

Health Consultation

Public Health Implications of Exposures to Low-Level
Volatile Organic Compounds in Public Drinking Water

ENDICOTT AREA INVESTIGATION
BROOME COUNTY, NEW YORK

NOVEMBER 30, 2006

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

You May Contact ATSDR Toll Free at
1-800-CDC-INFO

or

Visit our Home Page at: <http://www.atsdr.cdc.gov>

HEALTH CONSULTATION

Public Health Implications of Exposures to Low-Level
Volatile Organic Compounds in Public Drinking Water

ENDICOTT AREA INVESTIGATION
BROOME COUNTY, NEW YORK

Prepared by:

New York State Department of Health
Center for Environmental Health

and

The U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Superfund and Program Assessment Branch
Atlanta, Georgia

TABLE OF CONTENTS

STATEMENT OF ISSUES.....	1
BACKGROUND.....	2
A. Site Description and History.....	2
B. Description of Municipal Water System.....	2
C. Demographics.....	3
DISCUSSION.....	4
A. Summary of Environmental Data and Exposed Populations.....	4
B. Public Health Implications – Adult and Child Health Issues.....	6
Introduction.....	6
How to evaluate exposure to a single chemical for non-cancerous effects.....	7
How to evaluate exposure to multiple chemicals for non-cancerous effects.....	8
Non-cancer findings from drinking Endicott’s water.....	10
Non-cancer findings from bathing and showering in Endicott’s water.....	11
Findings for cancer risk.....	14
CONCLUSIONS.....	18
RECOMMENDATIONS.....	19
PUBLIC HEALTH ACTION PLAN.....	19
PREPARERS OF REPORT.....	21
REFERENCES.....	22
APPENDIX A.....	24
Tables	
APPENDIX B.....	30
Determining Oral Hazard Quotients and Hazard Indexes for Chemicals in Municipal Drinking Water	
APPENDIX C.....	34
Description of Technical Methods for Estimating Inhalation Exposure to Chemicals that Evaporate from Water	
APPENDIX D.....	40
Determining Inhalation Hazard Quotients and Inhalation Hazard Indexes from Bathing in Municipal Water Containing Chemicals	
APPENDIX E.....	43
Interim Public Health Hazard Category Classification	
APPENDIX F.....	45
Response to Public Comments	

STATEMENT OF ISSUES

The Agency for Toxic Substances and Disease Registry (ATSDR) and the New York State Department of Health (NYS DOH) developed this health consultation as part of an overall Public Health Response Plan to address the public health implications of environmental contamination in the Village of Endicott, Broome County, New York. The primary focus of this health consultation is to address concerns of the community about the potential health effects associated with exposure to low concentrations of volatile organic compounds (VOCs) in the public water supply.

Although the levels of VOCs in the two primary sources of drinking water to the Endicott community (i.e., the South Street wells and the Ranney well) meet all applicable state and federal drinking water standards, the community groups - Citizens Acting to Restore Endicott's Environment and Resident Action Group of Endicott - expressed concerns to the health agencies about the continued exposure of Endicott residents to several VOCs at low-levels, primarily those detected in the water from the South Street wells. Moreover, in addition to the VOCs, a question was raised regarding the combined risk of trihalomethanes or THMs (a by-product of the disinfection of drinking water) in the water along with the VOCs. Thus the question posed to ATSDR and the NYS DOH is related to the health effects of the combined exposure to several chemicals, also known as the science of mixtures.

Although the focus of this evaluation and question posed by the community relates to exposures to VOCs entering the distribution system via the South Street wells, ATSDR and the NYS DOH also obtained sampling information from the Broome County Health Department (BCHD) for the Ranney well - the primary source of water for the Village of Endicott. This health consultation evaluates the public health implications of drinking, bathing, and showering in water supplied from the South Street wells from 1980 to 2004, and from the Ranney well from 1992 to 2004. In the past, Village of Endicott residents were exposed to VOCs above drinking water guidelines from the Ranney well (before a treatment system was added in 1991). These exposures were previously evaluated in a 1994 public health assessment performed by the NYS DOH under a cooperative agreement with ATSDR (ATSDR 1994). The BCHD assisted ATSDR and the NYS DOH in gathering all the available historic monitoring data from both the South Street wells and from the Ranney well.

On October 12, 2004, NYS DOH and ATSDR released this health consultation for public comment. During the public comment period which ended on November 12, 2004, several comments were received. One of the main comments related to not including trichloroethene (TCE), one of the primary chemicals of concern to the public, in the original analysis. In addition, the public was concerned about several other aspects of the original analysis and conclusions. In response to these comments, the analyses conducted for the public comment draft health consultation were revised to include TCE. In addition, other analyses were conducted to address the community's concerns related to the original analysis. ATSDR and NYS DOH staff met with the members of the Western Broome Environmental Stakeholder's Coalition (WBESC) on May 24, 2005, to discuss the health agencies' response to public comments. The responses to all of the submitted public comments are shown in Appendix F.

BACKGROUND

A. Site Description and History

The Village of Endicott is a mixed residential, commercial, and industrial community in the Town of Union, Broome County, New York. Endicott has a rich industrial heritage that included large manufacturing operations at the Endicott Johnson Tannery and International Business Machines (IBM) facility. Many former and current businesses within the Village of Endicott used or use solvents containing VOCs. Such businesses include, but are not limited to, Endicott Johnson, IBM, automotive repair facilities, print shops and dry cleaners. As a result of leaks and spills associated with these operations and runoff from local landfills, groundwater and soil gas in the Endicott area are contaminated with VOCs.

B. Description of Municipal Water System

The Village of Endicott owns and operates its own municipal water supply system, the Endicott Municipal Water Supply. Currently, three production wells, situated along a 1.5-mile stretch of the north shore of the Susquehanna River between Nanticoke Creek and South Street in Endicott, draw groundwater from the deep aquifer providing drinking water to 48,000 customers (Village of Endicott 2004). These three wells are identified by name and number: Ranney well (well 32), Park well (well 28), and the South Street well (well 5). The water system is also supplemented at times with water from Johnson City and until January 1999, minor contributions were also made from the Davis Avenue well (well 37) in Endwell. The South Street well (well 5) and the Park well (well 28) are locally referred to as the South Street wells and will be identified as such throughout the remainder of this consultation. The distribution of public water by the Endicott Municipal Water Supply extends roughly from the Broome County-Tioga County line to the west, Robinson Hill Road to the east, the Union-Main Town line to the north and the Susquehanna River to the south, serving both the Village of Endicott and portions of the Town of Union.

In most areas of Endicott, the shallow and deep aquifers are separated by a layer of dense silt, which acts as a confining layer. In only a few locations, this confining layer is absent. Therefore, groundwater VOC contamination is mostly contained in the shallow aquifer. Nevertheless, both the shallow and deep aquifers in the area of Endicott are contaminated with VOCs. These VOCs could have come from industrial and manufacturing facilities and landfills that operated in the village. VOC-contaminated waste materials and spilled cleaning and industrial fluids entered the groundwater supplying the public wells and may continue to impact the water supply even though many of the sources of the contamination (leaks and spills from industrial and commercial users of VOCs) have been eliminated, and remediation efforts to clean up the affected soils and groundwater have been taken.

Ranney Well

The major source of public water is and has been the Ranney well (well 32). The Ranney well currently supplies about 92% of the public water (Broome County Health Department 2004). In

the early 1980s, routine monitoring of this main public water supply well detected VOCs at levels above New York State drinking water guidelines. As identified in the ATSDR public health assessment for Endicott Village Wellfield, the primary source of contamination for this well is the now-closed Village of Endicott Landfill (ATSDR 1994). The Endicott Village Wellfield was placed on the National Priorities List after the detection of VOCs in 1981. Measures taken to reduce exposures include installation of a temporary aerator on the Ranney well in 1983, installation of a purge well upstream of the well in 1984, installation of an air stripper on the well in 1991, installation of a second purge well in 1991, and starting in 1992, remediation of the landfill site. The remediation efforts consisted of landfill capping, gas venting, control and treatment of the leachate seep, and long-term maintenance of these systems. These efforts have reduced VOC contamination in the Ranney well to levels below state and federal standards.

South Street Wells

The South Street wells, comprised of the South Street well (well 5) and the Park well (well 28), are intermittently used to supply the public water system. The South Street wells are currently used to supply about 6% of the public water and might have supplied a higher percentage of water in the past (Broome County Health Department 2004). The community is concerned that contaminants in this water supply, although individually below New York State drinking water standards, could, when combined, produce an increased level of risk. Detections of VOCs in this well field have not exceeded New York State drinking water standards. In January 2004, Village of Endicott trustees accepted a \$2.1 million dollar gift from the IBM Corporation, which included funds for the installation of a treatment system on the South Street wells. In July 2005, the Village of Endicott completed construction of a packed tower aeration treatment system for well 5 and well 28, designed to further reduce VOC levels in water produced from those wells. By reducing low-level volatile organic compounds found in the municipal water supply, potential exposures are reduced. The system began treatment of water from well 5 during July 2005. The pump in well 28 will be upgraded so that it, too, can provide treated water. Well 28 has been off-line since September 2005.

The Endicott Municipal Water Supply operates on a grid-water system, meaning that neighborhoods closest to the wells are usually supplied at a greater rate from nearby wells as compared to wells farther away. For instance, those persons living close to the South Street Wells are likely served with greater amounts of water from the South Street wells than persons living farther away. However, due to system pressure variations, it is not possible to define strictly the areas of Endicott served by the Ranney well, as opposed to those areas served by the South Street wells. Varying mixtures of these water sources serve the Town of Union residents.

C. Demographics

The NYS DOH estimated the demographic characteristics of Endicott Municipal Water Supply residents using water supply boundary data supplied by Broome County Health Department and data from the 1990 and 2000 Census (US Bureau of the Census, 1991; 1992; 2001; 2002.) In

1990, 38,127 people lived in the area served by Endicott Municipal Water Supply. Approximately 97% had their race classified as White, 1% as Black, 2% as Asian or Pacific Islander, and less than one percent each American Indian/Eskimo/Aleut or other. One percent of these residents also identified their ethnicity as Hispanic or Latino. In 1990, about 8% of the population was under 6 years of age, 17% were 6 – 19 years of age, 60% 20 – 64 years of age, and 15% older than 64 years of age. Approximately 22.8% of the population consisted of females of reproductive age (15 – 44). In 1989, the median household income for the Census block groups comprising the majority of the water supply was \$32,690, with 7% of the population living below the poverty level.

In 2000, 36,120 people lived in the area served by the Endicott Municipal Water Supply. Approximately 94% were classified as White, 2% as Black, 2% as Asian or Pacific Islander, 1% as multiracial and less than one percent each Native American or other. One percent of these residents also identified their ethnicity as Hispanic or Latino. In 2000, about 7% of the population was under 6 years of age, 18% were 6 – 19 years of age, 57% 20 – 64 years of age, and 18% older than 64 years of age. Approximately 19.8% of this population consisted of females of reproductive age (15 – 44). The median household income for the Census block groups comprising the majority of the water supply was \$37,291 in 1999, with 10% of the population living below the poverty level. Please see Table 1, Appendix A for more information and comparisons to statewide statistics.

DISCUSSION

A. Summary of Environmental Data and Exposed Populations

Water samples from the South Street wells (wells 5 and 28) have been collected and analyzed for VOCs since January 1980 and July 1981, respectively. Treated water from the Ranney well (#32) has been sampled and analyzed for VOCs 210 times between 1991 and July 2004. Table 2, Appendix A contains a summary of the number of samples obtained and analyzed for VOCs for the Ranney and South Street wells by time period. Since 1982, water from various points within the Village of Endicott's water distribution system has been sampled and analyzed for THMs, although not on a continual basis. A summary of the number of water samples obtained and analyzed for THMs from the system, by year, is contained in Table 3, Appendix A.

The first step in trying to understand exposure levels for persons who received water from the Endicott Municipal Water Supply is to summarize the sampling data using various statistical methods. This is important because long-term exposures are best understood by looking at some type of measure of the central tendency of the data (e.g., averages). Moreover, the reader should understand the concept of detection limits and how ATSDR and NYS DOH treated a result that indicated the VOC or THM were not detected. The detection limit is the smallest amount of a chemical (VOC or THM) which the laboratory test can reliably measure in a sample during routine operating conditions. For VOCs, the detection limits for the South Street wells varied

from 1.0 part per billion (ppb) or micrograms per liter to 0.5 ppb for all VOCs. Since 1991, the detection limit for water samples obtained from the Ranney well has been 0.5 ppb for all VOCs. Three commonly used approaches to deal with a non-detectable level are: (1) that there is no VOC or THM present and thus the amount is zero, (2) that the VOC or THM is present and the amount is equal to one-half the detection limit, or (3) that the VOC or THM is present at the detection limit. For any one data set for a particular chemical, one of these methods could be the most appropriate, depending on the statistical distribution of the sample values. For simplicity, ATSDR and NYS DOH chose to use a single method for all the chemicals examined in this consultation. When a chemical was not detected, the agencies chose to use the detection limit as the concentration for each non-detectable level. The choice of method, however, had a minimal effect on the evaluation results.

ATSDR and NYS DOH chose to represent averages by using the arithmetic mean of the data. We used the arithmetic mean instead of geometric mean because the majority of the chemicals had statistical distributions that were normal (as opposed to log-normal). In addition, using the arithmetic mean was a more conservative approach as the arithmetic means were always higher than or equal to geometric means in this data set.

VOC water sampling values from the South Street wells were chosen for this analysis because they represent the highest levels of exposure. Residents of the entire water supply were not likely exposed to water solely from the South Street wells, given that the amount of water from the South Street wells represents only a small portion of the entire water supply. Due to the water distribution system, residents geographically closer to the South Street wells likely receive a greater portion of their water from these wells. Therefore, these residents would likely be the group exposed to the higher VOC levels discussed and evaluated in this health consultation.

A summary of the VOC water sampling results from the South Street wells and the Ranney well (after treatment) is contained in Tables 4 and 5, Appendix A, respectively. Based on an evaluation of the frequency of detection, the arithmetic mean, the 90th percentile (see Tables 4 and 5, Appendix A), and toxicity, ATSDR and NYS DOH chose the following VOCs for further evaluation:

- 1,1-dichloroethane (1,1-DCA)
- cis-1,2-dichloroethene (cis-1,2 DCE)
- 1,1,1-trichloroethane (TCA)
- vinyl chloride (VC)
- trans-1,2-dichloroethene (trans-1,2 DCE)

Specifically, as seen in Table 4, 1,1-DCA, cis-1,2 DCE, and TCA were clear choices because they were detected frequently, indicating they are likely contributors to long-term exposures. The frequency of detection for TCE, methylene chloride, and n-propyl benzene were generally low (i.e., less than or equal to about 5%) and the 90th percentile and arithmetic mean values were close to their respective detection limits. This indicates that most samples were at or below their detection limits, with only a few samples over many years having very low levels of the these VOCs. Therefore, ATSDR did not include these chemicals in the public comment release of the

health consultation. Because residents raised concerns about TCE after releasing the public comment health consultation, ATSDR has now included TCE in this evaluation (see Appendix F, Comment 1 for more details).

