Human Health Risk Assessment - Odor Control Project

Annapolis Water Reclamation Facility

Annapolis, Maryland

Prepared for

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Acronyms and Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ADE	average daily exposure
AEGL	Acute Exposure Guideline Level
ATSDR	Agency for Toxic Substances and Disease Registry
Ca	concentration of hydrogen sulfide in air
County	Anne Arundel County
CTE	central tendency exposure
FAQ	Frequently Asked Questions
H2S	hydrogen sulfide
HHRA	human health risk assessment
HQ	hazard quotient
IDLH	Immediately Dangerous to Life and Health
mg/m^3	milligrams per cubic meter
MRL	Minimal Risk Level
ppbv	parts per billion by volume
ppmv	parts per million by volume
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
REL	Recommended Exposure Limit
RfC	reference concentration
RME	reasonable maximum exposure
STEL	Short Term Exposure Limit
Terraphase	Terraphase Engineering Inc.
TLV	Threshold Limit Value
TWA	time-weighted average
$\mu g/m^3$	micrograms per cubic meter
USEPA	United States Environmental Protection Agency
WRF	Annapolis Water Reclamation Facility

1 Introduction

On behalf of Tidewater Inc., Terraphase Engineering Inc. (Terraphase) prepared this human health risk assessment (HHRA) in support of the Odor Control Project associated with the Annapolis Water Reclamation Facility (WRF; the Facility). The WRF is a wastewater treatment plant that is jointly owned by the City of Annapolis and Anne Arundel County (County). The County is responsible for its operation and maintenance. The Facility uses an activated sludge process to remove nutrients from the wastewater it receives. Treated effluent is then discharged into Chesapeake Bay.

The County recently initiated a series of upgrades to the WRF. As part of these upgrades, the County is evaluating the existing odor control system due to odors in the neighborhood surrounding the WRF. These odors are primarily due to the natural production of hydrogen sulfide, a gas that is generated from sludge process and is typically associated with a “rotten egg” smell.

Air dispersion modeling involves predicting how a chemical travels through the air from a source. It helps us understand where the chemicals will go, how much they could spread, and whether it might affect people, animals, or the environment.

To date, the odor control project has included air monitoring of hydrogen sulfide, air dispersion modeling, and an evaluation of technologies that will improve odor control at the Facility. This HHRA is also part of the odor control project and will assess the potential for health effects related to exposure to hydrogen sulfide in air at the WRF and of the neighborhood surrounding the WRF. The results of the HHRA will be used to assist the County in evaluating treatment options for controlling odors.

1.1 What is a Human Health Risk Assessment?

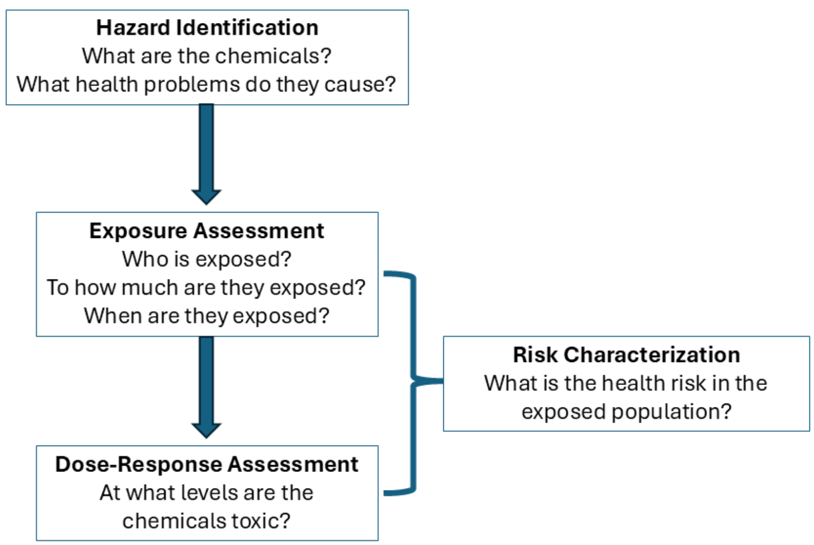
HHRA is a scientific process used by environmental managers to understand if chemicals in the environment could potentially cause harmful health effects in people who might be exposed to those chemicals. This HHRA follows the risk assessment process developed by the United States Environmental Protection Agency (USEPA), as described in its guidance document series entitled *Risk Assessment Guidance for Superfund* (USEPA 1989). Maryland and many other states follow the USEPA risk assessment framework.

