Health Consultation

Mountain View Sewer Gas Study

Scottsdale, Maricopa County, Arizona

Prepared by:
Arizona Department of Health Services
Under Cooperative Agreement With
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation

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Glossary

Acute exposure: Exposure to a chemical for a short duration of time. The U.S. Environmental Protection Agency (EPA) defines this duration as less than or equal to 24 hours; the Agency for Toxic Substances and Disease Registry (ATSDR) defines the duration as 1–14 days.

Agency for Toxic Substances and Disease Registry (ATSDR): A federal governmental agency within the U.S. Department of Health and Human Services whose mission is to take responsive public health actions and provide health information to prevent harmful exposures and disease related to toxic substances.

Ambient: Surrounding environment. "Ambient air" and "outside air" are used interchangeably.

American Conference of Governmental Industrial Hygienists (ACGIH): A voluntary member-based organization of professional industrial hygiene personnel in governmental or educational institutions whose purpose is to advance worker health and safety.

Arizona Ambient Air Quality Guidelines (AAAQG): Draft residential screening values for contaminants in ambient air developed by the Arizona Department of Health Services (ADHS). Contaminant concentrations that exceed the Arizona Ambient Air Quality Guidelines should be evaluated further to determine if they present a true health risk.

Arizona Department of Health Services (ADHS): The Arizona state agency whose mission is to protect and ensure the health of the state's population.

Ceiling limit: The maximum allowable exposure limit for an airborne chemical, which is not to be exceeded even momentarily.

Chronic exposure: Repeated exposure or contact with a toxic substance over a long period. The U.S. Environmental Protection Agency defines this period as a significant fraction of the animal's or human's lifetime. The Agency for Toxic Substances and Disease Registry defines chronic exposure as greater than 364 days.

Comparison value (CV): Media-specific screening chemical concentrations developed by the Agency for Toxic Substances and Disease Registry that are used by health assessors to select environmental contaminants for further evaluation.

Criteria air pollutants: Six widespread and common air pollutants regulated by the U.S. Environmental Protection Agency by standards to protect public health or the environment. The six criteria pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide.

Exposure: Contact made between a chemical, physical, or biological agent and the outer boundary of an organism. Exposure is quantified as the amount of an agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut).

Hazardous air pollutants (HAPs): One of the chemicals listed in section 112(b) of the Clean Air Act Amendments of 1990. Hazardous air pollutants are pollutants known or suspected to cause cancer or other serious health effects or adverse environmental effects. Hazardous air pollutants are regulated by the U.S. Environmental Protection Agency using technology-based standards.

Intermediate exposure: The Agency for Toxic Substances and Disease Registry defines intermediate exposure as spanning 15–364 days.

Lower explosive limit: The lowest concentration of a substance in air that will produce a fire or flash when an ignition source (flame, spark, etc.) is present. It is expressed in percent of vapor or gas in the air by volume.

Lowest-observed-adverse-effect level (LOAEL): From the U.S. Environmental Protection Agency-the lowest dose of chemical that produces statistically or biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control group.

Milligrams per cubic meter (mg/m^3): A way of expressing the concentration of dusts, gases, aerosols, or mists in the air. A milligram (mg) is a unit of weight in the metric system—1,000 milligrams equals 1 gram. A cubic meter (m^3) is a volume measurement in the metric system—1 m^3 is about 35.3 cubic feet or 1.3 cubic yards.

Minimal risk level (MRL): An estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure. Minimal risk levels are developed by the Agency for Toxic Substances and Disease Registry.

National Institute for Occupational Safety and Health (NIOSH): A federal governmental agency which tests and certifies respiratory devices, recommends occupational exposure limits, and assists the Occupational Safety and Health Administration (OSHA) by conducting research and investigations. The National Institute for Occupational Safety and Health is part of the Centers for Disease Control and Prevention in the U.S. Department of Health and Human Services.

No-observed-adverse-effect level (NOAEL): From the U.S. Environmental Protection Agency-the dose of chemical at which there are no statistically or biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control group; some effects may be produced at this dose, but they are not considered to be adverse, nor precursors to adverse effects.

Occupational Safety and Health Administration (OSHA): A federal government agency within the U.S. Department of Labor that develops and enforces occupational safety and health standards for most industry and businesses in the United States.

Odor threshold: The lowest concentration of a substance's vapor, in air, that a person can detect by smell. Odor thresholds are highly variable, depending on the individual and the nature of the substance.

pH: A measure of how acidic or basic (caustic) a substance is on a scale of 1 (very acidic) to 14 (very basic); pH 7 indicates that the substance is neutral.

Parts per million (ppm). A measurement used to express very small concentrations of a given substance present in a mixture; often used as a unit to measure the parts (by volume) of a gas or vapor in a million parts of air.

Peak: Maximum one-time exposure, usually 10 minutes. No other exposure is allowed. (Occupational Safety and Health Administration standard)

Permissible exposure limit (PEL): An exposure limit that is published and enforced by the Occupational Safety and Health Administration as a legal standard. A permissible exposure limit may be either a time-weighted-average (TWA) exposure limit (8 hour), a 15-minute short-term exposure limit (STEL), or a ceiling limit (CL).

Recommended exposure level (REL): An 8- or 10-hour time-weighted-average or ceiling limit exposure concentration recommended by the National Institute for Occupational Safety and Health that is based on an evaluation on health effects data.

