al. 1993 as cited in ATSDR 1997b), this lowest-observed-adverse-effect level (LOAEL) is still two orders of magnitude higher than the estimated exposure doses that ATSDR derived. Therefore, drinking water containing this level of TCE from the

Hartwell Road well field between 1983 and 1984 is not likely to have resulted in adverse noncancer health effects.

Cancer: EPA is currently reviewing the scientific literature pertaining to the carcinogenicity of TCE to determine its cancer classification (EPA 2003b). The link between TCE and cancer in people's drinking water is controversial. Available studies are inconclusive and the data are inadequate to establish an association. Some studies have shown that individuals drinking TCE-contaminated water with up to 220 ppb—a concentration about 7 times greater than the maximum level detected at Hartwell Road production wells suffered no increased incidence of cancer (ATSDR 1997b). ATSDR compared the estimated dose (0.00001 mg/kg/day; Table C-2) to the cancer effects levels (CELs) for TCE, which are based on animal studies in which carcinomas were observed at 1,000 mg/kg/day (NTP 1990 as cited in ATSDR 1997b). In comparison, the estimated exposure from ingesting water containing TCE at the well field would result in a dose millions of times below the CELs. On the basis of these results, ATSDR concludes that ingestion of TCE at the levels detected in the Hartwell Road production wells between 1983 and 1984 would not have caused an increased likelihood of developing cancer.

Dissolved Iron

Noncancer: Iron was detected at concentrations up to 31,000 ppb in the Hartwell Road production wells. Iron is a mineral that is often found in drinking water supplies. EPA considers this mineral to be a secondary—or aesthetic— contaminant because it can impart an unpleasant metallic taste to the water while still being safe to drink. Water high in iron can also cause reddish-brown staining on bathroom fixtures and laundry. The iron in water from the Hartwell Road well field contained dissolved or soluble iron. This type of iron is most common to water systems and creates the most complaints from water users (NCCES 1996).

The presence of iron in drinking water is, however, generally not considered a health problem. Iron in small amounts is essential to good health because it is used by the body to make hemoglobin, which carries oxygen in the blood from the lungs to other areas of the body. Iron can also help the body's resistance to stress and disease. According to the National Academy of Sciences, the median daily intake of dietary iron is roughly 11–13 mg/day for children 1 to 8 years old, 13–20 mg/day for adolescents 9 to 18 years old, 16–18 mg/day for adult men, and 12 mg/day for adult women (NAS 2001).

Iron is generally not harmful except when swallowed in extremely large doses, such as in the case of accidental drug ingestion. Acute iron poisoning has been reported in children under 6 years of age who have accidentally overdosed on iron-containing supplements for adults. According to the FDA, doses greater than 200 mg per event could poison or kill a child (FDA 1997). However, doses of this magnitude are generally the result of children ingesting iron pills. The daily increases in consumption (from drinking water from the Hartwell Road well field) are not likely to cause a person's daily dose to exceed levels known to induce poisoning (e.g., greater than 200 mg/event). Therefore, drinking water containing this level of iron from the

Hartwell Road well field between 1983 and 1984 is not likely to have resulted in adverse noncancer health effects.

Cancer: Iron is not known to be a carcinogen.

Finally, the exposure doses that ATSDR calculated are most likely overestimated by the use of maximum concentrations detected in the production wells. The water from any one production well was diluted with water from the other wells before being distributed to people's houses. Thus, the water people actually drank most likely contained much lower concentrations than the maximum contaminant concentration detected among the three wells. Therefore, ATSDR concluded that no adverse health effects are expected from drinking water from the Hartwell Road well field in the past.

II.B Exposure to VOCs During Showering

II.B.1 Acute Exposures

ATSDR evaluated possible inhalation exposures of Bedford residents to VOCs (benzene, and TCE) in the municipal water while showering. VOC exposure during showering poses a concern because these compounds can easily evaporate from water into the air. The VOC can then enter the body when a person breathes the air contaminated with the chemical. Exposure to the detected levels of VOCs in drinking water, which was evaluated previously in this appendix, was found to be below levels of health concern.

