

Health Consultation

ATHENS CLARKE COUNTY MUNICIPAL SOLID WASTE LANDFILL

ATHENS, CLARKE COUNTY, GEORGIA

CERCLIS NO. GA0001923903

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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.

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Prepared by:

**Georgia Division of Public Health
Under Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry**

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Summary

The Georgia Environmental Protection Division (GEPD) issued a permit for construction and operation of the Athens-Clarke County Municipal Solid Waste Landfill in 1976. In May 1988, contaminants were detected in drinking water from a well on the landfill property. Employees of the landfill property, including the caretakers and their children living on site, were using the contaminated groundwater for their drinking and domestic water supply. Upon discovering the contamination, GEPD and Athens-Clarke County immediately provided employees with an alternative water source and initiated extensive groundwater monitoring in the area. Through the monitoring, GEPD confirmed that several contaminated groundwater plumes are moving from the landfill toward nearby residential properties. GEPD sampled drinking water from water wells within 500 feet of the landfill property; no contaminants were found in any of the water wells at levels exceeding comparison values.¹ To ensure that future exposures would not occur, Athens-Clarke County took several precautionary measures, including providing nearby downgradient homesites with water from the municipal system and purchasing and vacating several residential properties bordering the landfill.

GEPD asked the Georgia Division of Public Health (GDPH) to conduct a public health investigation at this site. The cooperation between GDPH and GEPD was initiated through a memorandum of agreement for GDPH to address public health hazards at sites in Georgia, which GEPD regulates and where GEPD is concerned about environmental contamination. At this site, GEPD is concerned about possible adverse health effects caused by past, present, and future exposure to environmental contamination, specifically drinking water, from the landfill.

Employees and the family members who lived on the site and drank contaminated water might have experienced adverse health effects if exposure had continued. At the levels that were present in their water and for the length of time they were exposed, we would not expect them to have any illnesses that would be attributed to their exposure. We can provide their health care providers with information about their exposures if they would like to discuss the issue with their health care providers. Their exposure stopped in 1988. GDPH recommends

- (1) to ensure that residents are not exposed to contaminants present in groundwater, contaminated groundwater should not be used for consumption or any other use where people may come into contact with it;
- (2) GEPD should continue to require that Athens-Clarke County define the nature and extent of off-site groundwater contamination;
- (3) Athens-Clarke County should continue remediation efforts;
- (4) Athens-Clarke County should continue monitoring off-site groundwater;
- (5) a public health information repository should be established at the local public library for residents to review public health reports pertaining to the site.

¹ Comparison values are levels of contaminants in specific environmental media, in this case groundwater, that are used to select contaminants for exposure evaluation. Any level below a comparison value is considered safe.

Purpose and Statement of Issues

The Georgia Environmental Protection Division (GEPD) requested that the Georgia Division of Public Health (GDPH) address health issues associated with the Athens-Clarke County Municipal Solid Waste Landfill, a county-managed, operating landfill. For this health consultation, GDPH reviewed available groundwater sampling data to determine whether past exposure could have harmed employees and the family that lived on the site and whether precautionary measures conducted and planned are protective of public health.

Background

GEPD issued a permit for construction and operation of the Athens-Clarke County Municipal Solid Waste Landfill in 1976. In May 1988, two organic compounds, tetrachloroethene and vinyl chloride, were detected at levels above comparison values in a drinking water well located on the landfill property. Employees and the caretaker's family who lived on the site used the well water for drinking and other domestic purposes. Immediate resampling confirmed the presence of contamination, and an alternative water supply was provided. Employees of the landfill who had used water from the well were exposed to the contaminants for an indeterminate period of time; however, some contamination might have entered the groundwater as early as 1977 when the landfill began operating [1]. At the time the contamination was discovered, the caretakers of the landfill property and their children had lived on the property for approximately three years [2]. No information was provided about their predecessors, and the caretakers immediately began using an alternative water source. No information is available about the health status of employees or their children.

The on-site well was initially screened in 1988 for organic compounds in response to a complaint about foul taste and odor. GDPH found nothing to suggest any previous complaints were made. Groundwater monitoring prior to 1988 was conducted in compliance with the Georgia Rules for Solid Waste Management². At that time, no routine screening was conducted for organic constituents.