The HHRA consists of the following components:

- **Hazard Identification** identifies the types of chemicals to which those receptors may be exposed. For this HHRA, hydrogen sulfide is the chemical of potential concern. The hazard identification also presents the data that will be used in the HHRA.
- **Exposure Assessment** identifies the human populations that may be exposed (called “receptors”) to the chemical(s) of potential concern and the ways by which they may be exposed now or in the future. It also includes steps to quantify their exposure.

- **Toxicity Assessment** identifies the potential health effects associated with exposure to the chemical(s) of potential concern and quantifies how the health effects relate to the amount of exposure experienced by a receptor.
- **Risk Characterization** compares the level of exposure to the level of toxicity of a chemical and determines the likelihood for adverse health effects to occur, referred to as "risk." The results of the risk characterization are compared to risk management goals that are set by state and federal agencies as thresholds for action.

This 4-step process is shown in the following figure. Throughout each of the above components, the HHRA also includes a discussion of the uncertainties and limitations of the HHRA process and how those uncertainties could affect the HHRA outcome.



The 4-Step HHRA Process

The HHRA uses conservative assumptions to estimate *potential* health risks that could result from exposure to specific chemicals identified in the environment. The results of an HHRA do <u>not</u> indicate if people actually have become sick as a result of their exposure to chemicals or if they will develop health problems as a result of their exposure. An HHRA also does not calculate one's individual exposure to or risk from exposure to chemicals. The HHRA is a tool that helps environmental managers understand risks to determine the need for additional information and to support decisions regarding the need for further actions to reduce exposures.

1.2 Report Organization

This document presents the methods and assumptions used to perform the HHRA. It consists of the following sections:

- Section 2, the **Hazard Identification**, describes the potential health effects associated with exposure to hydrogen sulfide and the air monitoring program completed at the WRF and summarizes the analytical results.
- Section 3, the **Exposure Assessment**, describes the potential human receptors evaluated and the assumptions used in the HHRA to quantify receptor exposure.
- Section 4, **Toxicity Assessment**, identifies the toxicity values used to quantify how the health effects relate to the amount of exposure experienced by a receptor.
- Section 5, **Risk Characterization**, combines the results of the exposure assessment with the toxicity assessment to estimate the level of risk experienced by the receptor and how this level of risk compares to the risk management goals used to support decisions regarding the need for action.

Because the WRF is subject to federal occupational health and safety requirements[1] and has controls in place to ensure workers are not subject to an unsafe working environment, exposure of the workers at the WRF was evaluated separately by assessing their exposure relative to occupational exposure standards, guidelines, and safety procedures. This separate evaluation is presented in Section 6.

Section 7 summarizes the conclusions of the HHRA. Limitations of this report are discussed in Section 8, and references cited in the HHRA are provided in Section 9.

2 Hazard Identification

This HHRA evaluates potential health risks associated with the inhalation of hydrogen sulfide in air for receptors who live and work in the neighborhood around the WRF. Hydrogen sulfide from the WRF is the most likely main source of the odors experienced in the neighborhood around the WRF.

2.1 What is Hydrogen Sulfide?

Hydrogen sulfide is a colorless, flammable gas that is produced naturally when bacteria break down organic matter. It has an unpleasant smell similar to rotten eggs. Hydrogen sulfide is often found naturally in swampy areas and because of this, is often called swamp gas. Hydrogen sulfide can also be produced from man-made sources, such as factories. After it is produced, hydrogen sulfide is released to the air and can be transported through the atmosphere.

[1] The Facility subject to regulation under the Occupational Safety and Health Act (The Act) of 1970, including the requirements under Subpart Z which establishes safety and health standards for worker exposure to toxic and hazardous substances in air. The Act requires employers to ensure that worker exposure to all chemicals in air – regardless of their source – meet levels that represent a safe working environment.

> **What is a Part Per Billion?**
> Imagine you have a giant jar filled with 1 billion tiny marbles. If you remove just 1 marble and paint it red, that red marble represents 1 part per billion (ppb) of the marbles in the jar. With regard to air, if a certain chemical is present in air at 1 ppbv concentration, then for every billion molecules of air, just one molecule is of that chemical.