Reference concentration (RfC): An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population that is likely to be without risk of deleterious effects during a lifetime. It can be derived from a no-observed-adverse-effect-level (NOAEL), lowest-observed-adverse-effect-level (LOAEL), or benchmark concentration, with uncertainty factors generally applied to reflect limitations of the data used. Reference concentrations are generally used in the U.S. Environmental Protection Agency's noncancer health assessments and expressed in milligrams per cubic meter (mg/m^3).

Short-term exposure limit (STEL): The maximum concentration to which workers can be exposed for up to 15 minutes continually. There may be no more than four exposure periods per day, and there must be at least 1 hour between exposure periods. The daily time-weighted-average may not be exceeded, however.

Threshold limit value (TLV): Recommended guidelines for occupational exposure to airborne contaminants published by the American Conference of Governmental Industrial Hygienists. Threshold limit values represent the average concentrations in milligrams per cubic meter for an 8-hour workday and a 40-hour workweek to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

Total reduced sulfur (TRS): All reduced sulfur compounds including but not limited to hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide.

Time-weighted average (TWA): An allowable exposure concentration averaged over a normal 8-hour workday or 40-hour workweek.

Uncertainty factor (UF): One of several, generally 10-fold factors, used in deriving the reference concentration from experimental data. Uncertainty factors are intended to account for: 1) the variation in sensitivity among the members of the human population; 2) the uncertainty in extrapolating animal data to humans; 3) the uncertainty of extrapolating from data obtained in a study that is less than lifetime exposure to lifetime exposure, i.e., extrapolating from subchronic to chronic exposure; 4) the uncertainty in extrapolating from an lowest-observed-adverse-effect-level (LOAEL) rather than from a no-observed-adverse-effect-level (NOAEL); and 5) the uncertainty of extrapolating from animal data when the database is incomplete.

U.S. Environmental Protection Agency (EPA): The federal agency whose mission is to protect human health and safeguard the natural environment—air, land, and water.

Objective

The Arizona Department of Health Services (ADHS) is a cooperative agreement partner of the Agency for Toxic Substances and Disease Registry (ATSDR) headquartered in Atlanta, Georgia. The Agency for Toxic Substances and Disease Registry is an agency within the U.S. Department of Health and Human Services. The mission of the Agency for Toxic Substances and Disease Registry is to take responsive public health actions and to provide information to prevent harmful exposures and disease related to toxic substances.

In May 2003, a Scottsdale, Arizona, resident asked the Agency for Toxic Substances and Disease Registry in Atlanta to investigate possible sewer gas exposures in a Scottsdale residential neighborhood. In June 2003, the Agency for Toxic Substances and Disease Registry asked its cooperative agreement partner, the Arizona Department of Health Services, to conduct an investigation to determine if sewer gas exposures were occurring. Because ambient[*] and indoor air hydrogen sulfide data for the neighborhood were not available, the Arizona Department of Health Services and the resident collaborated in conducting an air monitoring investigation in the neighborhood from June 26, 2003, through July 15, 2003.

Background

In a May 20, 2003, letter to the Agency for Toxic Substances and Disease Registry and the Arizona Department of Health Services, the Scottsdale resident described discharges of sewer gas from manholes and a residential rooftop vent stack in the neighborhood. The resident stated in the letter that physical illnesses in some neighborhood residents, as well as symptoms the resident experienced while observing the sewer gas discharges, were similar to symptoms caused by exposure to hydrogen sulfide gas.

The resident's letter indicated there were occasional but significant discharges of sewer gas from manholes west of N. 64th Street in Scottsdale on E. Mountain View Road (see Appendix A for a map of the neighborhood). During these discharges, it was possible to detect sewer gas odor more than 50 feet from some manholes. Furthermore, on one occasion, while the manholes were discharging sewer gas, the main 4-inch vent stack on the roof of a nearby residence was also emitting a strong, continuous discharge of sewer gas. The resident pointed out that hydrogen sulfide, the main constituent of sewer gas, is slightly heavier than air and, therefore, the discharge could be settling to ground level in the neighborhood.

From sewer system engineering drawings obtained from the City of Phoenix, the resident concluded that the out-gassing was probably caused by a bottleneck at the intersection of E. Mountain View Road and N. 64th Street. At this intersection, the 33-inch diameter sewer main running east under E. Mountain View Road makes a 90-degree bend and empties into a smaller 27-inch diameter sewer main running south under N. 64th Street. The resident also suggested that

[*] Please consult the glossary at the beginning of the health consultation for definitions of terms and agency descriptions.

an additional source of gas generation may be turbulence caused by two 8-inch feeder lines emptying into the 33-inch diameter sewer from opposite directions on E. Mountain View Road.

Community Health Concerns

In preparing to conduct the study, the Arizona Department of Health Services learned that another homeowner in the Scottsdale neighborhood had contacted the City of Phoenix on a number of occasions in previous years regarding sewer gas odors. City of Phoenix examinations of the sewer system indicated nothing wrong with the city sewer system. In an interview with Arizona Department of Health Services staff, the homeowner stated there had been a sewer gas problem in the neighborhood for years and that the homeowner had suffered many symptoms and illnesses as a result of repeated exposures to the gas.

No neighborhood residents lodged formal complaints with the Arizona Department of Health Services during or after the study. However, two residents during one monitoring event and one resident during another monitoring event approached department staff and said there had been a pervasive sewer gas odor in the neighborhood. The residents did not specify how long the sewer gas odor had been present in the neighborhood.