ATSDR used the following screening level model and assumptions to estimate VOC concentrations in air during showering. Although some exposure may occur while in the bathroom, studies suggest that the highest inhalation exposure in the home occurs within the shower stall as a result of actually showering with VOC-contaminated water. Inhalation exposures to some VOCs in the shower were 2.1 to 4.9 times higher than corresponding bathroom exposures (Lindstrom 1994). Therefore, ATSDR used this model to approximate the VOC air concentration in the shower stall from showering with water containing the maximum detected VOCs. Different types of showering conditions, such as water temperature, humidity, and actual duration of the shower, might influence the concentrations of VOC released to the bathroom air. A more detailed analysis would require the use of chemical and physical properties and knowledge of more precise exposure parameters.

Table C-3 presents the estimated air concentrations of benzene and TCE during showering.

$$C_a = \frac{C_w \text{ x MT x FR x T}}{V}$$

where:

C_a	Concentration of the VOC in air (micrograms per cubic meter [$\mu g/m^3$])
C_w	Concentration of the VOC in water: micrograms per liter ($\mu g/L$)
MT	Mass transfer: 1 (represents 100% transfer of the VOC from water to the air)
FR	Flow rate (rate of water flowing from the shower head): 12 liters per minute (L/min). Average flow from a high flow shower head (EPA 1997).
T	Time in shower: 10 minutes. Average shower length (EPA 1997).
V	Volume of bathroom: 10 cubic meters (m^3). Based on a small bathroom with the dimensions of 7 feet by 7 feet by 8 feet.

These assumptions are protective–that is, believed to overestimate possible exposure conditions because:

- ATSDR assumes in the screening model that 100% of the VOCs are volatilized. Information about the chemical properties of VOCs, however, suggests that a portion of the VOCs would actually remain in the water and would not be released to a person breathing the air while showering in the bathroom.

- ATSDR assumes that all the VOCs released from the water to the indoor air and would remain in the bathroom used for showering. Because of bathroom fans or drafts at the door or windows, a portion of the VOCs would escape from the bathroom during the showering, thus lessening the air concentration in the bathroom. A small increase in VOC concentrations in other portions of the house might occur, however, these concentrations would still be well below the concentration estimated in the bathroom.

- ATSDR evaluated exposure to the maximum detected VOC concentrations found in the municipal well water between October 1983 through April 1984. ATSDR does not have sampling data for April 1983 to October 1983. No exposure was expected after the use of the well was discontinued.

Benzene

Showering with water containing 30 ppb of benzene would result in an estimated indoor air concentration during showering of 360 $\mu g/m^3$. The estimated concentration of benzene is above the acute inhalation MRL for benzene of 160 $\mu g/m^3$. The MRL is based on a study in which depressed immune systems were observed in mice

MRLs for exposures to contaminants in air are expressed as concentrations (i.e., $\mu g/m^3$) so that air concentrations can be directly compared to the MRLs, eliminating the need to estimate doses.

administered benzene. The lowest concentration at which this effect was observed in the mice (called the lowest-adverse effect level or LOAEL) was 35,586 μg/m^3 (Rozen 1984 as cited in ATSDR 1997a). In comparison, this value is about 100 times higher than the estimated benzene concentration in air during showering with water containing the maximum detected concentration of benzene found in Hartwell Road wells in the past.[3]

ATSDR further reviewed the scientific literature on inhalation exposure to benzene and human health effects. Benzene is readily absorbed by inhalation and is rapidly distributed throughout the body, particularly in fatty tissues. The half-life of benzene in humans, however, is just 1 to 2 days, and therefore, accumulation is not expected for either benzene or its metabolites. Benzene leaves the body primarily when exhaled through the lungs unchanged or excreted as metabolites in the urine (ATSDR 1997a)

No information was available on the adverse effects of breathing in benzene while showering. Information on other types of inhalation exposures suggest that short-term benzene exposure to human affects the central nervous system, marked by drowsiness, dizziness, headache, nausea, loss of coordination, confusion and unconsciousness. Nose and throat irritations have also been reported following short-term exposure. These effects have been observed at benzene concentrations greater than 79,000 μg/m^3 in occupational settings (CCOHS 2003). In most cases, people felt better when the exposure stopped and they began to breathe fresh air. The levels at which human health effects have been reported following short-term benzene exposure are more than 200 times greater than the estimated benzene air concentration released while showering with water from the well field in the past.