Hydrogen sulfide in air is measured using specialized air monitoring equipment. The levels of hydrogen sulfide from these monitors are often presented in units of parts per billion by volume (sometimes the acronym "ppbv" is used as shorthand). The air monitors used in neighborhood monitoring locations, around the WRF, can detect hydrogen sulfide at levels as low as 3 ppbv[2].

The health effects from exposure to hydrogen sulfide depend on the amount to which a person is exposed and the duration over which they are exposed. Inhaling air with hydrogen sulfide can affect respiratory, nervous, and cardiovascular systems. Exposure to low levels of hydrogen sulfide (less than or equal to 50,000 ppbv) may cause eye, nose, and throat irritation, may worsen asthma, or cause headaches and nausea. Exposure to very high levels (greater than 100,000 ppbv) can result in loss of consciousness, impacts to vital systems (for example, cardiovascular, neurological), and even death. The main health concerns associated with hydrogen sulfide exposure are related to adverse effects on vital systems. This does not include cancer, as hydrogen sulfide has not been shown to cause cancer in humans.

Most people can smell hydrogen sulfide in the air at very low levels ranging from 0.5 ppbv to 300 ppbv (ATSDR 2016). Odor, however, is not a reliable means of predicting health effects. Typical background levels of hydrogen sulfide in outdoor air (due to natural, non-specific sources) range from around 0.11 ppbv to 0.33 ppbv (ATSDR 2016).

Appendix A includes a Frequently Asked Questions (FAQ) document prepared by the Agency for Toxic Substances and Disease Registry (ATSDR). This FAQ includes more information about hydrogen sulfide exposure and its toxicity.

2.2 Air Monitoring Program

In 2024, the County initiated an air monitoring program to evaluate the levels of hydrogen sulfide in air at various locations at the WRF and within the surrounding neighborhood. This monitoring program and the data generated were described in detail in the following reports prepared by HDR, the consultant firm who conducted the air monitoring for the County:

- HDR (2024a). *Odor Control Monitoring Data, Annapolis Water Reclamation Facility Odor Control Evaluations.* May 20.
- HDR (2024b). *Odor Control Summer Monitoring Data, Annapolis Water Reclamation Facility Odor Control Evaluations.* December 10.

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[2] Based on information from the manufacturer: https://www.acrulog.com/wp-content/uploads/2024/07/Acrulog-PPB-Logger-Brochure.pdf.

This section presents only a brief summary of the monitoring program and results. More detailed information, including more information on the monitoring program, is available in the above two reports.

The air monitoring plan included multiple rounds of monitoring. Continuous monitoring of hydrogen sulfide concentrations and temperature at 14 locations was conducted over a four-week period from March 19, 2024 through April 22, 2024 (the "spring" event). Monitoring locations from this period are shown on **Figure 1**. Of these 14 locations, four monitoring devices (referred to as "loggers") were positioned at fenceline locations (at the boundary of the WRF) and 10 loggers were placed within the WRF. The fenceline monitors were positioned at the north, northwest, south, and southeast boundary of the WRF; however, the northwestern monitor was relocated on April 14 to be repositioned on the west side of the WRF near the Solids Facility (HDR, 2024a).

A similar monitoring event was conducted over a six-week period from July 1, 2024 to August 13, 2024 ("summer" event). Seven loggers were placed within the WRF and eight loggers were placed at three fenceline locations and five neighborhood locations. The five neighborhood locations are shown on **Figure 2** and include two at the Marina to the west of the WRF (Marina Store Front and Marina Fenceline), one at the Maritime Museum to the north of the WRF, and two in the Chesapeake Harbor Condominium Complex to the east of the WRF (HDR 2024b).

2.3 Air Monitoring Results

The air monitors were checked on a weekly basis for battery life and to extract (download) data. The data collected during the spring and summer events were presented in HDR 2024a and b and are briefly summarized below.

2.3.1 Water Reclamation Facility

Within the WRF, hydrogen sulfide monitoring was conducted at the influent pump station, the screen and Grit Building (Headworks), the primary clarifier, the odor control blowers, the gravity sludge thickener, solids facility, and the secondary clarifier in March and April 2024. Several of these monitoring locations were again sampled during the July and August 2024 monitoring event. According to WRF representatives, with the exception of the Headworks location, these monitors were located at specific processes and pulled from supply lines or covered areas where employees are typically not present except when equipment requires repairs. These monitoring locations included both controlled (sent to odor control treatment) and uncontrolled emissions (emitted directly to the atmosphere). The locations generally overlapped between the spring and summer monitoring events (HDR 2024b).