GEPD sampled individual water wells within 500 feet of the landfill property, and no contaminants exceeding comparison values were detected in any private well during any sampling event [3]. Analyses of samples collected from monitoring wells installed by Athens-Clarke County confirmed that several contaminated groundwater plumes are moving from the landfill toward nearby residential properties. In January 1989, Athens-Clarke County provided funds to connect residences within 500 feet of the landfill to the county water supply and to provide for annual testing upon request of individual water wells within 1,000 feet of the landfill boundary [4].

² The adoption of both federal and state legislation relative to the operation of landfills has resulted in new standards initially included within the Georgia Solid Waste Management Act of 1990 and amended with more stringent requirements in 1992, 1993, and 1994.

As a direct response to the need to characterize the nature and extent of groundwater contamination and further protect the health of residents near the landfill, a Corrective Measures Assessment program was completed for this site in three phases: Task I included a summary of the groundwater monitoring program initiated in 1988 and established site-specific correction and remediation goals and health protection standards; Task II involved evaluating and selecting a closure cap as a short-term solution to the growing contamination problem; and Task III included the Corrective Measures Evaluation Report with recommendations for long-term corrective measures which exceed the minimum requirements to protect human health and the environment and involved a public participation phase where citizens commented on the chosen corrective measure(s).

In December 1997, GEPD approved a remediation plan submitted by Athens-Clarke County that proposed the acquisition of all properties currently impacted by the contaminant plumes, those properties which models predict will be impacted by the plumes at some future date, and expansion of the "buffer" zone between the landfill property and the residential area from 50 to 200 feet beyond the plumes' projected outer limits [3]. Athens-Clarke County's proposal is based on consultants' predictions of the eventual spread of the contaminant plumes over the next 40 years and is not a requirement by GEPD or the Georgia Rules for Solid Waste Management [4]. Athens-Clarke County's position is that the additional land is needed for the management of potential health risks and associated liability [5]. Approximately 12 residential properties have been purchased by Athens-Clarke County, and if the contaminant plumes continue to move or increase in size or quantity, more properties will be purchased, and residents will have to relocate.

Site Description

The Athens-Clarke County Municipal Solid Waste Landfill occupies approximately 300 acres southeast of downtown Athens, Georgia, on land in both Clarke and Oglethorpe Counties. It is the only operational landfill for those counties. The landfill is bordered by Lexington Road (U.S. 78) and Dunlap Road to the south and east respectively, by agricultural land to the north, and a creek to the west. The landfill is visible from Lexington Road, which is the only road providing access.

Existing Disposal Area 1 borders Dunlap Road and contains about 50 acres of unlined, filled, waste disposal cells used from the landfill opening until 1989. Disposal Area 1 has been covered with several feet of dirt and is partially vegetated with grass and pine trees. Existing Disposal Area 2 in the northwest corner of the site is also unlined and began accepting waste in 1989. It was recently closed. Disposal Areas 1 and 2 were constructed and operated in accordance with federal and state laws that existed at that time [6]. The remaining four disposal areas are in compliance with current standards, have leachate collection systems, and should not contribute to contamination problems [7].

Groundwater monitoring suggests that contamination move as "pulses," indicating that rainstorms are a primary force moving the contamination. Neither the position of the leak in the landfill nor whether the leak is a single point or a general diffuse leak is known. Groundwater

flow analyses, chemical transport modeling, and monitoring well sampling data suggest that the contamination plumes flow south-southeast, under a pasture, toward the small creek south of Dunlap Road. Because the source of contamination is unclear and the contaminant plumes could impact additional residential areas, GEPD required that Athens-Clarke County define the nature and extent of off-site groundwater contamination and to delineate the boundaries of the plumes. In addition, because rainfall appears to be a primary driving force for plume movement, once the contaminant source areas are properly capped to prevent rain water intrusion, contaminant levels entering the groundwater should be substantially reduced [7]

Site Visit

GDPH staff, accompanied by the Clarke County Health Department Environmental Health Program Manager and the District Environmental Health Program Manager, visited the area on March 22, 1999. GDPH staff made the following observations:

- Site access was controlled by the scale house attendant during working hours and by a security fence surrounding approximately 85% of the landfill property. The site is patrolled by a security guard, and the entrance gate is locked during non-operating hours. Physical hazards that exist on site include vehicles, machinery, and equipment.
- Activity at the site appeared routine. Vehicles and several structures were present on site.
- No odors or leachate were evident.
- Trees and other plants separated the site from adjacent residential structures.