TCE

ATSDR estimated that showering with water containing 33 ppb of TCE would result in air concentration within the shower of 396 μg/m^3. In comparison, the estimated TCE in the bathroom air during showering is well below ATSDR's acute MRL for TCE in air of 10,748 μg/m^3. The acute MRL is based on a study of people exposed to TCE at a concentration of approximately 1,074,000 μg/m^3. At this LOAEL for acute exposures, exposed persons experienced fatigue and other transitory effects (Stewart 1980 as cited in ATSDR 1997b). Considering this information, ATSDR does not expect TCE-related health effects for people who showered with water originating from the well field.

II.B.2 Intermediate or Long-term Exposures

ATSDR evaluated intermediate and chronic exposures by expressing the acute dose as a time-weighted average (TWA). A TWA is the VOC concentration over a 24-hour period that matches the amount a person was exposed to in the 10 minute shower, as assumed in ATSDR's calculations. The TWAs were calculated as follows:

[3] Concentrations can be expressed in parts per billion (ppb). To convert ppb to μg/m^3, multiply the concentrations in ppb by the molecular weight/24.45. The molecular weight for benzene and TCE are 78.11 and 131.4, respectively.

$$\textbf{TWA } \mu g/m^3 = \frac{\text{Acute indoor air concentration } (\mu g/m^3)}{\text{The number of 10 minute intervals in a day, or 144 (unitless)}}$$

As shown in Table C-4, the TWA concentrations of the VOCs in air are below ATSDR's intermediate or chronic MRL or EPA's inhalation reference concentration (RfC), both of which represent the concentration in air below which no appreciable adverse effects are expected. Given that the estimated concentrations are below these health-based screening levels, no long-term health effects are expected for people who showered in the past with water obtained from the well field.

III. Evaluation of Exposure to Indoor Air Contaminants via Vapor Intrusion

Groundwater contamination at NWRIP Bedford involves the shallow aquifer at depths less than 50 feet. The majority of contaminants in the groundwater are volatile organic compounds (VOCs) that can move from the groundwater through soil, and eventually seep into basements and affect the indoor air.

Indoor air sampling data were not available for buildings at the site that are situated above a VOC plume. ATSDR therefore applied the Johnson and Ettinger (1991) model to estimate indoor air in those areas not sampled.

III.A. VOC Indoor Air Modeling

The U.S. Environmental Protection Agency (EPA) developed the Johnson and Ettinger model to estimate indoor air concentrations and associated health hazards from subsurface vapor intrusion into buildings. This model is a *screening-level* model that estimates the transport of contaminated vapors from either subsurface soils or groundwater into the spaces directly above the source of contamination (EPA 2003a).

The Johnson and Ettinger model is a first-tier screening tool that uses data about properties of the soil, chemical properties of the contaminant, and structural properties of the building (EPA 2003a). All but the most sensitive parameters have been set to either an upper bound value or the median value. As a result, the model is very conservative when predicting indoor air concentrations. To predict indoor air concentrations in homes at NWIRP Bedford, ATSDR entered the maximum groundwater for benzene and trichloroethylene (TCE) into the Johnson and Ettinger model. The model generates an infinite source building indoor concentration, which is the estimated indoor air concentration of the VOC contaminant for a building located above the plume.

Although the model is a useful tool that enables ATSDR scientists to conservatively predict indoor air concentration, it has limitations:

- It does not consider the effects of multiple contaminants.
- Its calculations do not account for preferential vapor pathways due to soil fractures, vegetation root pathways, or the effects of a gravel layer beneath the floor slab.
- The groundwater model does not account for the rise and fall of the water table due to aquifer discharge and recharge.
- The model also assumes that all vapor will enter the building, implying that a constant pressure field is generated between the interior spaces and the soil surface.
- It neglects periods of near zero pressure differential.
- Soil properties in the area of contamination are assumed to be identical to those in the area above the contamination.