In addition, vinyl chloride and trans-1,2 DCE also had low values for their respective 90th percentile and arithmetic mean values, they both were detected in water from well 28 relatively frequently. Moreover, because vinyl chloride is a known human carcinogen, it was included for its toxicity. Methyl tert-butyl ether (MTBE) was last found in treated water taken from the Ranney well (#32) and the distribution system during the March 2004 sampling. MTBE has not been detected in water from the three samplings since that time. The levels found in March 2004 were very low, less than the detection limit. Moreover, from 1992-2004, MTBE has been detected in treated water from the Ranney well (or distribution system) only four times, and each time very low levels. Therefore, MTBE was not included in the analysis because exposures were very low, infrequent and do not represent long-term exposures.

A summary of the THM water sampling results from the Village of Endicott's distribution system is contained in Table 6, Appendix A. As seen from Table 6, data are available for the following THMs: chloroform, bromodichloromethane, dibromochloromethane, and bromoform. The detection limit for individual THMs was 1.0 ppb. As can be seen from Table 6, all of the THMs analyzed were detected relatively frequently; therefore, using these criteria, all were included in the analysis.

B. Public Health Implications – Adult and Child Health Issues

Introduction

ATSDR and NYS DOH were asked to evaluate the possibility of harmful effects when people are exposed to public water containing multiple chemicals. As part of a mixtures evaluation involving multiple chemicals, the health scientist must first evaluate the individual chemicals in the mixture. This evaluation of individual chemicals serves as a building block for evaluating the mixture of chemicals. Information about individual chemicals in this report comes from ATSDR's toxicological profiles, which are a series of publications by ATSDR about individual chemicals or groups of chemicals. For this consultation, ATSDR used toxicological profiles for chemicals listed in Tables 7 and 8, Appendix B (ATSDR 2003; 1997a; 1997b; 1996; 1995; 1990; 1989).

This section will first introduce a brief summary of the general principles and terms used to evaluate individual chemicals, followed by a brief description of how to evaluate mixtures. ATSDR and NYS DOH will then present the findings for individual chemicals from drinking and bathing in public water. Following this discussion, we will present the findings from drinking and bathing in public water for the mixture of chemicals. Subheadings in the report will show the type of explanation provided.

The possibility that children could exhibit increased sensitivity to chemicals is taken into account when evaluating potential health risks associated with a low-level contamination of the

municipal water supply. ATSDR and NYS DOH emphasize the ongoing examination of relevant child health issues in all of our activities, including evaluating child-focused concerns through its mandated public health assessment activities. When evaluating exposure pathways and potential health effects from environmental contaminants, ATSDR and NYS DOH consider children and use health guidelines that are child-protective. Children are of special concern because of their play and other behavior patterns which give rise to greater potential for exposure. Children sometimes differ from adults in their susceptibility to hazardous chemicals, but whether a difference exists depends on the chemical. Children could be more or less susceptible than adults to health effects, and the relationship could change with developmental age.

How to Evaluate Exposure to a Single Chemical for Non-Cancerous Effects

Several risk assessment methods are available for evaluating exposure to individual chemicals in the environment. To evaluate the risk of non-cancerous effects, three major steps are required: 1) estimating a person's exposure to a chemical, which is called a dose, 2) comparing the estimated dose to a health guideline established by a health or environmental agency, and 3) if the health guideline is exceeded or if a health guideline does not exist, comparing the estimated dose to doses from human or animal studies that have or have not shown harmful effects. The goal for these steps is not only to decide if a health guideline has been exceeded, but also to decide what harmful effects might be possible.

The health guidelines commonly used for individual chemicals include A) ATSDR's oral and inhalation Minimal Risk Levels (MRL), and B) United States Environmental Protection Agency's (U.S. EPA's) oral Reference Dose (RfD) and inhalation Reference Concentration (RfC). Oral MRLs and RfDs are measured as milligrams (mg) of chemical per kilogram (kg) of body weight per day (mg/kg/day), while inhalation MRLs and RfCs are concentrations of a chemical in air measured as parts of chemical per million parts of air (ppm) or parts of chemical per billion parts of air (ppb).¹ MRLs, RfDs, and RfCs have similar definitions. They are the dose (in mg/kg/day) or the concentration in air (in ppm or ppb) below which non-cancerous harmful effects are unlikely. Described another way, if the estimated dose for someone is below the oral MRL or RfD, or if the air concentration is below inhalation MRL or RfC, then non-cancerous harmful effects are unlikely. MRLs, RfDs, and RfCs cannot be used to evaluate the cancer risk from a chemical. Other methods have been developed to evaluate cancer risk, and these methods are described later in the report.

To evaluate the potential for non-cancerous effects from exposure to individual chemicals, the concentration in air or the estimated dose is determined and compared to the appropriate health

¹ Air concentrations and inhalation air guidelines are sometimes reported as micrograms or milligrams of chemical per cubic meter of air ($\mu\text{g}/\text{m}^3$ or mg/m^3). When necessary and for ease of discussion, we have converted these air concentrations and guidelines to ppm or ppb.

guideline, such as an MRL, RfD, or RfC (steps 1 and 2 mentioned previously). One approach for making this comparison is to determine either the oral Hazard Quotient (oral HQ) or the inhalation Hazard Quotient (inhalation HQ) for each chemical. An oral or inhalation HQ is a number that allows the health scientist to determine whether the estimated oral dose or concentration in air is above or below a health guideline. The formulas for determining the oral and inhalation HQ for a chemical follows:

$$\text{Oral HQ}_{\text{individual chemical}} = \frac{\text{The Estimated Dose in People}}{\text{Oral Health Guideline}}$$

$$\text{Inhalation HQ}_{\text{individual chemical}} = \frac{\text{The Concentration in Air}}{\text{Inhalation Health Guideline}}$$

Therefore, both the oral and inhalation HQ is a number that lets the health scientist know if the estimated dose or concentration in air is above or below a health guideline. When the HQ is below one, the amount of chemical to which people are exposed to (i.e., the dose or the air concentration) is below the health guideline, and non-cancerous harmful effects are not likely from exposure to that individual chemical. When the HQ is greater than one, the estimated dose in people or the concentration in air is above the health guideline. To determine if specific harmful effects might occur when the estimated dose in people or the concentration in air exceeds the health guideline, further toxicological evaluation is necessary. For oral exposure, this additional toxicological evaluation (step 3 mentioned previously) compares the estimated doses in people to doses from human and animal studies that are known to cause harmful effects, and to doses from human and animal studies that are known not to cause harmful effects. A similar comparison is done for air exposures. In addition, the health scientist will review the toxicological, medical, and epidemiological literature for information that will help determine possible harmful effects. Again, the goal of this evaluation is to provide an opinion about those harmful effects that might be expected in the exposed population.

How to Evaluate Exposure to Multiple Chemicals for Non-Cancerous Effects

Because people are often exposed to several chemicals at the same time, health scientists are often asked to evaluate exposure to a mixture of chemicals. ATSDR recently developed guidance for evaluating chemical mixtures: the “Guidance Manual for the Assessment of Joint Toxic Action of Chemical Mixtures” (ATSDR 2004). ATSDR’s mixtures guidance manual describes ATSDR’s method to screen chemical mixtures initially for non-cancerous and for cancerous effects.

For non-cancerous effects, the guidance manual requires the health scientist to estimate an oral or an inhalation HQ for each chemical. The oral HQ for each chemical is then used to determine the oral Hazard Index (HI) for the mixture of chemicals. In the same manner, the inhalation HQ for each chemical is used to determine the inhalation Hazard Index (HI) for the mixture of chemicals. This step is used as a screening technique to indicate whether further evaluation is needed. Additional work would be needed to understand completely the interaction of the chemicals. Like the individual HQs, the oral and inhalation HI for the mixture is a number that provides insight into potential toxicity of the mixture. Specifically, the oral HI for a mixture is the sum of the oral HQ for each chemical in the mixture. Similarly, the inhalation HI for a mixture is the sum of the inhalation HQ for each chemical in the mixture. The formula for

determining the HI for a mixture containing three chemicals follows:

Oral $HI_{\text{mixture}} = \text{oral HQ}_{\text{chemical one}} + \text{oral HQ}_{\text{chemical two}} + \text{oral HQ}_{\text{chemical three}}$, or

Inhalation $HI_{\text{mixture}} = \text{inhalation HQ}_{\text{chemical one}} + \text{inhalation HQ}_{\text{chemical two}} + \text{inhalation HQ}_{\text{chemical three}}$

Whenever an HI for a mixture of chemicals exceeds 0.1, further evaluation is needed to determine if a concern for possible harmful effects might exist. Thus the health scientist needs to use methods beyond the initial screening method to make that decision. Because the HQs are based on different health endpoints (e.g., a kidney endpoint for chemical one, a neurological endpoint for chemical two, etc.), the health scientist can also conduct additional evaluations by looking at organ specific endpoints when the HI exceeds 0.1, using scientific and medical judgment to determine the potential for harmful effects.

To provide insight into a mixture's ability to cause interaction effects, the health scientist also will conduct what ATSDR calls a BINWOE analysis, which stands for Binary Weight of Evidence. A BINWOE uses a three-part analysis to determine:

- how two chemicals in a mixture might interact together to increase or decrease toxicity by reviewing mechanistic information available for the chemicals,
- the toxicological significance of two chemicals interaction, and
- if any information is available that might be used to modify their actions.

The results of the BINWOE analysis provide qualitative information that helps the health scientist understand if chemicals in a mixture will interact to increase or decrease toxicity. This understanding helps the health scientist interpret the HI score more accurately.

An important part of a BINWOE analysis is to predict whether any combination of two chemicals in the mixture might act in an additive, greater than additive, or less than additive manner. For instance, if two chemicals in the mixture act in an additive manner, the health scientist would expect that the dose of each chemical has an equal weight in its ability to cause harmful effects. Mathematically, the additive nature of chemical interactions is often presented as $2 + 3 = 5$. If two chemicals act in an additive manner, their individual HQs can be added when evaluating the two chemicals as a mixture.

Sometimes a mixture of chemicals might act in a greater than additive manner, which is referred to as a synergistic effect or synergism. When two chemicals are acting synergistically, one chemical is enhancing the effect of the other chemical. Mathematically, a chemical mixture with a synergistic effect is often presented as $2 + 3 = 8$ (or 6 or 12, depending upon how strong the synergistic effect between the two chemicals might be.) If a mixture contains two chemicals that interact synergistically, the health scientist knows that the HI for those two chemicals is greater than simply adding the individual HQs for each chemical.

A chemical mixture that acts in a less-than-additive manner is referred to as an antagonistic effect. In this case, one of the chemicals is reducing the effect of the other chemical. Stated another way, one chemical is protecting against the effect of another chemical. An antagonistic

effect might be presented mathematically as $2 + 3 = 4$. If a mixture contains two chemicals that interact in an antagonistic manner, the health scientist knows that the HI for those two chemicals is less than simply adding the individual HQs for each chemical. Other types of chemical reactions in a mixture are possible, and these are described in more detail in ATSDR's guidance manual for chemical mixtures. However, the three types of reactions described here (additivity, synergism, and antagonism) are the primary types. The BINWOE analysis provides the health scientist with more information about how the chemicals in the mixture might interact. This additional insight helps the health scientist to decide if harmful effects might be possible. Now that we have explained some of the terms and general principles ATSDR uses to evaluate individual chemicals, we will present the findings derived from evaluating the oral route of exposure (i.e., from drinking public water) and the findings from the inhalation route of exposure (i.e., from bathing and showering in public water). In conducting this evaluation, NYS DOH and ATSDR's Division of Health Assessment and Consultation, the division that writes health consultations, worked closely with ATSDR's Division of Toxicology, the division that developed ATSDR's guidance for evaluating mixtures.

Non-Cancer Findings from Drinking Endicott's Water

Evaluating oral exposure to the individual chemicals in Endicott's water

As described previously, the first steps involve 1) estimating the chronic oral dose of each chemical from drinking public water and 2) comparing the chronic oral dose for each chemical to a chronic oral MRL or oral RfD. An additional step in this comparison is to use the oral dose and the MRL or RfD to determine the oral Hazard Quotient (HQ) for each chemical. To estimate the oral dose, ATSDR and NYS DOH used the highest arithmetic mean of each chemical's concentration from the South Street wells. This process of estimating the dose and determining the oral HQ for each chemical is described in more detail in Appendix B.

Because children and adults drink different amounts of tap water each day (see Table 9, Appendix B), the chronic oral dose of each chemical from drinking tap water will vary slightly depending on the age and weight of the person. Tables 7 and 8, Appendix B show the chronic oral dose of six VOCs (1,1-DCA, cis-1,2-DCE, TCE, TCA, VC, and trans-1,2-DCE) and four trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane, and bromoform), for the different age groups, together with the chronic oral MRL or the RfD for each chemical. For example, the estimated dose of 1,1-DCA for children 1 to 3 years old is 0.000048 mg/kg/day. This dose can be compared to U.S. EPA's RfD of 0.1 mg/kg/day. This comparison shows that the estimated dose of 1,1-DCA in children 1 to 3 years of age is below the health guideline of 0.1 mg/kg/day. This means that children 1 to 3 years old who drank tap water are not likely to experience non-cancerous harmful effects from 1,1-DCA in tap water. The estimated dose of the other VOCs and the trihalomethanes also are below each chemical's health guideline; therefore, non-cancerous harmful effects are unlikely (see Table 7).

Tables 10 and 11, Appendix B show the oral Hazard Quotient for each chemical. The oral HQ is determined by dividing the estimated dose by the chronic health guideline (that is, the chronic oral MRL or the oral RfD). For example, the derivation of the oral HQ for 1,1-DCA in children aged 1 to 3 years follows:

Oral HQ_{children aged 1 to 3 years} = estimated dose for children 1 to 3 years old ÷ oral RfD

Oral HQ_{children aged 1 to 3 years} = 0.000048 mg/kg/day ÷ 0.1 mg/kg/day

Oral HQ_{children aged 1 to 3 years} = 0.00048

The oral HQ of 0.00048 is rounded to 0.0005 as shown in Table 10.

Because the oral HQ for chronic exposure is below 1, harmful effects are not likely for children 1 to 3 years old who drank tap water. The advantage of calculating an oral HQ is that one number shows whether the oral dose in children 1 to 3 years old is above (i.e., the oral HQ is greater than 1) or below (i.e., the oral HQ is less than 1) a chronic health guideline.

Conclusions for individual chemicals and non-cancerous effects from drinking Endicott's water

Because the oral HQ is less than 1 for each chemical in Endicott's water, adverse health effects from drinking Endicott's public water are not expected in children or adults. The amount of exposure to each chemical from drinking public water is far below the chronic health guidelines established by ATSDR and U.S. EPA.

Evaluating oral exposure to the mixture of chemicals in Endicott's water

Once the oral Hazard Quotient for each chemical is determined, the next step is to evaluate the mixture of chemicals in Endicott's water. This portion of the mixtures evaluation evaluates the interaction of chemicals from drinking Endicott's water.

The health scientist first reviews the individual oral Hazard Quotient for each chemical to decide if an oral Hazard Index (HI) is needed for the mixture of chemicals. ATSDR's mixture guidance states that if all the oral HQs for each chemical are less than 0.1, then interactions between the chemicals in the mixture are unlikely. Stated another way, the chemical mixture will not have any significant interactions (either additive, synergistic, or antagonistic) if each of the individual oral HQs are less than 0.1. ATSDR's mixtures guidance also states that if only one HQ exceeds 0.1, then interactions between that chemical and other chemicals in the mixture also are unlikely. As seen in Tables 10 and 11 in Appendix D, the HQ for each of the VOCs and trihalomethanes are far below 0.1. Therefore, interactive effects, either additive or synergistic, are not likely to occur; and, this mixture of chemicals is not harmful to people.