Following an examination of the residential properties adjacent to the landfill, Athens-Clarke County personnel concluded the site visit with an in-depth review of past, present, and planned activities at the site and a detailed description of the strategies planned to protect human health and the environment.

Community Health Concerns

To date, neither GDPH nor the Clarke County or Oglethorpe County Health Departments have received inquiries from the community about the Athens-Clarke County Municipal Solid Waste Landfill. In March 1999, GDPH staff investigated the Clarke County and University of Georgia Libraries and the *Internet* for accounts of community involvement activities regarding this site. No information was found at those locations. No local repository has been established for community members to access or provide information about the site. Several articles regarding this site were found in local newspapers: the *Athens-Banner Herald*, the *Athens Daily News*, and the *Flagpole*. The articles were, primarily, about resident relocation efforts.

The Citizens' Advisory Committee currently meets quarterly to address community concerns, including the potential for development of adverse health effects, about this site. The committee was established as part of the Facilities Issues Negotiation Process between citizens and the government of Athens-Clarke County and the Oglethorpe County Board of Commissioners as a result of the proposed expansion of the landfill in November 1992. On April 2, 1999, GDPH

staff met with the Athens-Clarke County representative of the Citizens' Advisory Committee and obtained documentation of community involvement activities and residents' health-related concerns.

According to representatives from the Citizens' Advisory Committee and Athens-Clarke County, several area residents are troubled by the acquisition of properties currently affected and projected to be affected by the contaminated groundwater plumes. Residents have also expressed a need to more fully understand the technical issues associated with this site and whether a health and safety plan will be put into practice during remediation efforts. Those concerns can be addressed by Athens-Clarke County and GEPA.

Residents have requested information about soil, air, surface water, and groundwater contamination. This health consultation provides health information about past exposure to contaminated groundwater and evaluates whether actions taken and planned to prevent exposure to contaminated groundwater are protective of public health. As additional data become available, GEPA will review the information and will respond to any health concerns people express about the site.

Discussion

Tetrachloroethene and vinyl chloride were identified in the on-site drinking water well at levels above comparison values in 1988. Table 1 lists the maximum levels of the contaminants that were detected in the water. Further investigation revealed that the well casing had not been adequately sealed, so chemicals leaking from the adjacent landfill cells were entering the well water. Upon discovering the contamination, employees were immediately provided with an alternative water source. The well was converted to a monitoring well, and no drinking water wells remain on site.

Fifty-five on-site shallow and deep water aquifer monitoring wells have been installed on site and sampled for an approved set of indicator parameters, inorganic chemicals, and volatile organic compounds. Analyses of sample results indicate that several contaminant plumes exist in groundwater around Disposal Areas 1 and 2, and the plumes are moving toward nearby residential properties.

Off-site groundwater monitoring has been conducted to determine the extent, boundaries, chemical concentrations, and movement of the contaminant plumes. Results were compiled and used for mathematical modeling, risk assessments, and additional engineering studies were designed to provide information needed to identify long-term corrective measures needed to comply with the current Georgia Rules for Solid Waste Management.

Athens-Clarke County and GEPA collected samples from individual water wells within 500 to 1,000 feet of the landfill property in 1988 and from 1992 through 1993 [3]. No contaminants were detected in any private well during any sampling event at levels that exceeded comparison values [3]. Therefore, no one off the site has been exposed to contaminants at levels that would

cause adverse health effects. Athens-Clarke County provided municipal water for residents living within 500 feet of the landfill and has provided annual testing upon request of all remaining individual water wells within 1,000 feet of the landfill [4].

Employees and the caretaker's family were exposed to contaminated water prior to 1988. This site is not accessible to the public, and no indication was found that any other people were exposed to on-site groundwater. Table 1 summarizes the maximum levels of contaminants found in the on-site well before it was converted into a monitoring well, and Table 2 provides information about who was exposed to the contamination. The employees and those living on the site were exposed to tetrachloroethene and vinyl chloride through ingesting the water, inhaling the vapors that volatilized into the air, and touching the water when bathing and performing other household tasks with the water. GDPH estimated exposure doses and evaluated whether the people who used the water might experience adverse health effects as a result of their exposure. Appendix A details the equation used to estimate the exposure doses.