Health Effects of Sewer Gas

Sewer Gas

Sewer gas is a generic name for a complex mixture of gases and airborne agents that result from the natural process of the decomposition of organic materials in sewage. Gases produced by domestic wastewater decomposition commonly include hydrogen sulfide (H_2S), ammonia (NH_3), methane (CH_4), and carbon dioxide (CO_2). Of these gases, only hydrogen sulfide and ammonia are malodorous. Sewer gas also contains sulfur dioxide (SO_2), nitrous oxides (NO_x), biological organisms, water vapor, and chemicals introduced into wastewater such as chlorine bleaches, industrial solvents, and gasoline. The presence and concentration of these components can vary with time, composition of the sewage, temperature, and pH (Hutter 1993; WDHFS 2003).

In urban residential neighborhoods, sewer gas can enter ambient air through manholes, pumping stations, rooftop vent stacks, and other routes. Sewer gas can enter indoor air in homes through floor drains, dried-out sewer traps, or cracks in the foundation (if the gases are in soil adjacent to the house), or from leaking or blocked roof vents.

The major adverse health effects and hazards from exposure to sewer gas include the following:

1. Poisoning from hydrogen sulfide gas;
2. Decreased vigilance or fatigue due to reduced oxygen levels (from CO_2 and CH_4);
3. Diseases from airborne sewage pathogens, i.e., bacteria, viruses, parasites (however, these microbes are short-lived when suspended in air);
4. Fires and explosions from methane gas, hydrogen sulfide, or other flammable gases accumulating in an enclosed space (Hutter 1993).

Hydrogen Sulfide (H_2S)

Hydrogen sulfide is the most commonly known and prevalent odorous gas associated with domestic wastewater. It is also the sewer gas component of greatest health concern (Dr. Selene Chou, ATSDR, personal communication, 2003). The conditions leading to hydrogen sulfide formation generally favor production of other malodorous organic gases. Many of those are also sulfur-bearing compounds, such as mercaptans and dimethyl disulfide. Because of this association, solving for hydrogen sulfide odor problems can often resolve other odor problems (Alken-Murray 2003).

Hydrogen sulfide is a colorless, flammable, highly toxic gas with a characteristic rotten egg odor. The reported odor threshold for hydrogen sulfide gas varies greatly, but it is generally less than 0.01 parts per million (ppm) (McGavran 2001). Some people may be able to detect the odor of hydrogen sulfide in air at concentrations as low as 0.0005 ppm (ATSDR 1999). Hydrogen sulfide can be especially dangerous because at concentrations over 100 ppm or at continuous low exposure concentrations most people can no longer smell hydrogen sulfide, making them unaware that they continue to be exposed to the gas (ATSDR 1999). Hydrogen sulfide is likely to remain in ambient air for less than one day, but it may persist for as long as 42 days (WHO 2003). The average hydrogen sulfide background concentration in the air in the United States is estimated to be between 0.0001 and 0.0003 ppm. The concentration of hydrogen sulfide in air in undeveloped areas of the United States is very low, between 0.00002 and 0.00007 ppm (ATSDR 1999).

Because hydrogen sulfide is a gas, inhalation is the major route of exposure, and the gas is rapidly absorbed through the lungs (WHO 2003). Hydrogen sulfide is a “broad spectrum” poison, meaning it can poison several different systems of the body (ATSDR 1999). Exposure to high concentrations of hydrogen sulfide is reported to be the most common cause of sudden death in the workplace (Collins 2000). At high concentrations, such as may occur in a confined workspace, hydrogen sulfide can cause severe lung inflammation, loss of consciousness, convulsions, respiratory arrest, heart failure, and death.

At low exposure levels, as are likely to occur in a residential area such as the Mountain View neighborhood, hydrogen sulfide will primarily cause eye and respiratory tract irritation (McGavran 2001). Prolonged exposure to low concentrations has not been well studied. However, low concentrations have been associated with neurological symptoms, including fatigue, headache, nausea, dizziness, loss of appetite, irritability, impaired memory, and altered mood states (McGavran 2001). Absent any physical effects, the odor of hydrogen sulfide alone can be annoying and affect well being. None of the available studies demonstrate that hydrogen sulfide causes cancer. Table 1, taken from a report by the World Health Organization, shows health effects of various hydrogen sulfide concentrations in air (WHO 2003).

Table 1. Human Health Effects at Various Hydrogen Sulfide Concentrations in Air

Exposure (ppm)	Effect/Observation	Reference
0.0005–0.01	Odor threshold	ATSDR 1999; McGavran 2001
0.01–0.6	Increased eye symptoms Increases in nausea Increased headache, mental symptoms, diseases of nervous system and sense organs	ATSDR 1999 (see Appendix B)
2.0	Bronchial constriction in asthmatic individuals	WHO 2003; ATSDR 1999
5.0	Increased eye complaints Mild respiratory, cardiovascular, musculoskeletal, and metabolic changes	WHO 2003 ATSDR 1999 (see Appendix B)
3.6–21	Eye irritation	WHO 2003
20	Fatigue, loss of appetite, headache, irritability, poor memory, dizziness Irritation of mucous membranes	WHO 2003 ATSDR 1999
100	Olfactory paralysis	ATSDR 1999
>560	Respiratory distress	WHO 2003
700	Death	WHO 2003