Conclusions for the mixture of chemicals and drinking Endicott's water

Children and adults are unlikely to experience non-cancerous harmful effects from the mixture of chemicals in Endicott's water. Non-cancerous harmful effects are unlikely because the individual chemicals in the mixture will not interact in any way that might be harmful.

Non-Cancer Findings from Bathing and Showering in Endicott's Water

Evaluating inhalation exposure to the individual chemicals in Endicott's water

While oral exposure to chemicals is obvious from drinking public water, residents also were

exposed to these chemicals when bathing or showering. This additional exposure occurred because some of the chemicals in water will volatilize (i.e., evaporate) from water into the air during a bath or shower. When this occurs, people will be exposed via inhalation as they breathe bathroom air while bathing and while in the bathroom just after a bath or shower. People also will absorb chemicals through the skin while bathing or showering in water containing these chemicals. Appendix C contains a technical description of the mathematical equations used to estimate the air concentration of chemicals in the bathroom that occur while showering. Appendix C also shows the equations used to estimate chemical absorption through the skin.

Similar to the process used to determine an oral Hazard Quotient, the first step in determining the inhalation Hazard Quotient for a chemical is to estimate the air concentration of each chemical during a shower. Table 12, Appendix D shows the estimated air concentration for children and adults from taking a shower along with the inhalation health guidelines.

Because chronic inhalation MRLs and RfCs are sometimes not available, it is necessary to use other sources to derive a health guideline. ATSDR's intermediate inhalation MRL is one of these sources.² For the purpose of estimating chronic inhalation MRLs for three chemicals in this health consultation, ATSDR and NYS DOH have chosen to apply an additional uncertainty factor of 10 to the intermediate inhalation MRL. This additional uncertainty factor is to account for the difference in exposure periods (i.e., intermediate to chronic exposure periods). The resulting health guidelines were used to calculate inhalation Hazard Quotients. These chemicals are listed in Table 12, Appendix D, and include cis-1,2-DCE, TCA, and trans-1,2-DCE. For 1,1-DCA, inhalation MRLs or RfCs were not available. Therefore, ATSDR identified a NOAEL (the no observed adverse effect level) from an animal study to derive what ATSDR calls a Target Organ Toxicity Dose (or TTD). For 1,1-DCA, ATSDR identified 500,000 ppb from an animal study as a level where no harmful effects were observed. For this health consultation, the concentration of 500,000 ppb was divided by an uncertainty factor of 1,000 to derive a health guideline of 500 ppb. Because of the large safety factor used, it is reasonable to assume that concentrations of 1,1-DCA in air that are below 500 ppb are unlikely to cause non-cancerous harmful effects. Therefore, the TTD of 500 ppb is used to calculate an inhalation HQ for 1,1-DCA (Table 12, Appendix D).

Table 13, Appendix D shows the trihalomethanes in Endicott's water together with the estimated indoor air concentration for children and adults who used the water for bathing and showering. Inhalation MRLs and RfCs are not available for several chemicals. Because animal and human

² ATSDR develops chronic inhalation MRLs for exposure periods greater than one year. The agency also develops intermediate inhalation MRLs that cover exposure periods of 2 weeks to 1 year. For some chemicals, the intermediate inhalation MRL was used to derive a health guideline to cover chronic exposure periods.

inhalation studies are also unavailable for these chemicals, it is not possible to determine an inhalation Target Organ Toxicity Dose. Therefore, ATSDR and NYS DOH converted chronic oral MRLs to chronic inhalation MRLs for these chemicals. This approach allows ATSDR and NYS DOH to include chemicals in the mixture that normally would have been omitted because of the lack of a health guideline. Specifically, the chronic oral MRLs for bromodichloromethane, dibromochloromethane, and bromoform were converted to a chronic inhalation MRL (see Table 13). This air concentration was then used to determine the inhalation HQ for these chemicals.

Using the estimated indoor air concentration from showering and the inhalation air guidelines in Tables 12 and 13, Appendix D, ATSDR and NYS DOH determined the inhalation Hazard Quotient for each chemical (see Tables 14 and 15, Appendix D). The individual inhalation HQ for the chemicals in Endicott's public water ranges from a high of 0.1 for chloroform and bromodichloromethane (for children) to a low of 0.0004 for vinyl chloride. Because the individual HQs are below 1, the estimated bathroom air concentration for each chemical is below the inhalation air guideline. Therefore, evaluating each chemical alone, non-cancerous harmful effects are unlikely.

Conclusions for individual chemicals from bathing and showering in Endicott's water

Because the inhalation HQ is less than 1 for each chemical in Endicott's water, children and adults are unlikely to experience non-cancerous harmful effects from bathing and showering in Endicott's public water. The amount of exposure to each chemical in public water is far established inhalation health guidelines, or it is below inhalation guidelines derived specifically for this health consultation.

Evaluating inhalation exposure to the mixture of chemicals in Endicott's water

Once the inhalation Hazard Quotient (HQ) for each chemical is determined, the next step is to evaluate inhalation exposure to the mixture of chemicals in Endicott's water. This part of the mixtures evaluation looks at evaluating the interaction of chemicals from breathing the mixture of chemicals that volatilize (i.e., evaporate) from Endicott's water.

To evaluate the chemical mixture in Endicott's water, the health scientist reviews the inhalation Hazard Quotient for each chemical to decide if an inhalation Hazard Index (HI) for the mixture is needed. ATSDR's mixture guidance states that if all the inhalation HQs for each chemical are less than 0.1, then interactions between the chemicals in the mixture are unlikely. Stated another way, the chemical mixture will not have any significant interactions (i.e., either additive, synergistic, or antagonistic) if each of the individual inhalation HQs is less than 0.1. ATSDR's mixtures guidance also states that if only one HQ exceeds 0.1, then interactions between that chemical and other chemicals in the mixture are unlikely. As seen in Tables 14 and 15, Appendix D, only two chemicals, chloroform and bromodichloromethane have an HQ of 0.1 for children. The corresponding HQ for adults is less than 0.1, specifically 0.08 for chloroform and 0.09 for bromodichloromethane. No evidence exists that chloroform and bromodichloromethane act synergistically. Because the chemicals are trihalomethanes, they are assumed to act in an additive manner. Therefore, the combined HI is the sum of the individual HQs; and, the combined HI for chloroform and bromodichloromethane in children is 0.2. Because the combined HQ of 0.2 is below 1, harmful effects are not likely.

Conclusions for the mixture of chemicals from bathing and showering in Endicott's water

Using the inhalation exposure to the mixture of chemicals in Endicott's water, children and adults are unlikely to experience non-cancerous harmful effects. The individual chemicals in the mixture will not interact in any way that might be harmful.

Evaluating total exposure

The question also can be raised that the combined or total exposure to chemicals from drinking and bathing in Endicott's water might be a concern for the mixture and for non-cancerous effects. Because the oral and inhalation HQ for each chemical is far below 0.1 for most chemicals and at 0.1 for only two chemicals by inhalation (see Tables 10, 11, 14, 15), the total exposure for the mixture is not likely to be a concern.

Findings for Cancer Risk

U.S. EPA has a method for estimating the cancer risk of chemicals that cause cancer by ingestion and by inhalation. A chemical that causes or might cause cancer in people is called a carcinogen. When people are exposed to a carcinogen in drinking water, the method for estimating their cancer risk involves multiplying the chronic oral dose of a carcinogen by what is called a cancer slope factor. The resulting number is the cancer risk and is estimated using the equation shown below and assuming 30 years of exposure in a 70-year life span:

Oral Cancer Risk =

$$\text{Chronic oral dose (in mg/kg/day)} \times \text{cancer slope factor (in } 1 / \text{mg/kg/day)} \times 30 \text{ years} / 70 \text{ years}$$

The resulting risk of cancer is called an excess cancer risk because it is the risk of cancer above the already existing background risk of cancer. U.S. EPA also states that the risk could be zero. Therefore, one interprets the excess cancer risk as being between 0 and some number for every 1 million people exposed to the estimated dose of a carcinogen over 30 years. The estimated cancer risk is above the already established background risk of cancer, which is about 1 in every 2 men and 1 in every 3 women over a lifetime. Thirty years of exposure is assumed because 30 years represents the 95th percentile of length of residency at one address; that is, only 5% of the people will live at the same residence for more than 30 years.

Either inadequate cancer information, or no cancer information exists for 1,1-DCA, cis-1,2-DCE, TCA, and trans-1,2-DCE. Therefore, it is not known if these chemicals can increase the risk of cancer from drinking Endicott's water. Other chemicals in Endicott's water have been shown to cause cancer in people or in animals (ATSDR 1989, 1990, 1995, 1996, 1997, 1997b, 2003). Table 16 shows the list of chemicals in Endicott's water and provides information about what is known of their cancer-causing potential.

U.S. EPA has revised its method for evaluating the carcinogenicity of chloroform; it no longer recommends an oral cancer potency factor for chloroform (U.S. EPA 2004). U.S. EPA made this

change because evidence suggests that chloroform-induced kidney and liver cancers in laboratory animals result only at high exposure levels that lead to repeated cellular damage and regeneration in the liver and kidneys. Scientists believe that excessive regeneration of cells following high level chloroform exposure is the process that leads to the formation of cancer cells. The U.S. EPA's Science Advisory Board has reviewed the agency's policy and agreed that chloroform-induced cancers are probably the result of high levels of exposure. However, a few members of the Science Advisory Board cautioned that it is not known if this is the only way chloroform could cause cancer. Because of this uncertainty, this health consultation will still report a numerical risk from inhalation of low-level chloroform but cautions the reader that the risk probably approaches or is close to zero because the chloroform levels are too low to cause cell damage and regeneration.

In addition, U.S. EPA has stated that their RfD of 0.01 mg/kg/day for chloroform can be considered protective against increased cancer risk from chloroform. ATSDR has established the same dose of 0.01 mg/kg/day for its chronic oral MRL. It should be pointed out that the estimated doses of chloroform in people who drank Endicott's water are below the U.S. EPA's RfD and ATSDR's MRL for chloroform.

U.S. EPA developed a range of cancer slope factors (CSF) for TCE from 0.02 to 0.4 / mg/kg/day that can be used to estimate a numerical cancer risk (EPA 2001). While we have estimated a numerical cancer risk for TCE, it is important to remember that TCE was detected only 3 times in the South Street well from 1980 to 2004. Because the detection limit was used to estimate the average concentration of TCE in Endicott's water, the numerical cancer risk that is calculated likely overestimates the risk of cancer from TCE. It is unlikely that finding TCE in Endicott's water 3 times over 25 years will increase people's risk of cancer from TCE.

Table 16. List of Chemicals in Endicott's Water and Cancer Status			
Chemical	Cancer Status	Oral Cancer Slope Factor 1/mg/kg/day	Inhalation Unit Risk 1/ug/m³
1,1-DCA	Some evidence in animals	--	--
cis-1,2-DCE	No information available	--	--
TCA	Inadequate information	--	--
trans-1,2-DCE	No information available	--	--
TCE	Sufficient evidence in animals	0.02 to 0.4	--
Vinyl chloride	Known to cause cancer in people	1.4	8.8E-6
Chloroform	Likely to cause cancer in people at high exposure levels but not at low exposure levels	0.031	6.8E-8
Bromodichloromethane	Causes cancer in animals but not enough evidence from human studies	0.062	-
Dibromochloromethane	Some evidence from animal studies that it will cause cancer but not enough evidence from human studies	0.084	-
Bromoform	Causes cancer in animals but not enough evidence from human studies	0.0079	1.1E-6

Cancer risk from drinking Endicott's water

To estimate the oral dose, ATSDR and NYS DOH used the arithmetic mean of each chemical's concentration as taken from the South Street wells. Using U.S. EPA's mathematical equation for estimating oral cancer risk, Table 17 shows the cancer risk from drinking Endicott's water for 30 years for the six carcinogens that have cancer slope factors. The cancer risk is greatest for vinyl chloride, which predicts between 0 and 4 additional cases of cancer if 1 million people were to drink Endicott's water for 30 years. The excess cancer risk is 0 to 2 per million people for bromodichloromethane and 0 to 1.5 for dibromochloromethane for every one million people exposed for 30 years. The estimated cancer risk from bromoform is less than 0.1 cases for every million people exposed. A range of cancer risks can be calculated for TCE because U.S. EPA has established a range of cancer slope factors (i.e., CSF equals 0.02 /mg/kg/day to 0.4 /mg/kg/day). Using these two cancer slope factors, the estimated cancer risk from TCE ranges from 0 to less than 0.1 per million people exposed to 0 to 1 per million people exposed.

The total excess risk of cancer from drinking Endicott's water for 30 years is 0 to 11 cases for every 1 million people. Stated another way, if 1 million people drank Endicott's water for 30 years, the number of extra cases of cancer might be somewhere between 0 and 11.

A large portion of this estimated cancer risk from drinking Endicott's water comes from vinyl chloride, which has an estimated risk of 0 to 4 cases of cancer for every one million people who drank Endicott's water for 30 years. We believe the actual risk from vinyl chloride is closer to zero because vinyl chloride was detected only once in well 5 and only 4 times in well 28 during the 24 years that these wells were monitored. Vinyl chloride was not detected in the remaining 62 samples from well 5 and was not detected in 61 samples from well 28. The estimated risk of 4 cancer cases comes mostly from assuming that vinyl chloride was present at ½ the detection limit. It is reasonable to assume that vinyl chloride was probably not present at all when samples came back as non-detectable, which would make the cancer risk from vinyl chloride close to zero. Similar to vinyl chloride, TCE is unlikely to increase cancer risk for anyone drinking Endicott's water because TCE was found only 3 times over the 24-year sampling period. It also is important to realize that the risk of cancer from chloroform probably approaches or is close to zero. The chloroform levels are too low to cause liver and kidney damage, which is thought to be necessary to increase the risk of cancer.

It should be noted that the estimated cancer risk of 0 to 11 cancers per million people exposed does not include the cancer risk, if any, that might come from three other chlorinated chemicals in Endicott's drinking water: cis-1,2-DCE, trans-1,2-DCE, and TCA (see Table 16). For these other chlorinated chemicals either insufficient information exists to calculate a cancer slope factor, a number needed to estimate a numerical cancer risk, or insufficient information exists to determine whether these chemicals can cause cancer in rodents or humans.

ATSDR's mixtures guidance for chemicals that cause cancer recommends that if two chemicals have a cancer risk that is between 1 in a million and 1 in 10,000, the chemicals should be evaluated to determine if they have any interactive effects. Like non-cancerous effects, chemicals might act in an additive, synergistic, or antagonistic effect for cancer. In Table 17, five chemicals have a cancer risk between 1 in 10,000 and 1 in a million from oral exposure:

TCE, vinyl chloride, chloroform, bromodichloromethane, and dibromochloromethane. No information could be found that indicates these chemicals interact (ATSDR 2003, 1997c, 1997b, 1989). In the absence of information about chemical interactions, ATSDR assumes that the chemicals will act in an additive manner to cause cancer. Therefore, the estimated cancer risk from exposure to this mixture of chemicals is not likely to exceed 0 to 11 cases per million people exposed.