Tetrachloroethene

The highest level of tetrachloroethene found in the on-site drinking water well was 5.59 parts per billion (ppb) (Table 1). The comparison value (CV) is 5.0 ppb. The CV is based on the maximum contaminant level (MCL) established by the U.S. Environmental Protection Agency (EPA). See the Appendix for definitions of CVs used in this document.

Estimates for tetrachloroethene inhalation and ingestion doses were calculated. Inhalation exposure was estimated at the same dose as ingestion because a dose associated with showering and other normal household water uses is similar to the dose resulting from ingestion [8]. The estimated exposures doses for inhalation and ingestion were added together for children and for adults, and the doses were below levels that would cause noncancer, adverse health effects.

EPA is reviewing data on whether tetrachloroethene might cause cancer in people. Studies to date are inconclusive about whether tetrachloroethene causes cancer in people. High levels, doses ranging from 471 to 1,072 milligrams per kilogram body weight per day (mg/kg/day), which are several thousand times higher than doses that result from ingesting contaminated water at the site, given to rats and mice did produce some liver tumors. Studies of people who consumed lower levels of tetrachloroethene, 21 ppb tetrachloroethene, were not conclusive. The water in those studies contained higher levels of other chemicals, such as trichloroethene, and had other limitations, such as identification of exact exposure doses, that made results difficult to interpret. However, some people did develop cancer who drank water containing tetrachloroethene and other contaminants. Until the reviews of studies are complete, we cannot evaluate any cancer risk that might exist for the people who used the contaminated well water, but the increased risk is likely negligible because the level was so low.

Vinyl Chloride

The highest level of vinyl chloride found in the on-site drinking water well was 2.37 ppb. The lowest CV is 0.02 ppb. This CV has been set for carcinogenic substances. EPA and the

Department of Health and Human Services have determined that vinyl chloride is a human carcinogen [10].

Estimates for vinyl chloride inhalation and ingestion doses were calculated. Inhalation exposure was estimated at the same dose as ingestion because a dose associated with showering and other normal household water uses is similar to the dose resulting from ingestion [7]. The estimated exposure doses for inhalation and ingestion of vinyl chloride were added together for children and adults, and the doses exceeded the MRL. For that reason, GDPH researched exposure further. No human or animal data found in the current literature suggest that noncancer, adverse health effects occur as a result of exposure to the low levels of vinyl chloride found at this site.

Inhalation of vinyl chloride has been associated with liver cancer found in people exposed to high levels in the workplace. The levels those people breathed were not provided, but the lowest level that caused cancer in animals was at less than 50 parts per million, which is more than 1,000 times greater than the level found in the water from the site. EPA has developed a cancer slope factor for vinyl chloride to help evaluate the risk of developing cancer as a result of exposure to vinyl chloride. People exposed to vinyl chloride over a 70-year lifetime at the levels found in the drinking water have little increased risk of developing cancer. However, because vinyl chloride is a human carcinogen, contact with contaminated groundwater should be avoided, and monitoring should continue to ensure that no future exposure to contaminated groundwater occurs.

Child Health Initiative

ATSDR recognizes that the unique vulnerabilities of infants and children demand special emphasis in communities faced with contamination of their water, soil, air, or food. Children are at a greater risk than adults from certain kinds of exposures to hazardous substances emitted from waste sites and emergency events. They are more likely to be exposed because they play outdoors, and they often bring food into contaminated areas. They are more likely to come into contact with dust, soil, and heavy vapors close to the ground. Also, they receive higher doses of chemical exposure because of their lower body weights. The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages.

Evidence exists that children used water from the on-site well (the parents were caretakers of the landfill property for approximately three years) [2]. Upon discovery of the contamination, the family was immediately provided with an alternative water supply. After evaluating the exposure, GDPH and ATSDR found the exposure should not result in any adverse health effects [2]. If requested, GDPH can provide further information to both the family who lived on the site and to their health care provider. No one else has been exposed to contaminants at levels associated with adverse health effects, and other children should not be exposed in the future as a result of actions taken and planned.