The reports prepared by HDR provide detailed discussion of air monitoring results at the WRF. Table 2.1 below summarizes monitoring results for WRF and fenceline monitoring locations.

Hydrogen sulfide was detected frequently at the WRF at both uncontrolled and controlled sources. The greatest concentrations at the uncontrolled sources were detected in the Headworks building, whereas the highest concentrations at the controlled sources were detected at the primary clarifiers.

Fenceline monitoring was also conducted at the boundary of the WRF: the north fenceline monitor located near the denitrification filters, the western fenceline monitor located near the septic hauler discharge, and the southern fenceline monitor near the primary clarifiers. In the spring monitoring event, there was also a fenceline monitor added to the southeast of the WRF.

A summary of data for fenceline monitors is shown in Table 1.

Table 1. WRF Hydrogen Sulfide Air Monitoring Results: Spring and Summer 2024

Monitoring Location	**Detection Frequency[a]**	**Range of Concentrations (ppbv)**
WRF- Uncontrolled Sources[b]	0 to 98%	0 to 60,000
WRF- Controlled Sources[c]	32 – 98%	0 to 39,200
Fenceline – Septic Hauler (west)	15%	0 – 2,500
Fenceline – South	51%	0 – 700
Fenceline - North	24%	0 – 100

a) *Number of detected readings divided by the total number of readings, expressed as a percentage.*

b) *Includes influent pump station (effluent), headworks building and effluent, solids building, aeration tank, secondary clarifier launder, and mudwell.*

c) *Includes influent pump station (influent), primary clarifier launder #1 and #2, odor control blowers, and gravity sludge thickeners 1 and 2.*

Hydrogen sulfide concentrations were not detected most of the time at the fenceline monitors (frequency of detection ranged from 2 percent to 24 percent in the spring monitoring event and 15 to 51 percent in the summer monitoring event). The highest concentrations were observed at the septic hauler location, with concentrations up to 276,000 ppbv in the spring event and 2,500 ppbv at the summer event. These spikes are likely occurring during septic unloading events (HDR 2024b).

In general, hydrogen sulfide levels at WRF and fenceline monitoring locations were higher in the summer than in the spring, likely associated with the fact that warmer temperatures typically increase biological activity and create anaerobic conditions that lead to higher hydrogen sulfide production and release to the atmosphere.

Section 6 discusses WRF monitoring data with respect to worker safety standards and guidelines.

2.3.2 Neighborhood

Hydrogen sulfide monitoring also was conducted in the neighborhood in summer 2024. A summary of these results is presented in Table 2 below. The table also includes the daily average concentrations calculated for each neighborhood monitoring location and the maximum of those daily averages.

Table 2. Neighborhood Hydrogen Sulfide Air Monitoring Results: Summer

Monitoring Location	Detection Frequency[a]	Range of Concentrations (ppbv)	Average Concentration[b] (ppbv)	Maximum Daily Average Concentration (ppbv)[c]
Maritime Museum	1%	0 - 16	0.08	0.99
Marina Storefront	5%	0 - 48	0.38	4.03
Marina Fenceline	4%	0 - 41	0.25	1.57
Chesapeake Harbor (pool/tennis)	3%	0 - 61	0.24	1.9
Chesapeake Harbor (roadway)	2%	0 - 20	0.10	1.1

a) Number of detected readings divided by the total number of readings, expressed as a percentage.

b) Average concentration across all readings during the entire monitoring period

c) The highest level among all the average daily (24-hour) concentrations.

In general, hydrogen sulfide was infrequently detected at the neighborhood monitoring stations. Highest detected concentrations were observed at the two marina locations and the Chesapeake Harbor pool and tennis courts location.

Overall, the average concentrations at neighborhood monitoring locations for the entire monitoring period were within the range of or slightly above typical background levels (0.11-0.33 ppbv). Sporadic detections of hydrogen sulfide occasionally exceeded odor thresholds and background levels.