Chemical	Excess Cancer Risk
TCE	0 to 1 case for every 1 million people exposed for 30 years
Vinyl chloride	0 to 4 cases for every 1 million people exposed for 30 years
Chloroform	0 to 2 cases for every 1 million people exposed for 30 years
Bromodichloromethane	0 to 2 case for every 1 million people exposed for 30 years
Dibromochloromethane	0 to 1.5 case for every 1 million people exposed for 30 years
Bromoform	0 to fewer than 0.1 case for every 1 million people exposed for 30 years

Cancer risk from bathing in Endicott's water

As described previously, bathing in Endicott's water will result in an inhalation exposure as chemicals in the water evaporate into the air which people breathe. U.S. EPA has a slightly different method for estimating the cancer risk when people are exposed to chemicals in air. This method involves multiplying the concentration of a chemical in air in micrograms per cubic meter (or mcg/m³) with a cancer slope factor based on air exposure. People are assumed to be exposed 30 years of a 70 year lifespan. The equation is as follows:

Inhalation Cancer Risk =

$$\text{Concentration of Carcinogen in Air (in mcg/m}^3\text{)} \times \text{Cancer Slope Factor for Air (in 1/mcg/m}^3\text{)} \times \frac{30 \text{ years}}{70 \text{ years}}$$

Using U.S. EPA's mathematical equation for estimating inhalation cancer risk, Table 18 shows the excess cancer risk from chemicals evaporating from Endicott's water during bathing and showering. The estimated cancer risk from vinyl chloride, chloroform, and bromoform is at or below 1 case for every million people exposed for 30 years.

Because only one chemical (vinyl chloride) has a cancer risk higher than one in one million, no interactive effects for cancer are likely from the chemicals in Endicott's water. Therefore, the excess risk of cancer remains between 0 and 2 in a million for people who used Endicott's water for 30 years. The estimated cancer risk of 0 to 2 per million does not include any cancer risk that might come from several other chlorinated chemicals and trihalomethanes in Endicott's water because either insufficient information exists to calculate a cancer slope factor, a number needed to estimate a numerical cancer risk, or because insufficient information exists to determine whether these chemicals can cause cancer in rodents or humans. It should be pointed out that the concentration of chloroform and the other trihalomethanes in Endicott's water is below drinking water standards and is similar to the concentration of chloroform and other trihalomethanes in other public water supplies (ATSDR 1997a). The chlorination of public water supplies is important in protecting against bacterial and other microbial waterborne diseases.

Table 18. Estimate of cancer risk from bathing and showering in Endicott's water for 30 years	
Chemical	Excess Cancer Risk
Vinyl chloride	0 to 1 case for every 1 million people exposed for 30 years
Chloroform	0 to 0.2 cases for every 1 million people who bathed or showered in Endicott's water
Bromodichloromethane	Could not be determined because U.S. EPA does not have an inhalation cancer slope factor
Dibromochloromethane	Could not be determined because U.S. EPA does not have an inhalation cancer slope factor
Bromoform	0 to fewer than 0.5 case for every 1 million people exposed for 30 years

Evaluating the combined cancer risk

ATSDR and NYS DOH examined the combination of chemicals in Endicott's water and their ability to cause a mixture effect in producing cancer. No information could be found that shows that chemicals might act in a synergistic way to cause a greater risk of cancer than what might be expected. Therefore, the mixture of chemicals is assumed to act in an additive manner in causing cancer and that the total risk of cancer is the sum of the individual risk of cancer for each chemical.

The excess risk of cancer from drinking Endicott's water for 30 years is 0 to 11 cases for every 1 million people. The excess risk of cancer from bathing in Endicott's water for 30 years is 0 to 2 in a million. Combining the risk of cancer from drinking and bathing in Endicott's water, the excess cancer risk ranges from zero to 13 extra cancer cases for every 1 million people who used Endicott's water.

As mentioned previously, the risk of cancer from chloroform, vinyl, chloride, and TCE is probably closer to zero because the chemicals were either detected only a few times over 24 years or the levels are too low to cause the repeated cellular damage that is thought to lead to cancer. If the cancer risk from these chemicals is excluded, the estimated cancer risk ranges from 0 to 4 cases of cancer for 1 million people exposed for 30 years. ATSDR and NYS DOH concluded that the cancer risk from using Endicott's public water is low.

CONCLUSIONS

Over the years, Endicott's public water was shown to contain small amounts of volatile organic compounds (VOCs) and trihalomethanes (THMs). NYS DOH and ATSDR were asked to evaluate the possibility that the combination of these chemicals together might cause harmful effects in residents who drank and bathed in Endicott's public water. Several steps are required to conduct a mixtures evaluation. First the individual chemicals are evaluated. Then the combination of chemicals can be evaluated. The approach that was used followed guidelines established by ATSDR in its "Guidance Manual for the Assessment of Joint Toxic Action of Chemical Mixtures" (ATSDR 2004).

The evaluation required determining people's exposure to chemicals from drinking Endicott's water and from bathing in that water. Looking at both routes of exposure and using ATSDR's mixtures guidance, ATSDR and NYS DOH concluded that Endicott's public water is of high quality and is suitable for both drinking and bathing. Water from the Endicott Municipal Water Supply is not expected to cause any non-cancerous harmful effects. This is true both for the individual chemicals and for the mixture of chemicals.

ATSDR and NYS DOH also evaluated the risk of cancer from the mixture of chemicals and concluded that the cancer risk from using Endicott's public water is low. This qualitative description of cancer risk comes from estimating a cancer risk in the range of 0 to 13 cases of cancer for every 1 million people that used Endicott's water for 30 years. As mentioned previously in the text, the risk of cancer from chloroform, vinyl chloride, and TCE is probably close to zero because the chemicals either were detected only a few times over 24 years or the levels were too low to cause the repeated cellular damage that is thought to lead to cancer. If the cancer risk from these chemicals is excluded, the estimated cancer risk ranges from 0 to 4 cases of cancer for every 1 million people exposed for 30 years. ATSDR and NYS DOH are describing this degree of cancer risk from using Endicott's public water as low.

In July 2005, the Village of Endicott completed construction of a packed tower aeration treatment system for well 5 and well 28, designed to further reduce VOC levels in water produced from those wells. By reducing low-level volatile organic compounds found in the municipal water supply, potential exposures are reduced.

Using ATSDR's public health hazard category classification (Appendix E), drinking, bathing, and showering in water supplied from the Endicott Municipal Water Supply's South Street wells from 1980 to 2004 and from the Ranney well from 1992 to 2004 is no apparent public health hazard. Based on public comments received by ATSDR and NYS DOH, an additional "worst-case" analysis was conducted that accounted for longer shower times, a more conservative approach to dealing water samples that did not detect a specific chemical, inclusion of all Ranney well water data before 1992, and the inclusion of other chemicals detected in the drinking water detected only a few times, including TCE. The result of the "worst-case" analysis does not change the conclusions of the health consultation; that is, Endicott's public water is of high quality and is suitable for both drinking and bathing.

RECOMMENDATIONS

No recommendations at this time.

PUBLIC HEALTH ACTION PLAN

This health consultation was made available for public review at the George F. Johnson Memorial Library, Village of Endicott, 1001 Park Street, Endicott, NY 13760 and at scheduled public availability session conducted in the Village of Endicott.

ATSDR and NYS DOH met with the WBSEC in May 2005 to discuss how the health agencies would respond to public comments received on the October 12, 2004 draft of the health consultation.

As a prudent public health measure, in July 2005, the Village of Endicott completed construction of a packed tower aeration treatment system for well 5 and well 28, designed to further reduce VOC levels in water produced from those wells.

BCHD and NYS DOH will continue to review water quality data from the Endicott Municipal Water Supply to assure that contaminant levels are tracked and appropriate actions are taken if contaminant levels increase to levels approaching New York State drinking water standards.

PREPARERS OF REPORT

New York State Department of Health Authors

Karolina A.H. Schabzes
Research Scientist
Bureau of Environmental & Occupational Epidemiology

Scarlett Messier
Research Scientist
Bureau of Environmental Exposure Investigation

Donald W.R. Miles
ATSDR Grant Coordinator
Bureau of Environmental Exposure Investigation

Agency for Toxic Substances and Disease Registry Authors

ATSDR Technical Project Officer
Greg Ulirsch, PhD
Senior Environmental Health Scientist
Superfund and Program Assessment Branch
Division of Health Assessment and Consultation

David Mellard, PhD
Toxicologist
Site Assessment and Radiological Branch
Division of Health Assessment and Consultation

REFERENCES

- [ATSDR] Agency for Toxic Substances and Disease Registry. 2004. Guidance manual for the assessment of toxic action of chemical mixtures. Atlanta: US Department of Health and Human Services.
- [ATSDR] Agency for Toxic Substances and Disease Registry. 1994. Public health assessment addendum. Endicott Village Wellfield (a/k/a Ranney Well). Endicott, Broome County, New York. Available at: http://www.atsdr.cdc.gov/HAC/PHA/endicott/end_toc.html Last accessed 27 September 2004.
- [ATSDR] Agency for Toxic Substances and Disease Registry. 1989. Toxicological profile for bromodichloromethane. Atlanta: US Department of Health and Human Services.
- [ATSDR] Agency for Toxic Substances and Disease Registry. 2003. Toxicological profile for bromoform/dibromochloromethane (update). Atlanta: US Department of Health and Human Services.
- [ATSDR] Agency for Toxic Substances and Disease Registry. 1997a. Toxicological profile for chloroform (update). Atlanta: US Department of Health and Human Services.
- [ATSDR] Agency for Toxic Substances and Disease Registry. 1997c. Toxicological profile for trichloroethylene (update). Atlanta: US Department of Health and Human Services.
- [ATSDR] Agency for Toxic Substances and Disease Registry. 1990. Toxicological Profile for 1,1-dichloroethane. Atlanta: US Department of Health and Human Services.
- [ATSDR] Agency for Toxic Substances and Disease Registry. 1996. Toxicological profile for 1,2-dichloroethene (update). Atlanta: US Department of Health and Human Services.
- [ATSDR] Agency for Toxic Substances and Disease Registry. 1995. Toxicological profile for 1,1,1-trichloroethane (update). Atlanta: US Department of Health and Human Services.
- [ATSDR] Agency for Toxic Substances and Disease Registry. 1997b. Toxicological profile for vinyl chloride (update). Atlanta: US Department of Health and Human Services.
- Broome County Health Department. Village of Endicott Water Supply. Volatile Organic Compound Summary. Water supply data compiled under the direction of Robert W. Denz, P.E., Director of Environmental Health Services. 2004. Data partially available at: <http://www.gobroomecounty.com/safety/HasEnvEndWells.php> Last accessed 27 September 2004.
- Bureau of the Census. 1991. 1990 Census of population and housing summary tape file 1 (STF1). Washington, DC: US Department of Commerce.

Bureau of the Census. 1992. 1990 Census of population and housing summary tape file 3 (STF3). Washington, DC: US Department of Commerce.

Bureau of the Census. 2001. 2000 Census of population and housing summary file 1(SF1). Washington, DC: US Department of Commerce.

Bureau of the Census. 2002. 2000 Census of population and housing summary file 3 (SF3). Washington, DC: US Department of Commerce.

[EPA] U. S. Environmental Protection Agency. IRIS (Integrated Risk Information System) database for chloroform. Available at: <http://www.epa.gov/iris/subst/0025.htm> Last accessed 29 September 2004.

[EPA] U.S. Environmental Protection Agency. 2001. Trichloroethylene Health Risk Assessment: Synthesis and Characterization. Washington: U.S. Environmental Protection Agency, EPA/600/P-01-002A.

Keating GA, McKone TE, Gillett JW. 1997. Measured and estimated air concentrations of chloroform in showers: Effects of water temperature and aerosols. *Atmospheric Environment*;31:123-130.

McKone TE, Knezovich JP. 1991. The transfer of trichloroethylene (TCE) from a shower to indoor air: experimental measurements and their implications. *J. Air Waste Management Association*;41:832-7.

Village of Endicott, New York. Water Department Web site. Available at: <http://www.endicottny.com/Depts/dept.htm#Water> Last accessed 29 September 2004.

APPENDIX A

Tables

**Table 1. Demographics of Residents in Endicott Municipal Water Supply
and New York State excluding New York City,
1990 and 2000**

Census Demographics	Endicott Water Supply 1990^{1,2}	New York State excluding NYC 1990^{1,2}	Endicott Water Supply 2000^{3,4}	New York State excluding NYC 2000^{3,4}
Total Population	38,127	10,667,891	36,120	10,968,179
Percent Male	47.8%	48.6%	47.7%	48.8%
Percent Female	52.2%	51.4%	52.3%	51.2%
Age Distribution				
<6	8%	8%	7%	8%
6-19	17%	19%	18%	20%
20-64	60%	59%	57%	58%
>64	15%	13%	18%	14%
Race Distribution				
White	97%	90%	94%	85%
Black	1%	7%	2%	8%
Native American	<1%	<1%	<1%	<1%
Asian / Pacific Islander	2%	2%	2%	2%
Other	<1%	1%	<1%	2%
Multi-Racial	Not collected	Not collected	1%	2%
Ethnicity Distribution				
Percent Hispanic	1%	7%	1%	6%
Median Household Income*	\$32,690	\$35,711	\$37,291	\$47,517
% Below Poverty Level*	7%	9%	10%	10%

* Median household income and percent below poverty level can only be calculated at the block group level and above.

1. US Bureau of the Census. 1991. *1990 Census of population and housing summary tape file 1 (STF1)*. US Department of Commerce.
2. US Bureau of the Census. 1992. *1990 Census of population and housing summary tape file 3 (STF3)*. US Department of Commerce.
3. US Bureau of the Census. 2001. *2000 Census of population and housing summary file 1(SF1)*. US Department of Commerce.
4. US Bureau of the Census. 2002. *2000 Census of population and housing summary file 3 (SF3)*. US Department of Commerce.

Well	Dates	Number of Samples	Comments
5	1980 -1989	15	No data for 1983-1985; 1-4 samples for other years
	1990 -1999	31	Mostly 2-4 samples per year
	2000 -2004	17	Quarterly sampling
28	1981 -1989	16	No data for 1984 and 1987; 1-4 samples for other years
	1990 -1999	30	1-4 samples per year
	2000 -2004	16	Quarterly sampling
32	1992 -2004	210	

Dates	Number of Samples	Comments
1982 – late 1992	56	
1993	0	No sampling for THMs during this period
1994 – 1999	24	
2000 – 2004	17	
Total 1982 – 2004	97	

Well #	Statistical Parameter	1,1 DCA	cis 1,2 DCE	TCA	TCE	1,1 DCE	Methylene Chloride	n-Propyl Benzene	Vinyl Chloride	PCE	trans 1,2 DCE
Well 5	Geometric Mean	0.71	1.48	0.71	0.29	0.28	0.29	0.25	0.28	0.27	0.27
Well 5	Arithmetic Mean*	0.79	1.69	0.92	0.33	0.29	0.34	0.25	0.29	0.28	0.28
Well 5	90th Percentile**	1.00	2.00	2.00	0.50	0.50	0.50	0.25	0.50	0.50	0.50
Well 5	Maximum	1.76	4.00	3.00	2.00	1.00	3.00	0.50	0.90	0.50	0.50
Well 5	Number of Detections ***	44	52	42	3	1	2	1	1	0	0
Well 5	Frequency of Detection (%)	74.58	88.10	71.20	5.08	1.69	3.39	1.69	1.69	0	0
Well 28	Geometric Mean	0.67	1.56	0.31	0.28	0.28	0.31	0.25	0.30	0.28	0.34
Well 28	Arithmetic Mean*	0.76	1.73	0.39	0.29	0.29	0.40	0.25	0.34	0.29	0.58
Well 28	90th Percentile**	1.00	2.00	0.50	0.50	0.50	0.50	0.25	0.50	0.50	0.95
Well 28	Maximum	1.71	3.00	2.50	0.50	0.50	4.00	0.25	2.00	0.50	5.00
Well 28	Number of Detections***	41	50	5	0	0	3	0	4	1	6
Well 28	Frequency of Detection (%)	70.69	86.20	8.62	0	0	5.17	0	6.9	1.72	10.34
Standard	NA	5	5	5	5	5	5	5	2	5	5

Source: Broome County Health Department

Notes:

1,1 DCA – 1,1-Dichloroethane

cis 1,2 DCE – cis 1,2-Dichloroethene

TCA – 1,1,1-Trichloroethane

TCE – Trichloroethene

1,1-DCE – 1,1-Dichloroethene

PCE – Perchloroethene or tetrachloroethene

trans 1,2-DCE – trans 1,2-Dichloroethene

Standard - New York State Drinking water standard

NA - Not applicable

* The arithmetic mean is considered a more appropriate measure of the "average" value than the geometric mean for these data because the data are distributed normally. In addition, using the arithmetic mean was a more conservative approach because arithmetic means were always higher than or equal to geometric means in this data set.