Enforceable Hydrogen Sulfide (H_2S) Standards

Table 2 shows government standards and guidelines applicable to hydrogen sulfide levels in air. Regulatory standards are enforceable under the law, but guidelines are nonbinding and not enforceable. Hydrogen sulfide in ambient air is not classified as a criteria air pollutant or a hazardous air pollutant under the federal Clean Air Act and, consequently, is not regulated by either the U.S. Environmental Protection Agency or the Arizona Department of Environmental Quality. The only enforceable hydrogen sulfide air quality standards in effect at this time are the Occupational Safety and Health Administration occupational regulations shown at the top of Table 2. The Occupational Safety and Health Administration set an 8-hour permissible exposure limit (PEL) of 10 ppm for hydrogen sulfide in the workplace and an acceptable ceiling concentration of 20 ppm, with a maximum level of 50 ppm allowed for 10 minutes if no other measurable exposure occurs. The Occupational Safety and Health standards are applicable to the workplace only.

Table 2. Standards and Guidelines Applicable to Hydrogen Sulfide in Air

Federal Regulations		
Occupational Safety and Health (OSHA)	Permissible exposure limit (PEL)—8-hour Short-term exposure limit (STEL)—15 minutes Acceptable ceiling concentration Peak—one-time 10-minute maximum exposure	10 ppm 15 ppm 20 ppm 50 ppm
Federal Guidelines		
Agency for Toxic Substances and Disease Registry (ATSDR)	Comparison value (CV) Acute Intermediate Minimal risk levels (MRLs) Acute (1–14 days) Intermediate (14–364 days)	 0.07 ppm 0.03 ppm 0.07 ppm 0.03 ppm
National Institute for Occupational Safety and Health (NIOSH)	Recommended exposure limit (REL)—10 minute exposure ceiling	10 ppm
American Conference of Governmental Industrial Hygienists (ACGIH)	Threshold limit value/time-weighted average (TLV/TWA) Threshold limit value/short-term exposure limit (TLV/STEL)	10 ppm 15 ppm
World Health Organization (WHO)	24-hour average 30-minute odor annoyance guideline	0.11 ppm 0.005 ppm
U.S. Environmental Protection Agency (EPA)	Reference concentration (RfC)—noncancer No-observed-adverse-effect-level (NOAEL)	0.001 ppm 10 ppm
Arizona (Draft) Guidelines		
Arizona Department of Environmental Quality (ADEQ)	Arizona ambient air quality guidelines (AAAQGs) 1-hour AAAQG 24-hour AAAQG	 0.13 ppm 0.08 ppm

Hydrogen Sulfide Guidelines (ATSDR and EPA)

The (nonenforceable) guidelines for hydrogen sulfide in air that are of greatest interest to health assessors are the the Agency for Toxic Substances and Disease Registry comparison values (CVs) and minimal risk levels (MRLs), and the U.S. Environmental Protection Agency reference concentrations (RfCs) (see Table 2). The Agency for Toxic Substances and Disease Registry comparison values are screening values conservatively developed based on the most sensitive receptors. A contaminant level that exceeds a comparison value does not necessarily indicate a health risk but rather that the contaminant is present in the environment at levels that warrant further evaluation. The Agency for Toxic Substances and Disease Registry minimal risk levels are estimates of daily human exposure to a hazardous substance likely to be without appreciable risk of adverse, noncancer health effects. The comparison values/minimal risk levels for hydrogen sulfide are 0.07 ppm for acute (1–14 day exposure) and 0.03 ppm for intermediate (14–364 day exposure). Although a chronic (>364 day exposure) comparison value/minimal risk level would be most applicable to long-term ambient air exposures to hydrogen sulfide gas, chronic values have not been developed for hydrogen sulfide gas due to insufficient data. The

Agency for Toxic Substances and Disease Registry minimal risk levels for hazardous substances can be found at URL: http://www.atsdr.cdc.gov (ATSDR 2003).

The U.S. Environmental Protection Agency developed an inhalation reference concentration for hydrogen sulfide that is used to assess human health risks. The reference concentration is an estimate of a daily inhalation exposure concentration that is likely to be without an appreciable risk of adverse, noncancer effects during a lifetime. The inhalation reference concentration for hydrogen sulfide was developed from a no-observed-adverse-affect-level (NOAEL) of 10 ppm derived from a study of nasal inflammation in rats caused by exposure to hydrogen sulfide.

To obtain the reference concentration, the no-observed-adverse-affect-level (NOAEL) of 10 ppm was divided by an uncertainty factor (UF) of 300 obtained by multiplying a factor of 3 for extrapolating from animals to humans; a factor of 10 to protect sensitive individuals; and a factor of 10 to adjust from subchronic to chronic exposure. The resulting reference concentration is 0.001 ppm (0.002 mg/m^3) (EPA 2003). The U.S. Environmental Protection Agency also developed a lowest-observed-adverse-affect-level (LOAEL) for hydrogen sulfide of 30 ppm. The lowest-observed-effect-level (LOAEL) is the lowest dose of chemical that produces adverse effects. Further information on the reference concentration, the no-observed-adverse-affect-level (NOAEL), and the lowest-observed-adverse-affect-level (LOAEL) for hydrogen sulfide can be found online in the U.S. Environmental Protection Agency's Integrated Risk Information System (IRIS) at URL: http://www.epa.gov/iris (EPA 2003).