Conclusions

Currently, the site poses no apparent public health hazard because exposure has stopped, and actions being taken will likely prevent future exposure.

The following conclusions are situation-specific.

1. Employees and the family members who used contaminated groundwater from the on-site well are not likely to develop adverse health effects as a result of their exposure because of the low levels of contaminants that were present in their water.
2. No one living within 500 feet of the landfill has been exposed to contaminants at levels associated with adverse health effects.
3. To ensure that future exposures will not occur, Athens-Clarke County has taken several precautionary measures, including providing nearby downgradient homesites with water from the municipal system. Additionally, Athens-Clarke County purchased several residential properties bordering the landfill to increase the buffer zone around the landfill and to prevent future development of property within the contaminant plumes.
4. No public repository has been established so that people can access information about this site.

Recommendations

The interpretation, advice, and recommendations presented are based on the data and information referenced and on discussion with state environmental officials. Additional data could alter the recommendations.

1. To ensure that residents are not exposed to contaminants present in groundwater, contaminated groundwater should not be used for consumption or any other use where people may come into contact with it.
2. Athens-Clarke County should continue remediation efforts.
3. Athens-Clarke County should continue monitoring off-site groundwater.
4. GDPH should establish a public health information repository at the local public library for residents to review public health reports pertaining to the site.

Public Health Action Plan

GDPH and ATSDR are committed to providing a plan of action to protect public health where recommendations indicate a need.

Actions Completed

GDPH provided this document for public review and comment at the Clarke County Public Library. That action opened the site repository, and other documents and information regarding this site may now be accessible at the library as they become available.

GEPD provided information to residents about contaminated groundwater. GDPH will provide assistance as needed.

To ensure that future exposures will not occur, Athens-Clarke County has taken several precautionary measures to protect public health. Those actions include

1. providing nearby, downgradient homesites with water from the municipal system,
2. purchasing several residential properties bordering the landfill to prevent potential exposures to the contaminated groundwater plumes,
3. remediating existing contaminated areas, and
4. monitoring off-site groundwater.

Actions Planned

As additional data become available, GDPH will review the information. GDPH will also respond to any health concerns posed about the site.

References

1. Athens-Clarke County, Notification Reporting Form, August 4, 1994.
2. Georgia Environmental Protection Division, *Record of Telephone Conversation*, September 27, 1988.
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5. Letter from Donald H. McCarty, Jr., Georgia Environmental Protection Division to James T. Corley, Athens-Clarke County, December 31, 1997.
6. Letter from Chasman, M.R. & Associates, P.C. to Ed Waterman, Athens-Clarke County, September 3, 1998.
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8. Weisel, C. and Wan-Kuen J., *Ingestion, Inhalation, and Dermal Exposures to Chloroform and Trichloroethene from Tap Water*, Environmental Health Perspectives, 104:1, June 1996.
9. Agency for Toxic Substances and Disease Registry, *Toxicological Profile for Tetrachloroethene*, update, 1999.

10. Agency for Toxic Substances and Disease Registry. *Toxicological Profile on CD ROM: Vinyl Chloride*, update, 1999.

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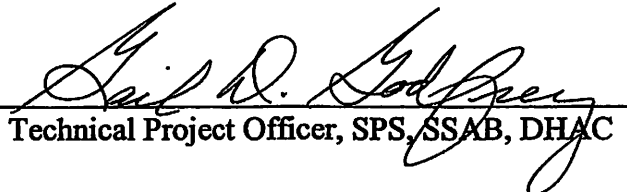
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Certification

This Athens-Clarke County Municipal Solid Waste Landfill Health Consultation was prepared by the Georgia Department of Human Resources under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the health consultation was begun.


Technical Project Officer, SPS, SSAB, DHAC

The Division of Health Assessment and Consultation, ATSDR, has reviewed this health consultation and concurs with the findings.