** The percentile statistic indicates the percentage of results that are above or below the stated percentile. In this case, 90% of the values were below and 10% were above the stated value. *** VOCs that have never been detected are not shown in this table and were not further evaluated.

**Table 5. Summary of VOC Treated Water Sampling Results from the Ranney Well
1992 to 2004 (results in ppb)**

Statistical Parameter	1,1 DCA	cis 1,2 DCE	TCE	Methylene Chloride	MTBE	Benzene	Toluene	Chloroethane
Arithmetic Mean*	0.26	0.42	0.26	0.28	0.25	0.25	0.25	0.40
Geometric Mean	0.25	0.29	0.25	0.26	0.25	0.25	0.25	0.26
90th Percentile**	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Maximum	1.59	22.00	0.75	4.00	0.50	0.70	0.50	30.00
Number of Detections***	3	22	4	3	4	1	2	1
Frequency of Detection (%)	2	11	2	1	1	<1	1	<1
Standard	5	5	5	5	10	5	5	5

Source: Broome County Health Department

Notes:

1,1 DCA - 1,1-Dichloroethane

cis 1,2 DCE - cis 1,2-Dichloroethene

TCE – Trichloroethene

MTBE – Methyl tert-butyl ether

Standard – New York State Drinking water standard

* The arithmetic mean is considered a more appropriate measure of the "average" value than the geometric mean for these data because the data are distributed normally. In addition, using the arithmetic mean was a more conservative approach because arithmetic means were always higher than or equal to the geometric means in this data set.

** The percentile statistic indicates the percentage of results that are above or below the stated percentile. In this case, 90% of the values were below and 10% were above the stated value.

***VOCs that have never been detected are not shown in the table and were not further evaluated.

Table 6. Summary of THM Water Sampling Results from the Village of Endicott Public Water System--1982-2004 (results in ppb)

Statistical Summary	Total THM	Chloroform	Bromodichloro- methane	Dibromochloro- methane	Bromoform
Geometric Mean	5.3	2.2	1.8	1.2	0.7
Arithmetic Mean*	13.9	7.6	3.9	2.2	0.9
50th Percentile**	6	2	2	1	0.5
75th Percentile	6	3	2	1	0.5
90th Percentile	14	5	5	4	2
Maximum	409	350	99	36	4
Minimum	ND	ND	ND	ND	ND
Total samples	97	97	97	97	94
Frequency of Detection (%)	87.6	84.5	72.2	55.7	30.9
Standard	80	***	***	***	***

Source: New York State Department of Health

Notes:

THM - Trihalomethanes

* The arithmetic mean is considered a more appropriate measure of the "average" value than the geometric mean for these data because the data are distributed normally. In addition, using the arithmetic mean was a more conservative approach because arithmetic means were always higher than or equal to the geometric means in this data set.

** The 50th percentile indicates that 50% of the samples contained concentrations at or below the value in the field for each of the listed contaminants (i.e. 50% of the samples contained chloroform concentrations less than or equal to 2 ppb).

*** The MCL for total THMs (bromoform, chlorodibromomethane, bromodichloromethane, and chloroform) formed in public water systems as a result of disinfection is 80 ppb.

APPENDIX B

Determining Oral Hazard Quotients and Hazard Indexes
For Chemicals in Municipal Drinking Water

How to Determine Hazard Quotients and Hazard Indexes For Chemicals in Municipal Water

To determine whether or not harmful effects might have occurred in people who were exposed to chemicals in Endicott's water, ATSDR estimated the amount of exposure to these chemicals (1) from drinking public water, (2) from bathing or showering, and (3) from breathing indoor air during and immediately after the shower.

Estimating doses from drinking public water

The average tap water intake for adults is six 8 ounce glasses every day (or 1.4 liters), while the average tap water intake for children 1 to 3 years is two to three 8 ounce glasses every day (or 0.6 liters). Table 9 shows the average tap water intake rates for various age groups in the US (U.S. EPA 1997). From these intake rates, it is possible to estimate the dose (expressed in mg/kg/day) of chemicals for people who drank public water. The first step in evaluating exposure to each chemical is to compare the estimated doses to health guidelines, such as ATSDR's Minimal Risk Level (MRL). An MRL is an estimate of the daily human exposure to a chemical that is likely to be without an appreciable risk of adverse noncancerous effects over a specified duration of exposure. Stated another way, if the estimated dose for a person is below the MRL, then the person is not likely to experience (non-cancerous) harmful effects from drinking the water. When oral MRLs are not available, doses can be compared to U.S. EPA's Reference Dose (RfD) or other health guidelines, if one is available.

If the estimated dose is below the oral MRL, then non-cancerous harmful effects are unlikely. If the oral MRL is exceeded, further toxicological evaluation is required to determine if non-cancerous harmful effects might be possible. This additional evaluation involves comparing the estimated dose in people exposed to a contaminant to doses in human and animal studies that showed harmful effects. The estimated dose can also be compared to doses in human and animal studies that did not show harmful effects. From this comparison, it is possible to decide if harmful effects might be possible in people at a site who are exposed to a contaminant. In addition to ATSDR's MRLs, U.S. EPA also develops similar health guidelines called Reference Doses (RfD) for ingestion exposures and Reference Concentrations (RfC) for inhalation exposures. A reference dose is the amount of chemical that someone can be exposed to for a lifetime below which noncancerous harmful effects are unlikely.

The equation for determining an oral dose for people who drank public water follows:

$$\text{Oral Dose} = (\text{chemical concentration in water} \times \text{tap water intake/day}) \div \text{body weight}$$

Tables 7 and 8 show the doses for each chemical for the various age groups.

Calculating the Oral Hazard Quotient for Each Chemical

From the doses in Tables 7 and 8, it is possible to calculate the oral Hazard Quotient (HQ) for each chemical. Tables 10 and 11 show the individual HQs for each chemical. The Oral Hazard

Quotient is calculated using the following equation:

$$\text{HQ} = \text{Estimated Dose for a Chemical} \div \text{Oral MRL or RfD for that Chemical}$$

Since the HQ for each chemical in Tables 10 and 11 is far below 1, harmful effects from exposure to individual chemicals are not likely. Stated another way, since the estimated dose of each chemical for people who drank public water is far below the oral MRL or RfD, harmful effects are not likely.

Age Group	1,1-DCA Dose in mg/kg/day	cis-1,2-DCE Dose in mg/kg/day	TCA Dose in mg/kg/day	VC Dose in mg/kg/day	t1,2-DCE Dose in mg/kg/day	TCE Dose in mg/kg/day
Children 1 to 3 years	0.0000482	0.0001031	0.0000561	0.0000207	0.0000354	0.0000201
Children 3.1 to 5 years	0.000043	0.0000919	0.00005	0.0000185	0.0000315	0.0000179
Children 6 to 12 years	0.0000158	0.0000338	0.0000184	0.0000068	0.0000116	0.0000066
Teenagers 13 to 17 years	0.0000139	0.0000298	0.0000162	0.000006	0.0000102	0.0000058
Adult women 18 years and older	0.0000186	0.0000397	0.0000216	0.000008	0.0000136	0.0000078
Adult men 18 years and older	0.0000159	0.0000340	0.0000185	0.0000068	0.0000117	0.0000066
Oral MRL	None	None	None	0.003	None	None
Oral RfD	0.1	0.01	0.28	0.003	0.02	0.00146 ^a

^a Health Canada developed this reference dose for TCE . The U.S. EPA developed the other reference doses in Table 7.

Age Group	Chloroform Dose in mg/kg/day	Bromdichloro- methane Dose in mg/kg/day	Dibromochloro- methane Dose in mg/kg/day	Bromoform Dose in mg/kg/day
Children 1 to 3 years	0.0004636	0.0002379	0.0001342	0.0000549
Children 3.1 to 5 years	0.0004133	0.0002121	0.0001196	0.0000489
Children 6 to 12 years	0.0001522	0.000078	0.000044	0.000018
Teenagers 13 to 17 years	0.000134	0.0000688	0.0000388	0.0000168
Adult women 18 years and older	0.0001786	0.0000917	0.0000517	0.0000212
Adult men 18 years and older	0.0001531	0.0000786	0.0000443	0.0000181
Oral MRL	0.01	0.02	0.09	0.2

Age Group	Number of 8 ounce glasses per day	Amount of tap water drank per day in liters ³	Body Weight in kg
Preschool Children 1 to 3 years	2 to 3	0.6	10
Preschool Children 3.1 to 5 years	3 to 4	0.87	16
Elementary School Children	3	0.7	35
Teenagers	4	0.97	55
Adult Women	6	1.4	60
Adult Men	6	1.4	70

Age Group	1,1-DCA	cis-1,2-DCE	TCA	VC	t1,2DCE	TCE
Children 1 to 3 years	0.0005	0.01	0.0002	0.007	0.002	0.01
Children 3.1 to 5 years	0.0004	0.009	0.0002	0.006	0.002	0.01
Children 6 to 12 years	0.0002	0.003	0.00007	0.002	0.0006	0.004
Teenagers 13 to 17 years	0.0001	0.003	0.00006	0.002	0.0005	0.004
Adult women 18 years and older	0.0002	0.004	0.00008	0.003	0.0007	0.005
Adult men 18 years and older	0.0002	0.003	0.00007	0.002	0.0006	0.005

	Chloroform	Bromodichloro-methane	Dibromochloro-methane	Bromoform
Children 1 to 3 years	0.05	0.01	0.002	0.0003
Children 3.1 to 5 years	0.04	0.01	0.001	0.00024
Children 6 to 12 years	0.02	0.004	0.0005	0.00009
Teenagers 13 to 17 years	0.01	0.003	0.0004	0.00008
Adult women 18 years and older	0.02	0.005	0.006	0.0001
Adult men 18 years and older	0.02	0.004	0.0005	0.00009`

³ Intake rates for tap water are based on U.S. EPA's Exposure Factors Handbook, Chapter 3 (see Chapter 3.6, Recommendations) (U.S. EPA 1997).

APPENDIX C

Description of Technical Methods
for Estimating Inhalation Exposure to Chemicals that Evaporate from Water

Description of Technical Methods for Estimating Exposure to Chemicals that Evaporate from Water

As mentioned previously, when adults and children bathe or shower in water containing chemicals that evaporate, these chemicals will get into the body in two ways. First, some chemicals can penetrate the skin during the time that a resident is bathing or showering; and, second, they will evaporate from the water into indoor air where adults and children will be exposed when they breathe the air.

Volatilization from showers

Scientists have studied how chemicals volatilize from shower water and have developed mathematical equations for estimating indoor air levels in the shower and bathroom (Andelman 1985, Andelman 1990, Jo et al. 1990, Wester and Maibach 1986). Therefore, the maximum concentration of a chemical in bathroom air can be estimated during a shower and for the amount of time spent in the bathroom following a shower. The average person takes a 15 minute shower and remains in the bathroom for 10 minutes. However, 5 percent of people take 30-minute showers and remain in the bathroom for 30 minutes. ATSDR and NYS DOH used these longer periods (a 30-minute shower and a 30-minute bathroom stay) to estimate exposure to chemicals in bathroom air. The following equation was used to estimate bathroom air concentration:

$$C \text{ air max} = (k) (Fw) (Ts) (Cw) / Va$$

where,

C air max = maximum concentration in air during the shower and after period in bathroom,

k = fraction of chemical that evaporates from water while showering (assumed to be 0.6),

Fw = flow rate of water through shower head in L/minute (assumed to be 8 liters/minute),

Ts = duration of shower in minutes (assumed to be 30 minutes),

Va = volume of shower and bathroom in liters, (assumed to be 10,000 liters, the approximate size of a small bathroom), and

Cw = concentration of chemical in water in mg/L (Andelman 1990).

The following example shows how units cancel to arrive at mg chemical per cubic meter of air.

$$C \text{ air max} = (k) (Fw) (Ts) (Cw) / Va$$

$$C \text{ air max} = (\%) (\text{L water/min}) (\text{min}) (\text{mg chemical/L water}) / \text{L air}$$

$$C \text{ air max} = \text{mg chemical} / \text{L air}$$

$$C \text{ air max} = \text{mg/L air} \times 1000 \text{ L air/m}^3$$

$$C \text{ air max} = \text{mg/m}^3.$$

Using 1,1-DCA at 0.00079 mg/L as an example, the following bathroom air concentration is estimated for people who take a 30 minute shower:

$$C_{\text{air max}} = (0.6) (8 \text{ L water/min})(30 \text{ min}) (0.00079 \text{ mg/L water}) (1,000 \text{ L air/m}^3) / (10,000 \text{ L air})$$

$$C_{\text{air max}} = 0.011376 \text{ mg/m}^3$$

To convert mg/m^3 to ppm then

$$C_{\text{air max}} = 0.011376 \text{ mg/m}^3 \div 4.047 = 0.0028 \text{ ppm or } 2.8 \text{ ppb}$$

Therefore, the concentration of 1,1-DCA in bathroom air for people who take a 30-minute shower is estimated to be 2.8 ppb.

Dermal intake converted to an air concentration

In addition to exposure from breathing chemicals, people also absorb these chemicals through their skin while showering and bathing. Using a skin permeability constant, scientists have developed an equation for estimating the amount of chemical that is absorbed through the skin during a shower (Brown et al. 1984). Chemical exposure via skin can be estimated using the following formula:

Skin dose =

$$(\text{skin permeability constant}) (\text{duration of exposure})(\text{total body surface area})(\text{percent of body surface area exposed})(\text{chemical concentration in water})(\text{fraction remaining after volatilization})$$

The units are $(\text{L/cm}^2 \text{ -- hr}) (\text{hr}) (\text{cm}^2) (\%) (\text{mg/L})(\%)$, which cancel out to mg. The permeability constant for chlorinated organic chemicals is assumed to be 0.001 L/cm-hr (Brown et al. 1984) and 40% of the chemicals is assumed to remain in the shower water after volatilization (Andelman 1985, McKone 1991). For adults the assumed breathing rate for light activity is 1.39 m^3/hr , while for children the assumed breathing rate for light activity is 0.84 m^3/hr . For skin surface area, the assumed area is 18,150 cm^2 for adults and 11,750 cm^2 for children (U.S. EPA 1997). Because 5% of people take 30-minute showers, the assumed duration of a shower is 30 minutes.