Low Dose Studies

Appendix B contains a table summarizing the results of studies conducted on the health effects of low dose exposure (<10 ppm) to hydrogen sulfide and total reduced sulfur (TRS). The table was compiled from the Agency for Toxic Substances and Disease Registry's *Toxicological Profile for Hydrogen Sulfide* (ATSDR 1999). These studies suggest that exposure to hydrogen sulfide from 5 to 16 ppm may cause respiratory, cardiovascular, musculoskeletal, dermal, and metabolic health effects, while ocular, gastrointestinal, and neurological effects may occur below 1 ppm.

Appendix B also shows the results of low dose exposure to total reduced sulfur. Total reduced sulfur is a complex mixture of hydrogen sulfide, methyl mercaptan, and methyl sulfides from pulp mills. Because the observed health effects were caused by exposure to a mixture (although the authors indicate that hydrogen sulfide comprised the dominant sulfur compound of the mixture at about two thirds), caution must be used in drawing conclusions from these studies. The *Toxicological Profile for Hydrogen Sulfide* containing the studies referenced in Appendix B is available at URL: http://www.atsdr.cdc.gov/toxprofiles/tp114.html.

Methods and Results

Target Population

Homes within the area where off-gassing and sewer gas odor had been detected by the resident were the primary focus of the investigation. This area, shown in Appendix A, is bounded by E. Mountain View Road on the south, E. Turquoise Avenue on the north, N. 64th Street on the east, and N. 61st Place on the west. There are 21 residences within this neighborhood with a maximum estimated potentially affected population of 80 residents. The Arizona Department of Health Services received approval from two residents, one of which was the resident who requested the investigation, to collect data inside their homes. If appreciable levels of sewer gas were detected in the Mountain View neighborhood, the study would have been expanded to surrounding neighborhoods.

Methods

The Arizona Department of Health Services and the resident collected ambient air hydrogen sulfide data in the neighborhood from June 26, 2003, through July 15, 2003. Data were collected with a hand-held BW Defender Multi-Gas Detector®, manufactured by BW Technologies Ltd. The multi-gas detector monitors four gases simultaneously and continuously: combustibles (methane), oxygen (deficiency/enrichment), carbon monoxide, and hydrogen sulfide. The multi-gas detector was capable of detecting the four gases to minimum detection (sensitivity) levels, but not below. The minimum detection levels for the meter were hydrogen sulfide—1 ppm, methane—1% lower explosive limit (LEL), carbon monoxide—1 ppm, and oxygen—0.1%.

Appendix C shows the dates and times data were collected and whether the data were collected by the resident or the Arizona Department of Health Services. Arizona Department of Health Services staff collected data in front of each residence in the neighborhood. Department sampling was usually from 10:00–11:00 AM because flow data from a wastewater metering station on E. Mountain View Road indicated that peak flows occurred in the neighborhood during this time. The resident, on the other hand, primarily collected data on a "spot-check" basis. The dates and times of resident sampling presented in Appendix C are from McSweeney (2003).

Results

The BW Defender Multi-Gas Detector® registered no detection of hydrogen sulfide in ambient or indoor air during the study, suggesting that hydrogen sulfide was not present in the neighborhood from June 26, 2003, through July 15, 2003, at levels equal to or greater than 1 ppm (the meter's lowest detection level for hydrogen sulfide). Nor did the meter detect carbon monoxide or methane in ambient or indoor air, suggesting that these compounds were also not present in the neighborhood at levels above the meter's lowest detection capability. No decreases in ambient or indoor oxygen were detected.

On several sampling occasions, Arizona Department of Health Services staff and the resident noted a mild sewer gas odor in ambient air downwind of manholes on E. Mountain View Road, suggesting that hydrogen sulfide may have been present at levels over the reported odor threshold of 0.0005–0.01 ppm (see Table 1). Over the weekend of June 26, 2003, just before the beginning of the study, the City of Phoenix sealed a manhole located at the intersection of E. Mountain View Road and N. 64th Street. According to the resident, the sewer gas odor was much stronger and widespread in the neighborhood before the manhole was sealed. An Arizona Department of Health Services employee visiting the neighborhood on June 17, 2003, before the manhole was sealed, noted strong sewer gas odors on E. Mountain View Road and in the area of the intersection of N. 62nd Place and E. Turquoise Avenue. After the manhole was sealed, the same Arizona Department of Health Services employee detected mild intermittent sewer gas odors on E. Mountain View Road only.

Limitations

The BW Defender Multi-Gas Detector® has the advantage of measuring combustibles and lowered oxygen associated with hydrogen sulfide in sewer gas; however, it has the disadvantage of having a minimum detection level (sensitivity) to hydrogen sulfide of only 1 ppm. This means that if hydrogen sulfide gas were present in the neighborhood at levels below 1 ppm, the meter would have been unable to detect these concentrations.

Discussion

Studies suggest that, in general, sewer gas production is greatest during the summer months, which should have maximized detection of hydrogen sulfide in the present study. Steven Davidson, a consulting engineer with extensive experience with wastewater collection systems in the Phoenix area, states in reference to the Phoenix metropolitan area, "Sulfide production is highly sensitive to wastewater temperature, and therefore, large seasonal variations in odor are typical in this area. Sulfide and H_2S production are typically at least 4 times higher in the summer than in the winter. Thus, the time of greatest odor impact is most often in the summer, even though wastewater flow is significantly higher in the winter" (S. Davidson, Brown and Caldwell, letter to resident, July 23, 2003).