Chief, SPS, SSAB, DHAC, ATSDR

Tables

Table 1

**Contaminants of Concern in On-Site Drinking Water, Comparison Values, and Estimated
Doses for Children and Adults**

(See Appendix A for explanation of Comparison Values and MRLs)

Contaminant	Maximum Level ($\mu\text{g/L}$)	Drinking Water Comparison Value*		Estimated Dose (mg/kg/day) and MRL** (ppm)
		Concentration ($\mu\text{g/L}$)	Reference	
Trichloroethene	5.59	100 400 5.0	RMEG (child) RMEG (adult) MCL	Child: 0.0017 Adult: 0.00048 MRL = 0.1 ¹
Vinyl chloride	2.37	0.2 0.7 0.02 2.0	EMEG (child) EMEG (adult) CREG MCL	Child: 0.00048 Adult: 0.000136 MRL = 0.00002

$\mu\text{g/L}$: micrograms per liter

mg/kg: milligrams per kilogram

RMEG: Reference Dose Media Evaluation Guide

MCL: Maximum Contaminant Level

EMEG: Environmental Media Evaluation Guide

CREG: Cancer Risk Evaluation Guide

MRL: Minimal Risk Level. All MRLs are based on chronic duration oral exposure unless otherwise indicated

¹ Based on intermediate duration inhalation exposure [9]

Table 2
Exposure Pathways

Completed Exposure Pathways

Pathway Name	Source	Medium	Exposure Point	Exposure Route	Receptor Population	Time of Exposure
On-site groundwater	Landfill	Groundwater	Potable water	Ingestion, Inhalation, Dermal	Employees (<30*)	Past

* The approximate number of exposed individuals is the estimate of persons who were employed at the facility during the duration of suspected contamination.

Appendix

Comparison Values, Minimum Risk Levels, and Exposure Doses

Comparison Values (CVs) are contaminant concentrations that are found in specific environmental media (air, soil, water) that are used to select contaminants for further evaluation. Concentrations above CVs do not necessarily pose a health threat.

Cancer Risk Evaluation Guidelines (CREGs) are estimated contaminant concentrations that would be expected to cause no more than one excess cancer in one million (1×10^{-6}) persons exposed over a lifetime (70 years). CREGs are calculated from the U.S. Environmental Protection Agency's cancer slope factors.

Environmental Media Evaluation Guidelines (EMEGs) are based on minimal risk levels (see definition of MRLs). Any exposure to contaminant levels below EMEGs are not expected to cause adverse health effects; therefore, contaminants present at levels below EMEGs can be eliminated from further evaluation.

Reference Dose Media Evaluation Guidelines (RMEGs) are used by health assessors when a chronic EMEG does not exist and when the RMEG is lower than other CVs. The RMEG is derived from the EPA Reference Dose. Similar to MRLs, Reference Doses are estimates of daily human exposure to a chemical that are likely to be without an appreciable risk of harmful (noncarcinogenic) effects.

Maximum Contaminant Levels (MCLs) represent the maximum permissible level of a contaminant in drinking water which is delivered to any user of a *public* water system that the U.S. Environmental Protection Agency (EPA) deems protective of public health over a lifetime (70 years) at an exposure rate of drinking 2 liters of water *per day* for an adult and 1 liter of water *per day* for a child. In addition to health considerations, MCLs are developed with consideration for other factors such as technical capability to treat water to keep contaminant levels at or below MCLs.

A **Minimal Risk Level (MRL)** is a health screening exposure dose used to determine whether a site-specific exposure should be further evaluated for noncancer, adverse health effects. MRLs are based on human and animal studies of noncancer effects, and are reported for acute (14 days), intermediate (15-364 days), and chronic (365 days) exposures. MRLs are developed using safety factors believed to be protective of sensitive populations. Where sufficient toxicologic information is available, the Agency for Toxic Substances and Disease Registry (ATSDR) has derived MRLs for inhalation and oral routes of exposure at each duration of exposure (acute, intermediate, and chronic). MRLs are published in ATSDR's *Toxicological Profiles* for specific chemicals.

Exposure Doses are derived by calculating the amount of a contaminant that is taken into the body of an exposed human over a period of time. The following equation was used in this document to estimate the exposure dose resulting from contact with contaminated groundwater:

$$ED = \frac{C \times IR \times EF}{BW}$$

where;

ED = exposure dose

C = contaminant concentration (highest level found in a specific medium)

IR = intake rate of contaminated medium (based on average ingestion rates of 2 liters/day for adults; 1 liter/day for children)

EF = exposure factor

BW = body weight (based on average weights for: adults, 70 kg ; children, 10 kg)