The following example using 1,1-DCA shows the estimated dose for adults from skin absorption and shows how to convert that estimated dose to an air concentration. First, it is necessary to estimate the skin intake using the previously described equation:

$$\text{Skin intake, adults} = (0.001 \text{ L/cm}^2\text{-hr})(30/60\text{hr})(18,150 \text{ cm}^2)(1)(0.00079 \text{ mg/L})(0.4).$$

$$\text{Skin intake, adults} = 0.00287 \text{ mg 1,1-DCA}$$

Next, it is necessary to convert the skin intake of 0.00287 mg to an equivalent air concentration that someone would breathe while taking a 30-minute shower.

Air concentration from skin exposure, adults =

Skin intake / inhalation rate x shower duration =

$$(0.00287 \text{ mg}) / (1.39 \text{ m}^3/\text{hr} \times 1 \text{ hr}/60 \text{ minutes} \times 30 \text{ minutes}) = 0.00287/0.695 =$$

$$0.0041 \text{ mg/m}^3 \text{ (which equals 1 ppb).}$$

Therefore, a concentration of 0.0041 mg/m³ 1,1-DCA in air breathed for 30 minutes during a shower is equivalent to the estimated skin intake of 0.00287 mg from a 30 minutes shower. Converting the skin intake into an air concentration allows both routes of exposure to be summed to provide a combined exposure level.

Chronic exposure

To evaluate chronic exposure, it is necessary to also include the additional chemical exposure that occurs the remainder of the day. The amount of exposure during the remainder of the day can be estimated using background levels of chemicals in indoor air, which is available from U.S. EPA's TEAM study and other U.S. EPA air databases (Wallace 1987).

To estimate the total intake of a specific chemical from bathing in contaminated water, the following exposures need to be considered:

Total intake_{specific chemical} =

inhalation intake_{30 minute shower and additional 30 minute bathroom stay}

+ skin intake_{30 minute shower}

+ inhalation intake_{remainder of the day}

Thus, the equation to estimate intake from each pathway is as follows:

$$(C \text{ air max})^4 (\text{hourly breathing rate in m}^3/\text{hr}) (1 \text{ hr}/60 \text{ min}) (\text{total bathroom time in minutes})$$

$$+ (L/\text{cm}^2 \text{ --hr})(\text{hr})(\text{cm}^2)(\% \text{ surface area})(\text{mg/L})(\% \text{ not volatilized during shower})$$

$$+ (\text{Indoor air levels in mg/m}^3)(\text{daily air breathing rate in m}^3/\text{day})$$

As an example, the total intake for adults from bathing in 1,1-DCA-contaminated water containing 0.00079 mg/L) is:

⁴ As previously described, C air max in the bathroom = (k) (Fw) (Ts) (Cw) / Va

Total daily intake, adults _{1,1-DCA} =

$$\begin{aligned} & (0.01137 \text{ mg/m}^3) (1.36 \text{ m}^3/\text{hr}) (1 \text{ hr}/60 \text{ min}) (60 \text{ min}) \\ & + (0.001 \text{ L/cm}^2\text{-hr})(30/60)(18,150)(0.00079 \text{ mg/L})(0.4) \\ & + (0.01296 \text{ mg/m}^3)(21.95 \text{ m}^3/\text{day}) \end{aligned}$$

Total intake _{1,1-DCA} = 0.0158 mg + 0.00287 mg + 0.28447 mg = 0.3032 mg/day

The next step is to convert the total daily intake (in mg/day) for 1,1-DCA into a daily (24 hour) air concentration. This 24-hour air concentration becomes the chronic exposure level that can be used to determine if harmful effects might be possible from taking a daily shower over long periods (e.g., years) To estimate the 24-hour air concentration that is equivalent to a daily intake of 0.3032 mg/day involves the following calculations:

24-hour Air Concentration =

$$(\text{Total daily intake}_{1,1\text{-DCA}} \text{ in mg}) \div (\text{average amount of air breathed per day m}^3/\text{day})$$

For adults, the 24-hour Air Concentration of 1,1-DCA =

$$(0.3032 \text{ mg/day}) \div (21.95 \text{ m}^3/\text{day}) = 0.0138 \text{ mg/m}^3$$

To convert mg 1,1-DCA/m³ to ppm and then to ppb involves the following calculations:

$$[(0.0138 \text{ mg/m}^3) \div (4.047)] (1,000 \text{ ppb/ppm}) = 3.4 \text{ ppb.}$$

Therefore, for adults the estimated 24-hour concentration of 1,1-DCA in household air is 3.4 ppb, and this concentration can be used to determine if harmful effects might occur from long-term exposures over many years. It should be pointed out that for 1,1-DCA, most of the total exposure estimate comes from background levels of 1,1-DCA in indoor air. Based on a study by Gupta (Gupta 1984), ATSDR's Toxicological Profile for 1,1-DCA cites indoor air levels of 1,1-DCA as being 3.2 ppb. The contribution to estimated total indoor air from water containing 1,1-DCA at 0.00079 mg/m³ is 0.02 ppb, which does not add any significant exposure to 1,1-DCA when background levels of 1,1-DCA are already at 3.2 ppb.

Appendix C References

- Andelman JB. 1985. Inhalation exposure in the home to volatile organic contaminants of drinking water. *Sci Total Environ* 47:443-460.
- Andelman JB. 1990. Total exposure to volatile organic compounds in potable water. In: Ram NM, Christman RF, Cantor KP, editors. *Significance and treatment of volatile organic compounds in water supplies*. Chelsea, Michigan: Lewis Publishers, p.485-504.
- Brown HS, Bishop DR, Rowan CA. 1984. The role of skin absorption as a route of exposure for volatile organic compounds in drinking water. *Am J Pub Health* 74:479-484.
- [U.S. EPA] US Environmental Protection Agency. 1997. *Exposure factors handbook, Volume I: general factors*. Washington: National Center for Environmental Research; EPA/600/8-89/043. Available at <http://www.epa.gov/ncea/exposfac.htm> Last accessed 27 September 2004.
- Gupta KC, Ulsamer AG, Gammage R. 1984. Volatile organic compounds in residential air: Levels, sources, and toxicity. *Proceedings of the 77th Air Pollution Control Association, Annual Meeting* 1:9.
- Jo WK, Weisel CP, Liroy P. 1990. Chloroform exposure and the health risk associated with multiple uses of chlorinated tap water. *Risk Anal* 10:581-585.
- McKone TE, Knezovich JP. 1991. The transfer of trichloroethylene (TCE) from a shower to indoor air: experiment measurements and their implications. *J Air Waste Manage Assoc* 41:832-837.
- Wallace L. 1987. *The total exposure assessment methodology (TEAM) study: summary and analysis: volume I*. Washington DC: U.S. Environmental Protection Agency; Office of Research and Development.
- Wester RC, Maibach HI. 1986. Skin absorption of chemical contaminants from drinking water while bathing or swimming. In: Chambers PL, Gehring P, Sakai F, editors. *New concepts and developments in toxicology*. Amsterdam: Elsevier Science Publishers BV, p. 169-174.

APPENDIX D

Determining Inhalation Hazard Quotients and Inhalation Hazard Indexes
from Bathing in Municipal Water Containing Chemicals

Table 12. Estimated inhalation exposure levels of chemicals in ppb from showering in public water

Age	1,1-DCA ppb	cis-1,2-DCE ppb	TCA ppb	VC ppb	trans- 1,2DCE ppb	TCE ppb
Children	3.52	0.679	1.31	0.21	0.23	0.096
Adults	3.41	0.46	1.22	0.14	0.16	0.065
Chronic Inhalation MRL or RfC	None	None	None	38.5	None	None
Intermediate Inhalation MRL ÷ Uncertainty Factor	None	20 ^c	70 ^d	--	20 ^e	None
Inhalation NOAEL or LOAEL^a ÷ Uncertainty factor	500 ^b	–	–	--	--	60 ^f

^a When an inhalation MRL or RfC is not available, a LOAEL or NOAEL from a human or animal study can be divided by an uncertainty (safety) factor to derive a Target Organ Toxicity Dose (TTD). An inhalation LOAEL is the lowest concentration in air from a human or animal study that has been shown to cause an adverse affect. An inhalation NOAEL is a concentration in air from a human or animal study that was shown to not cause an adverse effect.

^b For 1,1-DCA a NOAEL of 500,000 ppb was identified based on an a 13 week study of several animals (rat, guinea pig, rabbit, and cat). This NOAEL was divided by an uncertainty factor of 1,000. (ATSDR 1990)

^c For cis-1,2-DCE, the intermediate MRL of 200 ppb was used to derive a Target Organ Toxicity Dose. The intermediate MRL was divided by an uncertainty factor of 10 (10 for intermediate to chronic). (ATSDR 1996)

^d For TCA, the intermediate MRL of 700 ppb was used to derive a Target Organ Toxicity Dose by using an uncertainty factor of 10 to account for intermediate to chronic exposure. (ATSDR 1995)

^e For trans-1,2-DCE, the intermediate MRL of 200 ppb was used to derive a Target Organ Toxicity Dose of 20 ppb by dividing the MRL by an uncertainty of 10 to account for intermediate to chronic exposure. (ATSDR 1996)

^f For TCE, a LOAEL of 300,000 ppb was identified based on a 2 year rat study. Rats were exposed 5 days per week, 7 hours per day. An uncertainty of 1,000 was applied.

Table 13. Estimated inhalation exposure levels of chemicals in ppb from showering in public water

	Chloroform ppb	Bromodichloro- methane ppb	Dibromochloro- methane ppb	Bromoform ppb
Children	2.43	0.92	0.411	0.143
Adults	1.65	0.63	0.279	0.097
Inhalation MRL	20	None	None	None
Chronic oral MRL converted to a Chronic inhalation MRL^a	--	6.7 ^b	42.8 ^c	60.9 ^d

^a When an inhalation MRL is not available and when inhalation LOAELs or NOAELs are not available, the oral MRL can be used to derive an inhalation Target Organ Toxicity Dose for inhalation.

^b For bromodichloromethane, the chronic oral MRL of 0.018 mg/kg/day was used to derive a chronic inhalation MRL.

^c For dibromochloromethane, the chronic oral MRL of 0.09 mg/kg/day was used to derive a chronic inhalation MRL.

^d For bromoform, the chronic oral MRL of 0.2 mg/kg/day was used to derive a chronic inhalation MRL.

Table 14. Inhalation Hazard Quotient (HQ) for children and adults for each chemical in Endicott's water. The HQ is rounded to one significant figure.

Age Group	1,1-DCA	cis-1,2-DCE	TCA	VC	trans-1,2- DCE	TCE
Children	0.007	0.03	0.02	0.005	0.01	0.002
Adults	0.007	0.02	0.02	0.004	0.008	0.001

Table 15. Inhalation Hazard Quotient (HQ) for children and adults for each chemical in Endicott's water. The HQ is rounded to one significant figure.

	Chloroform	Bromodichloro- methane	Dibromochloro- methane	Bromoform
Children	0.1	0.1	0.01	0.002
Adults	0.08	0.09	0.007	0.002

APPENDIX E

Interim Public Health Hazard Category Classification

INTERIM PUBLIC HEALTH HAZARD CATEGORIES

CATEGORY / DEFINITION	DATA SUFFICIENCY	CRITERIA
<p>A. Urgent Public Health Hazard</p> <p>This category is used for sites where short-term exposures (< 1 yr) to hazardous substances or conditions could result in adverse health effects that require rapid intervention.</p>	<p>This determination represents a professional judgment based on critical data which ATSDR has judged sufficient to support a decision. This does not necessarily imply that the available data are complete; in some cases additional data may be required to confirm or further support the decision made.</p>	<p>Evaluation of available relevant information* indicates that site-specific conditions or likely exposures have had, are having, or are likely to have in the future, an adverse impact on human health that requires immediate action or intervention. Such site-specific conditions or exposures may include the presence of serious physical or safety hazards.</p>
<p>B. Public Health Hazard</p> <p>This category is used for sites that pose a public health hazard due to the existence of long-term exposures (> 1 yr) to hazardous substance or conditions that could result in adverse health effects.</p>	<p>This determination represents a professional judgment based on critical data which ATSDR has judged sufficient to support a decision. This does not necessarily imply that the available data are complete; in some cases additional data may be required to confirm or further support the decision made.</p>	<p>Evaluation of available relevant information* suggests that, under site-specific conditions of exposure, long-term exposures to site-specific contaminants (including radionuclides) have had, are having, or are likely to have in the future, an adverse impact on human health that requires one or more public health interventions. Such site-specific exposures may include the presence of serious physical or safety hazards.</p>
<p>C. Indeterminate Public Health Hazard</p> <p>This category is used for sites in which “critical” data are <i>insufficient</i> with regard to extent of exposure and/or toxicologic properties at estimated exposure levels.</p>	<p>This determination represents a professional judgment that critical data are missing and ATSDR has judged the data are insufficient to support a decision. This does not necessarily imply all data are incomplete; but that some additional data are required to support a decision.</p>	<p>The health assessor must determine, using professional judgment, the “criticality” of such data and the likelihood that the data can be obtained and will be obtained in a timely manner. Where some data are available, even limited data, the health assessor is encouraged to the extent possible to select other hazard categories and to support their decision with clear narrative that explains the limits of the data and the rationale for the decision.</p>
<p>D. No Apparent Public Health Hazard</p> <p>This category is used for sites where human exposure to contaminated media may be occurring, may have occurred in the past, and/or may occur in the future, but the exposure is not expected to cause any adverse health effects.</p>	<p>This determination represents a professional judgment based on critical data which ATSDR considers sufficient to support a decision. This does not necessarily imply that the available data are complete; in some cases additional data may be required to confirm or further support the decision made.</p>	<p>Evaluation of available relevant information* indicates that, under site-specific conditions of exposure, exposures to site-specific contaminants in the past, present, or future are not likely to result in any adverse impact on human health.</p>
<p>E: No Public Health Hazard</p> <p>This category is used for sites that, because of the absence of exposure, do NOT pose a public health hazard.</p>	<p>Sufficient evidence indicates that no human exposures to contaminated media have occurred, none are now occurring, and none are likely to occur in the future</p>	

*Such as environmental and demographic data; health outcome data; exposure data; community health concerns information; toxicologic, medical, and epidemiologic data; monitoring and management plans.

Appendix F
Response to Public Comments

After releasing this health consultation on October 12, 2004, ATSDR and NYDOH received several comments from the public. These comments are listed below along with the agency's response, including a description of changes that were in the health consultation because of the comment. All page numbers referred to in the public comments listed below relate to the public comment version of this health consultation.

1. Comment: The health consultation does not include trichloroethylene (TCE), which is the main chemical of concern in the environmental issues in Endicott.

Response: The reason ATSDR and NYS DOH did not include TCE in the public release of the health consultation was because TCE is found infrequently in Endicott's municipal water supply. From 1980 to 2004, TCE was detected three times out of 59 samples from well 5. TCE was not detected in any of the 58 samples from well 28. Because TCE was raised as a concern, however, the original analysis conducted for the draft public comment health consultation was revised to consider TCE. We would like to caution the reader, though, that the average level calculated for well 5 (that is, 0.3 ppb) most likely overestimates the actual average level of TCE because we used 1/2 the detection limit for the 56 times that TCE was not detected (please see Discussion, Summary of Environmental Data and Exposed Populations Section for an explanation of detection limit issues).