Hydrogen sulfide was not detected by the multi-gas detector, suggesting that hydrogen sulfide gas was not present in the neighborhood at 1 ppm or higher. Therefore, the health effects listed in Appendix B for exposures greater than 1 ppm would not be expected to occur in the neighborhood and are primarily presented for informational purposes.

However, hydrogen sulfide gas may have been present at times along E. Mountain View Road below the 1 ppm detection level of the meter. The studies in Appendix B suggest that concentrations of hydrogen sulfide in air below 1 ppm may cause olfactory, gastrointestinal, and neurological effects. The Agency for Toxic Substances and Disease Registry's comparison values for hydrogen sulfide in air—0.07 ppm (acute) and 0.03 ppm (intermediate)—and the U.S. Environmental Protection Agency's inhalation reference concentration of 0.001 ppm are below 1 ppm. Although adverse health effects are unlikely below 1 ppm, specific exposures would need further evaluation.

The Agency for Toxic Substances and Disease Registry's comparison values are far below the Occupational Safety and Health Administration 8-hour standard for hydrogen sulfide in air of 10 ppm. The Occupational Safety and Health Administration believes that the safe limits of exposure of healthy workers to hydrogen sulfide gas are much greater than the odor detection level of the gas. Hydrogen sulfide levels that might be encountered in the Mountain View neighborhood are well within the Occupational Safety and Health Administration safe limits. However, the Occupational Safety and Health Administration standards were not established to be protective of people with respiratory problems or other sensitive populations.

Significant air pollution in the Phoenix metropolitan area further hampers efforts to identify the possible effects of low levels of hydrogen sulfide in the Mountain View neighborhood. Ozone, in particular, can affect the well being of sensitive individuals. Consequently, it can be difficult to separate health affects from hydrogen sulfide and other air pollutants.

Child Health Considerations

The Agency for Toxic Substances and Disease Registry and the Arizona Department of Environmental Health recognize that the unique vulnerabilities of infants and children demand special emphasis in communities faced with contaminants in the air. There is little information in the literature to judge the effects of exposure to hydrogen sulfide on infants and children; however, it is likely that the same toxicity seen in adults will be seen in children.

It is generally thought that children are at greater risk than adults from exposure to ambient air pollutants. Children play outdoors more than adults. Children breathe a greater volume of air relative to body weight, resulting in a higher body burden of pollutants. Because hydrogen sulfide is slightly heavier than air and tends to sink, and because children are shorter than adults, children might be exposed to larger amounts of hydrogen sulfide than adults in the same situations. The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages.

Conclusions

- Because the multi-gas sampling meter could not detect concentrations of hydrogen sulfide below 1 ppm, the Arizona Department of Health Services concludes that sewer gas represents an indeterminate health hazard along E. Mountain View Road.

- Ambient hydrogen sulfide present on E. Mountain View Road does not present an urgent public health hazard.

Recommendations

- If offensive sewer gas odors are noted in the future, neighborhood residents should notify the City of Phoenix and the Arizona Department of Health Services, Office of Environmental Health. Residents should avoid contact with the gas during any future episodes.

Public Health Action Plan

The public health action plan for the Mountain View neighborhood describes actions taken and those to be taken at and near the site by the Agency for Toxic Substances and Disease Registry and the Arizona Department of Health Services. The purpose of the public health action plan is to identify potential and ongoing public health hazards and to provide a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment.

Completed, Ongoing, or Future Actions

- The Arizona Department of Health Services measured levels of hydrogen sulfide, carbon monoxide, methane, and oxygen in ambient and indoor air in the Mountain View neighborhood from June 26, 2003, through July 15, 2003.

- The Arizona Department of Health Services will consider reopening the study if residents report significant sewer gas odors in the neighborhood in the future.