III.B. VOC Indoor Air Modeling Results

ATSDR compared the modeled indoor air VOC concentrations from vapor intrusion to a reference value for that compound. Based on this strategy, ATSDR found that none of the predicted air concentrations exceeded reference values and thus were not at levels that could cause adverse health effects.

Table C-5 lists the indoor air concentrations that ATSDR estimated for VOCs considered in this analysis. We emphasize that these are *conservative estimates:* our initial modeling application assumed that the maximum concentration of VOCs detected in the plume entered the home. As the table indicates, the estimates of the indoor air concentrations of the VOCs were lower than the associated ATSDR inhalation minimal risk level (MRL) and the levels at which effects have been observed in animal studies or exposed humans (also known as the lowest-observed-adverse-effect levels). The findings suggest that the air concentrations of VOCs inside buildings above the plume do not reach unhealthy levels as a result of the operations at NWIRP Bedford.

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Table C-1. Estimated Exposure Doses—Noncancer Effects From Ingestion of Hartwell Road Drinking Water

Contaminant	Maximum Detected Contaminant Concentration (ppb)	Estimated Exposure Dose [a]		Health Guideline	Basis for Health Guideline
		Adult	Child		
Benzene	30	0.0008 mg/kg/day	0.003mg/kg/day	0.004 mg/kg/day	EPA chronic oral RfD
TCE	33	0.0009 mg/kg/day	0.003 mg/kg/day	0.0003 mg/kg/day	EPA chronic oral RfD
Dissolved Iron	31,000	62 mg/day	31 mg/day	18 mg/day	FDA daily value

Sources: EPA 2003b; FDA 2003.

Key: ppb = parts per billion; mg/day = milligram of contaminant per day; mg/kg/day = milligrams of contaminant per kilogram of body weight per day; RfD = EPA's reference dose.

Table C-2. Estimated Exposure Doses—Cancer Effects From Ingestion of Hartwell Road Drinking Water

Contaminant	Maximum Detected Contaminant Concentration (ppb)	Estimated Exposure Dose (mg/kg/day) † (Adult)	CSF $(mg/kg/day)^{-1}$	Theoretical Excess Cancer Risk§	CEL for Oral[a] Exposure (mg/kg/day)
Benzene	30	0.00001	0.055	6×10^{-7}	25; zymbal gland carcinoma NTP 1986
TCE	33	0.00001	0.4	5×10^{-6}	1,000; heptatocellular carcinomas, mice; NTP 1990

† CELs are reported in ATSDR 1997a, 1997b.
§ CSFs are reported in EPA Region 3 risk-based concentration table.

Table C-3: Acute Inhalation Exposure Concentrations and Comparison Values

VOC	EstimatedAcute Indoor Air Concentration During a Showering Event ($\mu g/m^3$)	Acute MRLs ($\mu g/m^3$)	LOAELs † ($\mu g/m^3$)	
Benzene	360	160	35,586	Rozen et al. 1984. A decreased response of the immune system in mice.
TCE	396	10,748	1,074,000	Stewart et al. 1970. Mild neurological effects in humans.

Sources: ATSDR 1997a, 1997b.

† The LOAELs are the lowest LOAELs reported in the literature and serve as the basis for the acute inhalation MRLs.

Table C-4: Time-Weighted Averages for Intermediate/Long-Term Inhalation Exposures

VOC	Acute Indoor Air Concentration During a Showering Event (µg/m^3)	TWA (µg/m^3)	MRL/RfC (µg/m^3)	
			Intermediate	Chronic
Benzene	360	2.5	13 (MRL)	30 (RfC)
TCE	396	2.7	537 (MRL)	No value

Sources: ATSDR 1997a, 1997b; EPA 2003b.

Table C-5. Model Incremental Risk and Indoor Air Concentrations

VOC	Maximum Groundwater Concentration (ppb)	Model Indoor Air Concentration		Inhalation MRL (ppb)	LOAEL (ppb)
		µg/m^3	ppb		
Benzene	75	0.966	11.54	4 (Intermediate)	780
TCE	2,300	46.1	8.5	100	50,000
1,1-DCE	1,200	81.1	24.0	Not available	10,000 NOAEL in animal studies

Sources: ATSDR 1994, 1997a, 1997b; EPA 2003b.