The addition of TCE did not change the conclusions of the October 2004 draft public comment health consultation. Moreover, TCE and other organic chemicals not originally included in the analysis were included in a "worst-case" analysis in response to public comments (see response to comment 6 below).

2. Comment: Of the nine chemicals listed in Table 16 on page 16, only four are ultimately considered in the calculation of cancer risk from drinking water. Of the chemicals from the table that are used in the calculation, all are trihalomethanes (THMs) that originate from the chlorination of the drinking water. So, the chemicals that were "spilled" into the aquifer are not even considered.

Response: Vinyl chloride is not a THM but is a breakdown product of "spilled chemicals" and is included in the estimate of cancer risk from drinking Endicott's water (see Table 17). For three of the chlorinated chemicals listed in Table 16 (cis-1,2-DCE, trans-1,2-DCE, and TCA), either no information is available or inadequate information is available about the chemicals' ability to cause cancer. As indicated in response to comment 1 previously, we included TCE, a probably human carcinogen, in the revised analysis for the final health consultation.

No human or animal studies have been conducted to evaluate whether exposure to cis-1,2-DCE or trans-1,2-DCE could cause cancer. When long-term cancer studies are not available, clues to a chemical's ability to cause cancer might be found in genetic studies on microorganisms. These studies typically evaluate a chemical's ability to cause direct damage to DNA (deoxyribonucleic acid), the chemical that makes up the genes that are involved in cancer. All such studies for trans-1,2-DCE have been negative, that is, trans-1,2-DCE does not appear to damage DNA; therefore, it is unlikely that trans-1,2-DCE might cause cancer in animals or humans. For cis-1,2-DCE, most studies have shown that cis-1,2-DCE does not damage DNA; however, a few studies

have shown that cis-1,2-DCE can damage DNA, particularly after activation by mammalian enzymes. The results for cis-1,2-DCE in microorganism make this chemical a candidate for long-term rodent studies that are conducted to assess whether a chemical might cause cancer in humans. Until these rodent studies are conducted, it is not possible to know if cis-1,2-DCE might cause cancer in humans.

For TCA, an inhalation study in rats and mice did not find evidence of increased cancer rates. Oral exposure to TCA in a rat study showed an increase in leukemia in rats; however, the authors of the study stated that definite conclusions about TCA's ability to cause leukemia could not be drawn because the study was poorly designed. Because of the limitations of this study, inadequate information is available about TCA's ability to cause cancer in humans.

As stated in Table 16, some evidence is available from animal studies that 1,1-DCA might cause cancer in rodents. A rodent study conducted by the National Cancer Institute (NCI) provided what NCI characterizes as suggestive, but not conclusive, evidence that 1,1-DCA can cause cancer in rodents and mice. A two-year study in rodents showed a non-statistically significant increase in cancers of the blood vessels and mammary glands in female rats and cancer of the liver in male rats. The increase was not statistically significant because animals in both the control and the treated groups died, thus reducing the study's ability to rule out chance variation as the reason for the increase in cancer rates. However, a statistically significant increase was found in uterine cancer in female mice. Because of poor survival rates, NCI concluded that the evidence for cancer was only suggestive. In another mouse study, another investigator did not find an increase in lung and liver tumors. Therefore, 1,1-DCA is characterized as having some evidence from animal studies for causing cancer.

Because of the limitations in studies on 1,1-DCA, 1,2-DCE, and TCA, U.S. EPA has not developed a quantitative method for estimating a numerical cancer risk. Therefore, it is not possible to include these chemicals in any numerical estimate of cancer risk at this time.

Our impression is that the commenter is pointing out that the inability to estimate a numerical cancer risk adds uncertainty to the numerical cancer risk that is presented in Tables 17 and 18. We agree and will add the following text to the health consultation to describe this uncertainty:

“It should be noted that the estimated cancer risk of 0 to 11 cancers per million people exposed by drinking Endicott's water does not include the cancer risk, if any, that might come from four other chlorinated chemicals in Endicott's drinking water: cis-1,2-DCE, trans-1,2-DCE, 1,1-DCA, and TCA (see Table 16). For these other chlorinated chemicals either insufficient information exists to calculate a cancer slope factor, a number needed to estimate a numerical cancer risk, or insufficient information exists to determine whether these chemicals can cause cancer in rodents or humans.

3. Comment: On page 16, it is stated that the total cancer risk from these four chemicals is between 0 and 5 cancers per million people. Contaminants in our drinking water that can cause 5 cancers per million people is not acceptable.

Response: Because of the estimated increase in cancer risk, ATSDR and NYS DOH concluded that using Endicott's municipal water might result in a low increased risk of cancer. A large portion of the estimated risk from drinking Endicott's water comes from vinyl chloride, which has an estimated risk of 0 to 4 cases of cancer for every one million people who drank Endicott's water for 30 years. We believe the actual risk from vinyl chloride is closer to zero because vinyl chloride was detected only once in well 5 and only 4 times in well 28 during the 24 years that these wells were monitored. Vinyl chloride was not detected in the remaining 62 samples from well 5 and 61 samples from well 28. The estimated risk of 4 cancer cases comes mostly from assuming that vinyl chloride was present at ½ the detection limit. Using ½ the detection most likely overestimates the actual risk from vinyl chloride in these wells over the 24 year sampling history. We used the approach of assuming ½ the detection limit because this is commonly used by public health agencies in evaluating environmental exposures. We have added the following sentences to the health consultation that provides more information about the uncertainty in the cancer risk from vinyl chloride:

“A large portion of this estimated cancer risk from drinking Endicott's water comes from vinyl chloride, which has an estimated risk of 0 to 4 cases of cancer for every one million people who drank Endicott's water for 30 years. We believe the actual risk from vinyl chloride is closer to zero because vinyl chloride was detected only once in well 5 and only 4 times in well 28 during the 24 years that these wells were monitored. Vinyl chloride was not detected in the remaining 62 samples from well 5 and was not detected in 61 samples from well 28. The estimated risk of 4 cancer cases comes mostly from assuming that vinyl chloride was present at near the detection limit. It is reasonable to assume that vinyl chloride was probably not present at all when samples came back as non-detectable, which would make the cancer risk from vinyl chloride close to zero. Similar to vinyl chloride, TCE is unlikely to increase cancer risk for anyone drinking Endicott's water because TCE was found only 3 times over the 24-year sampling period.”

4. Comment: Of the nine chemicals listed in Table 16 on page 16, only three are considered in the calculation of cancer risk from bathing and showering.

Response: Much of what is explained previously in response 2 applies here to the chemicals listed in Table 16. To summarize briefly, it is not possible to estimate a numerical cancer risk for seven chemicals in Table 16 because U.S. EPA could not

develop a cancer slope factor or because it is not known whether the chemicals can cause cancer.

As mentioned previously, however, our impression is that the commenter is pointing out that the inability to estimate a numerical cancer risk adds uncertainty to the numerical cancer risk that is presented in Table 18. We will add the following text to the health consultation that describes this uncertainty:

“This estimated cancer risk does not include any cancer risk that might come from several other chlorinated chemicals and trihalomethanes in Endicott's water because either insufficient information exists to calculate a cancer slope factor, a number needed

to estimate a numerical cancer risk, or because insufficient information exists to determine whether these chemicals can cause cancer in rodents or humans.”

5. Comment: Again, the conclusion for evaluating the combined cancer risk (page 18) ranges from zero to 11 cancers per million (including chloroform, which is included and excluded in the discussion in this report. Eleven additional cancers per million is not acceptable to the community.

Response: We believe that while this is the theoretical range of estimated cancer risks that can be calculated from the municipal well data, the actual risk is probably closer to zero than to 11. We will provide a better explanation of uncertainty in the public health consultation so that the reader understands the uncertainty in the estimated cancer risk. We will revise several sentences in the conclusions to read as follows:

“ATSDR and NYS DOH concluded that the cancer risk from using Endicott’s public water is low. This description of cancer risk comes from estimating a cancer risk in the range of 0 to 11 cases of cancer for every 1 million people that used Endicott’s water for 30 years. It is our belief, however, that the estimated cancer risk is close to zero because of uncertainties in how these cancer risks are estimated. These uncertainties are explained in more detail in the text.”

6. Comment: The assumptions used in Estimating Inhalation Exposure to Chemicals that Evaporate from Water (Appendix C, pages 35 – 36) can be challenged:

- a. Fraction of chemical (k) that evaporates from water while showering is assumed to be 0.6. For all chemicals? Based on what evidence? Source of this estimate?
- b. Duration of shower (Ts) ten minutes? Ten minute showers are much too short to reflect the reality of showering for many people. Also, the shower is on for X amount of time, but many people are in the bathroom for more than just the shower. Many people may be in the bathroom for a half hour or more and be breathing that contaminated air.

In addition to the concerns about the assumptions in the draft public comment health consultation regarding the duration of showers, concern was expressed in other public comments regarding:

- The use of ½ the detection limit for chemicals in water samples considered not detected, instead of using non-detectable concentrations just below the detection limit.
- Inclusion of all years of data from the Ranney well instead of from 1992 forward.
- The inclusion of chemicals only detected a few times (TCE, methylene chloride, MTBE, PCE, benzene, and others).

The following “worst-case” analysis considers persons who take long showers, but also includes revised data that calculates the average for a chemical at the just below the detection limits instead of ½ the detection limit, averages for all available data for the Ranney well (including

data before 1992), and includes chemicals that were detected only a few times which also includes “spilled chemicals”.

Response to 6

ATSDR and NYS DOH have re-calculated the concentration of chemicals in Endicott’s water using a concentration just below the detection limit when the chemical was not detected. Table 19 provides a comparison of this concentration to the concentration when ½ the detection limit was used to estimate the concentration when the chemical was not detected.

Table 19. Average Concentration of Chemicals		
Chemical	Using Concentration just below the detection limit for non-detectable samples in ppb	Using ½ the detection limit for non-detectable samples in ppb
Cis 1,2-DCE	1.73	1.69
1,1-DCE	0.56	0.29
1,1-DCA	0.83	0.79
TCA	0.99	0.92
TCE	0.57	0.33
VC	0.65	0.34
Trans 1,2-DCE	0.84	0.58
Chloroform	7.64	7.6
BDCM	4.06	3.9
DBCM	2.4	2.2
Bromoform	1.39	0.33

As expected, the concentration of all chemicals is slightly higher when a concentration just below the detection limit is used instead of using ½ the detection limit. It is important to realize, though, that the concentration calculated by using a value just below the detection limit is not drastically different from the concentration calculated using ½ the detection limit. The higher concentration was used to answer the questions that follow.

Response to Comment 6a; Fraction of Chemical that Evaporates from Water

The assumption that 60% of the chemical will evaporate from shower water comes from several experiments conducted by T. E. McKone and G. A. Keating (McKone 1991, Keating 1997). McKone’s experiment showed that 60% of TCE was transferred from water to air during a shower. McKone also found that water temperature did not affect the percentage of TCE transferred to air nor did shower times up to 20 minutes change the percentage. Keating conducted similar experiments with chloroform, showing that 65% of chloroform was transferred to air during a shower using standard shower nozzles.

ATSDR and NYS DOH are assuming that the other chemicals have similar volatilization percentages during showers.

In addition to considering how much chemical evaporated during a shower, we took the estimated value that remains in the shower water and estimated how much chemical is absorbed through the skin. The estimated amount of dermally absorbed chemical was then added to the estimated amount that evaporated. Using both the evaporated amount and the dermally absorbed amount allowed us to have a better estimate of total exposure than had we only looked at how much chemical evaporated.

Because of the comment, however, we decided to see what effect would result should a different percentage be used for how much chemical evaporated from shower water. Instead of the 60% that was used, we changed the percentage to 90%, that is, we assumed that 90% of the chemical evaporated from the shower water and 10% remained for dermal absorption. We calculated HQs for two chemicals assuming 90% of the chemicals evaporated during the shower. We then compared these HQs to the HQs that were determined assuming 60% of the chemical evaporated. The results follow:

Inhalation HQ 1,1-DCA (60%)	0.0649
Inhalation HQ 1,1-DCA (90%)	0.065
Inhalation HQ chloroform (60%)	0.0160
Inhalation HQ chloroform (90%)	0.0186

While small differences are found in the HQs, the differences are very small and do not change the outcome of the evaluation. The reason the differences are so small is because we included dermal absorption as part of the inhalation HQ for each chemical.

Response to 6b: Changing Shower Times and Bathroom Stays

The shower time of 10 minutes comes from work by Andelman and from U.S. EPA's Exposure Factors Handbook, which provides information about the average length of a shower. We have reviewed U.S. EPA's Exposure Factors Handbook (EFH) (Chapter 15) again and have decided to change the length of time for showers. The average shower time will be changed to 15 minutes; and, 35 minutes will be used as the shower time for 5% of the people who take longer showers. Specifically, 5% of the people take showers that last longer than 30 minutes. These shower times of 15 and 30 minutes are reported in Table 15-21 (EFH, Chapter 15) as the 50th and 95th percentile and come from a national survey conducted by U.S. EPA, the National Human Activity Pattern Survey (NHAPS). U.S. EPA's Chapter 15 can be found at this website: <http://www.epa.gov/ORD/WebPubs/exposure/chap15.pdf>

We also reevaluated the length of time that people stayed in the bathroom. This activity is also covered in U.S. EPA's EFH in Chapter 15 and was information gathered during U.S. EPA's NHAPS survey. The average person remains in the bathroom for 10 minutes

after a shower while the 95th percentile person remains in the bathroom for 30 minutes (that is, 5% of the people remain in the bathroom after bathing for more than 30 minutes). Therefore, we will use a 30-minute shower time and an additional 30-minute bathroom stay for 5% of the people who remain in the bathroom for longer periods. Table 20 shows the average shower times and bathroom stays for various age groups.

Table 20. Shower Times and Bathroom Stays				
	Average Shower Time in minutes	Average Bathroom Stay in Minutes	Extended Shower Time for 5 percent of people in minutes	Extended Bathroom Stay for 5 percent of people in minutes
1 to 4 years	10	2	50	15
5 to 11 years	15	5	40	15
12 to 17 years	15	5	45	30
18 to 64 years	15	10	30	30
65 and older	10	10	30	30

Making these two changes will give an estimated exposure for the typical person (that is, a person who takes a 15-minute shower and remains in the bathroom for 10 minutes) and for the person who takes a 30-minute shower and remains in the bathroom for 30 minutes afterwards. When estimating the bathroom air concentration for 5 percent of children who take very long showers, ATSDR and NYS DOH used the longer shower times of 40, 45, and 50 minutes depending on the age group (see Table 20).

We also evaluated other chemicals that occurred infrequently in Endicott’s public water and that were not listed in the original public release of the health consultation. We evaluated these chemicals because residents were concerned about their presence in public water. The chemicals are listed here:

- TCE
- Methylene Chloride
- Tetrachloroethylene (PCE)
- Benzene
- Toluene
- Chloroethane
- Methyl-t-butyl ether
- n-Propyl benzene

Results of Additional Evaluation For Oral Exposures

Chronic Oral Exposure from Drinking Endicott’s Water

Using all of the environmental data from Endicott’s municipal water and the higher detection limit, the chronic oral HQs for THMs and VOCs are significantly below 0.1 for

all age groups (children and adults) (see Tables 21 and 22). The HQs for the VOCs not included in the public release version of the report (e.g., TCE, methylene chloride, PCE, benzene, etc.) also were far below 0.1.