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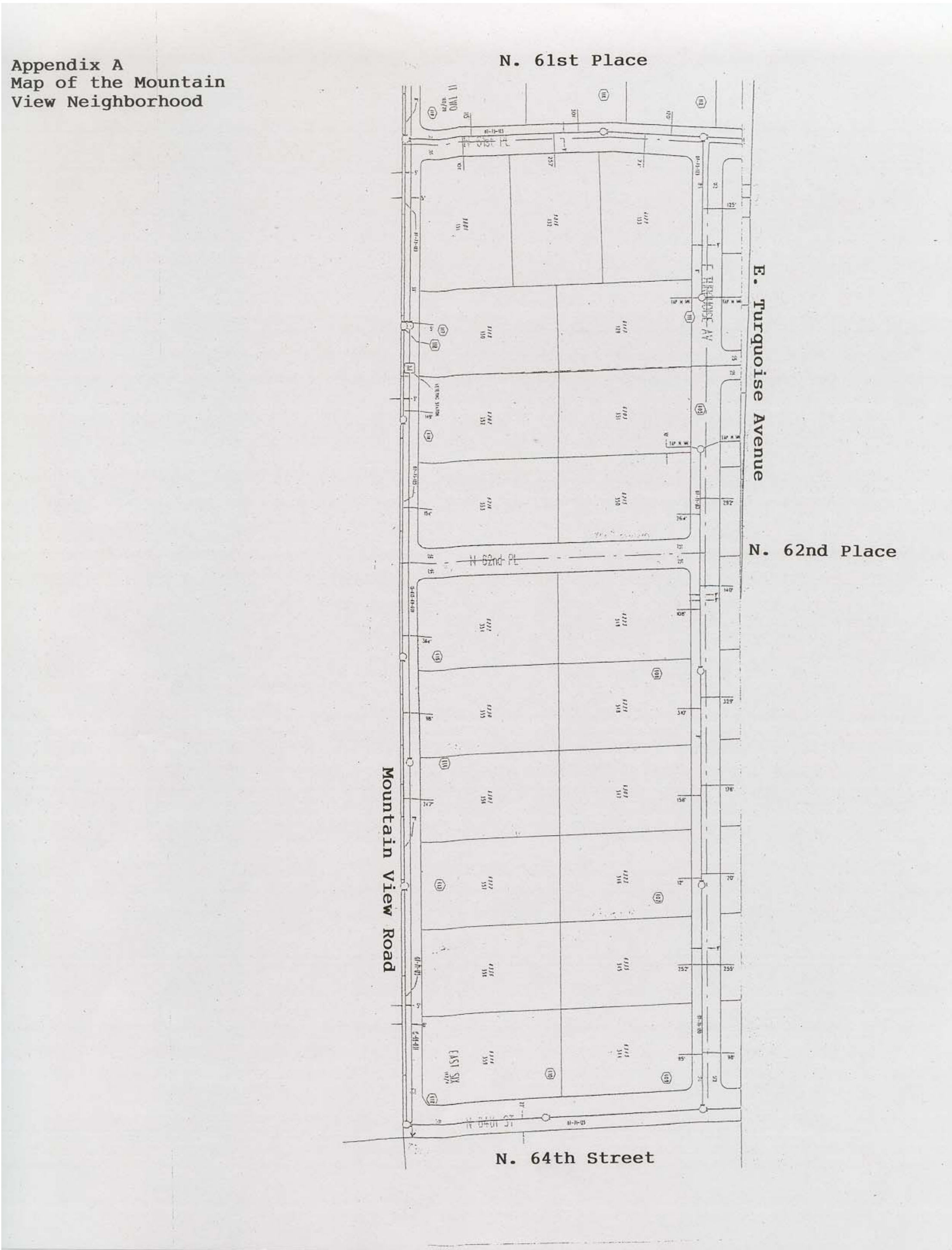
Appendix A: Map of the Mountain View Neighborhood



Appendix B: Health Effects of Low-Dose Inhalation of Hydrogen Sulfide

Studies	Contaminant	Concentration/Exposure Period (ppm)		Health Effects
Systemic				
Respiratory				
Bhambhani & Singh (1991)	H_2S	5	16 minutes, exercise	Significant increase in O_2 uptake
		2.5		Respiratory exchange ratio decreased significantly
Bhambhani et al. (1994)	H_2S	5	30 minutes, exercise	No effect
Bhambani et al. (1996)	H_2S	10	15 minutes, exercise	No altered pulmonary function
Jappinen et al. (1990)	H_2S	2	30 minutes, asthmatics	Indication of bronchial obstruction in 2 of 10 asthmatics
	H_2S	<10		No altered pulmonary function
Jaakkola et al. (1990)	TRS	0.003 mean; 0.04 maximum 4-hour 0.001 mean; 0.02 maximum 4-hour		Significant increase in nasal symptoms, cough. Nonsignificant increase in breathlessness
Marttila et al. (1994)	TRS	0.003 mean; 0.04 maximum		Nonsignificant increase in nasal symptoms and cough in children
Marttila et al. (1995)	TRS	0.007		No effect
		0.007–0.02		Significant nasal and pharyngeal irritation
		>0.02		Significant nasal and pharyngeal irritation
Haahtela et al. (1992)	TRS	0.1 maximum 4-hour		Increased respiratory symptoms
Partti-Pellinen et al. (1996)	TRS	Annual mean 0.002–0.003		Increased eye and nasal irritation, cough, breathlessness, headache
		24-hour average 0.0–0.04		Increased eye and nasal irritation, cough, breathlessness, headache
		1-hour maximum 0.1		Increased eye and nasal irritation, cough, breathlessness, headache
Cardiovascular				
Bhambhani and Singh (1991)	H_2S	5	16 minutes, exercise	No change in heart rate
Bhambhani et al. (1994)	H_2S	5	30 minutes, exercise	No change in heart rate
Bhambhani et al. (1996b, 1997)	H_2S	5, 10	30 minutes, exercise	Impaired anaerobic metabolism
Musculoskeletal				
Bhambhani and Singh (1991) & Bhambhani et al. (1994, 1996a 1996b, 1997)	H_2S	5, 10	30 minutes, exercise	Minimal above-normal increases in blood lactate concentrations and changes in citrate synthetase indicating inhibition of the aerobic capacity of exercising muscle
Metabolic				
Bhambhani and Singh (1991)	H_2S	5	16 minutes, exercise	Significant increase in blood lactate concentrations
		2	16 minutes, exercise	No increase in blood lactate concentrations
Bhambhani et al. (1994, 1996b)	H_2S	5	30 minutes, exercise	No significant increase in lactate concentration; decrease in muscle sythase in men
Bhambhani et al. (1997)	H_2S	10		Significant increases in blood lactate concentrations; no significant changes in muscle lactate dehydrogenase, citrate synthase, or cytochrome oxidase

Ocular				
Haahtela et al (1992)	H_2S	Maximum 4-hour 0.1, 24-hour average 0.03		Significant increases in eye symptoms
Marttilla et al. (1994, 1995)	TRS	0.007 0.007–0.02 >0.02		No effect Eye symptoms Eye symptoms
Jaakkola et al. (1990)	TRS	Annual mean 0.004 Daily peak 0.07		Twelve times more eye irritation than people without exposure
Gastrointestinal				
Haahtela et al.	H_2S	Highest 4-hour 0.1, 24-hour average 0.03		Significant increases in nausea Significant increases in nausea
Marttila et al. (1994, 1995)	TRS	0.007 0.007–0.02 >0.02		 Significant increase in nausea
Dermal				
Tvedt et al (1991a, b)	H_2S	8–16		Peeling of facial skin of one patient
<u>Neurological Effects</u>				
Gaitonde et al. (1987)	H_2S	0.6	1 year	Ataxia, choreoathetosis, dystonia, inability to stand in one 20-month-old child
Haahtela et al. (1992)	H_2S	Maximum 4-hour 0.1, 24-hour average 0.03		Significant increase in headache, mental symptoms
Marttila et al. (1994, 1995)	TRS	0.007 0.007–0.02 >0.02		No effect No effect Nonsignificant increase in headaches
Bates et al. (1997, 1998)	H_2S	Median 0.01, with 35% of measurements > 0.05 and 10% > 0.3		Significant increases in diseases of nervous system and sense organs
<u>Reproductive Effects</u>				
Hemminki and Niemi (1982)	H_2S	Annual mean 0.003		Nonsignificant increase in spontaneous abortion

TRS = Total reduced sulfur; complex mixture of hydrogen sulfide, methyl mercaptan, methyl sulfides from pulp mills. Hydrogen sulfide represents two thirds of the TRS.
The ATSDR *Toxicological Profile for Hydrogen Sulfide* containing the studies referenced in Appendix B can be found at URL: http://www.atsdr.cdc.gov/toxprofiles/tp114.html.

Appendix C: Mountain View Sewer Gas Odor Sampling Schedule – June 27, 2003, through July 15, 2003

Thursday, June 26, 2003	9:00 PM	Resident	
Friday, June 27, 2003	9:20 AM	Resident	
	9:55 PM	Resident	
Saturday, June 28, 2003	9:20 AM	Resident	
	8:52 PM	Resident	
	10:00 PM	Resident	
Sunday, June 29, 2003	9:10 PM	Resident	
	10:00 PM	Resident	Homeowner ill for several days from sampling manholes with resident
	11:22 PM	Resident	
Monday, June 30, 2003	9:00 AM	Resident	
	11:40 AM	Resident	
	9:30 PM	Resident	
Tuesday, July 1, 2003	10:30 AM	ADHS & resident	
	7:44 PM	Resident	
	10:34 PM	Resident	
Wednesday, July 2, 2003	5:00 AM	ADHS	Smelled gas, 30 feet from manhole #117 & 118; Indoor readings (homeowner)
	10:30 AM	ADHS & resident	Smelled gas 20 feet from manhole #414; Indoor readings (homeowner)
	8:05 PM	Resident	
	9:00 PM	ADHS & resident	Indoor readings (homeowner)
Thursday, July 3, 2003	6:10 AM	ADHS	Indoor readings (homeowner)
	10:30 AM	ADHS & resident	Indoor readings (homeowner)
	8:00 PM	ADHS & resident	
	11:30 PM	Resident	
Friday, July 4, 2003	9:15 PM	Resident	
Saturday, July 5, 2003	11:15 AM	Resident	
	7:45 PM	Resident	
	9:30 PM	Resident	
	10:30 PM	ADHS	No meter, no gas smell
Sunday, July 6, 2003	12:26 AM	Resident	
	10:00 PM	Resident	
	10:30 PM	ADHS	No meter, no gas smell
Monday, July 7, 2003	12:05 AM	Resident	
	12:50 AM	Resident	
	9:25 PM	ADHS & resident	
Tuesday, July 8, 2003	12:50 AM	Resident	
	10:10 AM	ADHS & resident	
	8:30 PM	Resident	
Wednesday, July 9, 2003	12:20 AM	Resident	
	10:30 AM	ADHS & resident	
	10:00 PM	ADHS & resident	Smelled gas near manhole #414
	10:30 PM	Resident	
Thursday, July 10, 2003	9:30 AM	ADHS & resident	
	8:00 PM	Resident	
	10:45 PM	Resident	
Friday, July 11, 2003	11:00 AM	ADHS & resident	Smelled gas near manhole #117

	8:25 PM	Resident	
Saturday, July 12, 2003	12:30 AM	Resident	
	9:55 PM	Resident	
Sunday, July 13, 2003	9:20 PM	Resident	
Monday, July 14, 2003	12:40 AM	Resident	
Tuesday, July 15, 2003	10:00 PM	Resident	

Certification

This Mountain View Sewer Gas Study Health Consultation was prepared by the Arizona Department of Health Services under cooperative agreement with the Agency for Toxic Substances and Disease Registry. It is in accordance with approved methodology and procedures existing at the time the health consultation was initiated.

Technical Project Officer
SPS, SSAB, DHAC

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

Chief, SSAB, DHAC, ATSDR