Because the HQ for each chemical is below its respective health guideline, noncancerous harmful effects are not likely. Because none of the individual HQs exceed 0.1, it is not necessary to calculate the HI for the mixture. The chemicals will not interact to cause harmful effects.

Age Group	1,1-DCA	cis-1,2-DCE	TCA	VC	t1,2DCE	TCE
Children 1 to 3 years	0.0005	0.01	0.0002	0.01	0.003	0.02
Children 3.1 to 5 years	0.0004	0.009	0.0002	0.01	0.002	0.02
Children 6 to 12 years	0.0002	0.003	0.00007	0.004	0.0008	0.007
Teenagers 13 to 17 years	0.0001	0.003	0.00006	0.004	0.0007	0.007
Adult women 18 years and older	0.0002	0.004	0.00008	0.005	0.001	0.009
Adult men 18 years and older	0.0002	0.003	0.00007	0.004	0.0009	0.008

	Chloroform	Bromodichloro-methane	Dibromochloro-methane	Bromoform
Children 1 to 3 years	0.05	0.01	0.002	0.0003
Children 3.1 to 5 years	0.04	0.01	0.001	0.0004
Children 6 to 12 years	0.02	0.004	0.0005	0.0001
Teenagers 13 to 17 years	0.01	0.004	0.0005	0.0001
Adult women 18 years and older	0.02	0.005	0.006	0.0002
Adult men 18 years and older	0.02	0.004	0.0005	0.0001

Results of Additional Evaluation For Inhalation Exposures Using Extended Shower Times and Bathroom Stays

Chronic Inhalation Exposure from Showering in Endicott's Water

To address concerns raised about the length of time that people take showers and remain in the bathroom afterwards, ATSDR changed its input parameters for its shower model to evaluate the possibility of harmful effects occurring in people who take longer showers and remain in the bathroom for longer periods. We will evaluate exposure for the 5

percent of the people who take extended showers and have extended bathroom stays. Depending on the age group, 5 percent of people take showers that last 30 to 50 minutes and stay in the bathroom afterwards for 15 to 30 minutes (see Table 20).

Using all the environmental data, extended shower times and bathroom stays, and the higher detection limit, the chronic inhalation HQs for people who take extended showers and have extended bathroom stays are shown in Tables 23 and 24. The HQs for each VOC, bromochloromethane, and bromoform are below 0.1. The HQs for the VOCs not included in the public release version of the report (e.g., TCE, methylene chloride, PCE, benzene, etc.) also were far below 0.1. Only chloroform and bromodichloromethane have HQs of 0.1

Table 23. Inhalation Hazard Quotient (HQ) for children and adults for each chemical in Endicott's water. The HQ is rounded to one significant figure.						
Age Group	1,1-DCA	cis-1,2-DCE	TCA	VC	trans-1,2-DCE	TCE
Children	0.007	0.03	0.02	0.01	0.02	0.003
Adults	0.007	0.02	0.02	0.007	0.01	0.002

Table 24. Inhalation Hazard Quotient (HQ) for children and adults for each chemical in Endicott's water. The HQ is rounded to one significant figure.				
	Chloroform	Bromodichloromethane	Dibromochloromethane	Bromoform
Children	0.1	0.1	0.01	0.003
Adults	0.08	0.1	0.007	0.002

It is important to remember that the individual HQ for each chemical indicates how close the estimated exposure is to exceeding a health guideline. For instance, the chloroform HQ of 0.1 for children and the bromodichloromethane HQ of 0.1 for children and adults means that the estimated exposure is 10 times below the health guideline for each chemical. No harmful effects are likely from exposure to these chemicals. In addition, no evidence exists that chloroform and bromodichloromethane act synergistically. Because the chemicals are trihalomethanes, they are assumed to act in an additive manner. Therefore, the combined HI for the two chemicals is the sum of their individual HQs. The combined HI for chloroform and bromodichloromethane is 0.2. Because the combined HQ of 0.2 is below 1, harmful effects are not likely.

ATSDR and NYS DOH have concluded that the small amount of VOCs and trihalomethanes in Endicott's water is not likely to have a mixture effects for people who take extended showers and have extended bathroom stays. The people who have typical shower times (i.e., 15 minutes) and typical bathroom stays (10 minutes) have

lower exposure. Therefore, noncancerous harmful effects are not likely regardless of how long a shower is or how long someone stays in the bathroom afterwards.

As stated above, this conclusion regarding non-cancerous effects also takes into account other concerns by the public regarding assumptions made in the public comment version of this health consultation and the addition of other chemicals not included in the original analysis.

Evaluating Cancer Risk for People Who Take Extended Showers and Have Extended Bathroom Stays

Using all the environmental data, extended shower times and bathroom stays, and the higher detection limit, The Table 25 shows the estimated cancer risks for chemicals that have a cancer slope factor. The estimated cancer risk ranges from a low of less than 1 in a million (e.g., bromoform) to a high of 0 to 8 cases per million people exposed (vinyl chloride). The combined cancer risk from oral and inhalation exposure is 0 to 20 cancer cases per million people exposed (or 0 to 2 per 100,000 people exposed). It is important to remember that this cancer risk isn't the risk for all people in Endicott, but rather only for those 5 percent of people who take extended showers and have extended bathroom stays. Most of the estimated cancer risk comes from the estimated risk for vinyl chloride (11 per million) and chloroform (2 per million).

Chemical	Risk from Oral Exposure	Risk from Inhalation Exposure
Vinyl Chloride	0 to 8 per 1,000,000	0 to 3 per 1,000,000
Chloroform	0 to 2 per 1,000,000	0 to 0.2 per 10,000
Bromodichloromethane	0 to 2 per 1,000,000	Not Available
Dibromochloromethane	0 to 2 per 1,000,000	Not Available
Bromoform	0 to 0.1 per 1,000,000	0 to 0.7 per 1,000,000
TCE	0 to 2 per 1,000,000	Not available
Total Risk By Route	0 to 16 per 1,000,000	0 to 4 per 1,000,000
Total Risk	0 to 20 per 1,000,000 or 0 to 2 per 100,000	

A large portion of the total estimated cancer risk from using Endicott's water comes from vinyl chloride, which has an estimated risk of 0 to 8 cases of cancer for every one million people who drank Endicott's water for 30 years and 0 to 3 cases of cancer for every one million people who showered in Endicott's water. We believe the actual risk from vinyl chloride is closer to zero because vinyl chloride was detected only once in well 5 and only 4 times in well 28 during the 24 years that these wells were monitored. Vinyl chloride was not detected in the remaining 62 samples from well 5 and was not detected in 61 samples from well 28. The combined (oral and inhalation) estimated risk of 0 to 11

cancer cases comes mostly from assuming that vinyl chloride was present at the detection limit. It is reasonable to assume that vinyl chloride was probably not present at all when samples came back as non-detectable, which would make the cancer risk from vinyl chloride close to zero. Similar to vinyl chloride, TCE is unlikely to increase cancer risk for anyone using Endicott's water because TCE was found only 3 times over the 24-year sampling period. It also is important to realize that the risk of cancer from chloroform probably approaches or is close to zero. The chloroform levels are too low to cause liver and kidney damage, which is thought to be necessary to increase the risk of cancer.

U.S. EPA has developed a new policy specifically for chloroform, which is described in the text of this health consultation for Endicott. The text is repeated here:

“U.S. EPA has revised its method for evaluating the carcinogenicity of chloroform; it no longer recommends an oral cancer potency factor for chloroform (U.S. EPA 2004). U.S. EPA made this change because evidence suggests that chloroform-induced kidney and liver cancers in laboratory animals result only at high exposure levels that lead to repeated cellular damage and regeneration in the liver and kidneys. Scientists believe that excessive regeneration following chloroform damage is the process that leads to the formation of cancer cells. U.S. EPA's Science Advisory Board has reviewed the agency's policy and agreed that chloroform-induced cancers are probably the result of high levels of exposure. But some members of the Science Advisory Board cautioned that it is not known if this is the only way chloroform could cause cancer. Because of this uncertainty, this health consultation will still report a numerical risk from low-level chloroform but cautions the reader that the risk probably approaches or is close to zero – the chloroform levels are too low to cause cell damage and regeneration.”

If the risk of cancer from vinyl chloride, TCE, and chloroform approaches or is close to zero, the estimated risk of cancer from the other chemicals in Endicott's water is 0 to 5 cases for every 1 million people who used Endicott's water for 30 years and who took extended showers and extended bathroom stays.

In the public release health consultation for Endicott, ATSDR and NYS DOH concluded that the estimated cancer risk from using Endicott's public water is low. This conclusion remains the same. Again, as stated above, this conclusion regarding cancerous effects also takes into account other concerns by the public regarding assumptions made in the public comment version of this health consultation and the addition of other chemicals not included in the original analysis.

7. Question: Why does ATSDR use an HQ of 0.1 as a cut off for deciding when to evaluate interaction effects between two chemicals?

Response: An HQ of 0.1 was chosen as a cut off for deciding when to evaluate two chemicals for possible interaction effects for the following reason:

When an HQ for a chemical is less than 0.1, it means that the estimated dose for someone is more than 10 times below the health guideline. Since most health guidelines are set

100 to 1,000 times below levels that cause mild effects, an HQ that is less than 0.1 means that the estimated dose is now more than 1,000 to 10,000 times below levels that cause mild effects. ATSDR could find no examples in the scientific literature where interaction effects between chemicals would be significant when their estimated doses were 1,000 to 10,000 times below effect levels, even when these interactions might be synergistic. Therefore, using an HQ of 0.1 seems to be a very conservative tool for eliminating chemicals for further evaluation.

8. Question: Table 2, page 26 of draft report—why was there no data for 1983-1985—was well 5 offline?

Response: In addition to answering the question posed by the public, ATSDR and NYS DOH, with assistance from the Broome County Health Department, also tried to determine why there were no sampling data for Well 28 from 1984-1987 and to determine why there were no THM distribution data from 1988-late 1995.

The Broome County Health Department reviewed their records and confirmed that there are no sampling data points for VOCs for the periods indicated on Table 2. Routine monitoring for VOCs was required by the New York State Department of Health regulations beginning in January of 1988. Prior to that date, most water supplies initiated sampling to determine the scope of VOC contamination at their groundwater sources. Most larger supplies, including the Village of Endicott, continued this sampling at their primary sources as a means to monitor the quality of water served to consumers. During the period from 1983-1987, Wells #5 and #28 were considered a single source withdrawing from a common aquifer. That is why both sources were not always sampled at the same time. Samples were taken for one of the supplies in every year except in 1984. By January 1988, most problems at Broome County groundwater sources had been identified. Monitoring was then initiated to track exposures at all routine supply sources.

The THM data that NYS DOH gathered from available databases did not show data for the time between 1988 and late 1995. Subsequent to the public comment draft, NYS DOH staff worked with the Broome County Health Department to fill the data gap. The Broome County Health Department provided additional THM data for 1988 - 1995, with the exception of 1993. These data are included in the final document and are used in the calculations for the “worst-case” analysis described in response to comment 6 above.

9. Comment: In Appendix A—Tables 4, 5, and 6, is the maximum the maximum possible or the maximum reading at Endicott. Some of the report is written very technically and is hard to understand.

Response: The value provided is not the maximum possible value. The maximum value provided in Tables 4, 5, and 6 were the maximum level for each contaminant detected in either the Ranney Well, the South Street Wells, or in the distribution system (for THMs only). For example, in Table 4, for 1,1 DCA, the maximum level detected in Well 5 between 1980 and 2004 was 1.76 ppb.

Although ATSDR and NYS DOH attempted to make the discussion of the mixtures methodology and our findings based on the results of the evaluation of the exposures to VOCs in the Endicott public drinking water clear and easy to read, we acknowledge that there is much technical information in the report. Because of this, we held two working sessions with the WBSEC and one availability session with the general public to explain the results and how we arrived at them. In addition, for those who are not interested in the technical portion of the report, we suggest that you review the conclusions and recommendations of the health consultation and the information sheet that was developed for the release of the public comment version of the report in October 2004. (Further, the public is welcome to contact the authors of the report for additional information or explanation).

10. Question: Are there any interaction with heavy metals like lead in pipes?

Response: ATSDR performed an initial review of the toxicological literature to determine if there is any evidence of an interactive effect of VOCs with lead. Currently there is insufficient evidence available to determine if there are interactive effects between VOCs and lead. Additional review will be performed when ATSDR updates its Toxicological Profile for lead.

11. In Table 4, Summary of VOC Water Sampling Results (page 27) the asterisk states that the arithmetic mean is a more appropriate measure. In the calculations on page 36, the geometric mean is use. Why?

Response: The concentration reported on page 36 is incorrect. We have changed it to the arithmetic average.

12. No matter how many times I tried calculating the example in this description, I get a different answer than the one shown.

Response: We have reviewed the calculations in Appendix C and placed parentheses as needed to show the order of division and multiplication steps. Hopefully, the steps are clearer now and can be followed more easily.

13. Under Discussion B, Public Health Implications, 'Cancer Risk', does the report analyze the effect of the mix of chemicals or only chemicals on a one-by-one instance?

Response: ATSDR and NYS DOH examined the combination of chemicals in Endicott's water to cause a mixture effect in producing cancer. No information could be found that shows that chemicals might act in a synergistic way to cause a greater risk of cancer than what might be expected. Therefore, ATSDR and NYS DOH assumed that the risk of cancer from the mixture of chemicals is additive; that is, the total risk of cancer is the sum of the individual risk of cancer for each chemical.

The sum of the individual cancer risks is explained in the text of the health consultation

and presented in Table 17 for drinking water and Table 18 for bathing. ATSDR and NYS DOH have characterized the risk of cancer as low. As stated in the text and in the conclusion, over half the of the estimated cancer risk comes from vinyl chloride, TCE, and chloroform. As mentioned previously, the risk of cancer from these chemicals is probably close to zero because the chemicals were either detected only a few times over 24 years or the levels are too low to cause the repeated cellular damage that is thought to lead to cancer.

Additional text has been added to the public health implications section of the health consultation to better explain the issues raised by this comment.

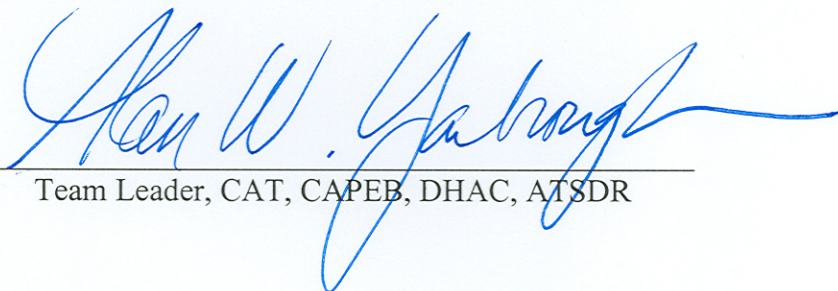
CERTIFICATION

The health consultation for the evaluation of the public health implications of exposures to VOCs in public drinking water for the Endicott Area Investigation was prepared by ATSDR and by the New York State Department of Health under a cooperative agreement. It is in accordance with approved methodology and procedures existing at the time the health consultation was initiated. Editorial review was completed by the cooperative agreement partner.



Technical Project Officer, CAT, CAPEB, DHAC

The Division of Health Assessment and Consultation (DHAC), ATSDR, has reviewed this health consultation, and concurs with its findings.



Team Leader, CAT, CAPEB, DHAC, ATSDR