2.4 Uncertainties for Hazard Identification

Uncertainties associated with the hazard identification include the following:

- The hydrogen sulfide data are limited to a set number of monitoring locations, so there is uncertainty regarding hydrogen sulfide levels in areas lacking a monitor. However, monitoring point locations were selected based on representation of neighborhood areas where odors have been noted or expected.
- Hydrogen sulfide levels can vary over time. However, monitors collected readings every 10 minutes throughout the monitoring period, providing good representation of this variability over time. The length of the monitoring events is expected to provide a good representation of fluctuating meteorological conditions (like wind speed and direction).
- For the neighborhood locations, data were collected only during summer months, so there is uncertainty about how hydrogen sulfide levels may change during other parts of the year. However, data from WRF points indicate concentrations were generally the highest during the summer months, so the summer monitoring data is likely a conservative estimate of concentrations that occur throughout the year.

3 Exposure Assessment

The purpose of the exposure assessment is to identify the human receptors that could be exposed to chemicals, the pathways through which those receptors could be exposed (sometimes referred to as "exposure routes"), and to estimate the amount of the chemical to which they could be exposed over a given time (commonly referred to as their "exposure period"). For those receptors, the HHRA also selects the age ranges that most likely represent the longest exposure period or the most sensitive period of the receptor's life.

For the purposes of supporting risk management decision-making, USEPA's risk assessment framework involves evaluation of the *Reasonable Maximum Exposure* (RME) for each receptor group. Reasonable Maximum Exposure is the highest exposure that is *reasonably* expected to occur (USEPA 1989). Estimating this level of exposure involves using conservative health-protective assumptions including the chemical concentration and the time over which the receptors are assumed to be exposed.

For this HHRA, Terraphase estimated Reasonable Maximum Exposure.

3.1 Exposure Setting

The WRF is located in Annapolis, Maryland. It is bordered by Chesapeake Harbor Drive, Chesapeake Harbor Drive West, and Edgewood Road. The WRF property consists of several buildings and outdoor headworks, clarifiers, aeration basins, and filters related to the wastewater treatment process. The WRF is bordered to the east and south by residential neighborhoods. A marina is located to the west of the WRF. To the north lies undeveloped parkland and the Annapolis Maritime Museum.

3.2 Exposed Populations

The most likely receptor groups exposed to hydrogen sulfide at and around the WRF are:

WRF workers: According to WRF representatives, staff are typically present at the WRF from 6:00 A.M. to 3:00 P.M. and normally are not present at the Facility overnight. Workers generally spend only a minimal amount of time at the locations where the gas monitors were placed, unless they are repairing a piece of equipment.

WRF workers could potentially inhale hydrogen sulfide in air while inside the headworks building as well as in outdoor air while working in outside areas of the plant. This exposure is expected to be short-term, however, due to the limited amount of time spent at the various WRF equipment and locations that were monitored.

As discussed earlier, the WRF worker assessment is presented separately in Section 6.

Neighborhood residents: Residential dwellings are located along Chesapeake Harbor Drive and Chesapeake Harbor Drive West, located south and east of the WRF, respectively. Adult and child residents who live in this neighborhood could potentially inhale outdoor air with hydrogen sulfide that was generated from the WRF.

Neighborhood workers or visitors: People who work at the marina or the maritime museum or visitors to those establishments or other places in the vicinity of the WRF could potentially inhale outdoor air with hydrogen sulfide that was generated from the WRF. However, neighborhood residents most likely are present in their homes throughout the day and year-round and are expected to have a higher exposure potential compared to workers or visitors. Therefore, residents and workers are selected as the receptor groups with the highest potential for exposure in the neighborhood and are the focus of this HHRA.

3.3 Estimation of Exposure

The USEPA defines exposure as the "*contact with a chemical or physical agent*" (USEPA 1989). Exposure to receptors is estimated by using certain assumptions about the level of a chemical, the route through which the receptor is exposed to the chemical, the amount of time spent exposed to a chemical, and sometimes physiological characteristics. For this HHRA, the primary exposure pathway (or route) is inhalation.

Inhalation exposures are calculated by adjusting the chemical concentration in the air (C_a) by the amount of time the receptor is exposed. An exposure that occurs over a short period of time (for example, over minutes to days) is referred to as an acute exposure. Acute exposures can be assessed using the chemical concentration in the air at a given time – they are not prorated based on the exposure period. Exposure that occurs repeatedly over a longer period of time (typically years) is referred to as chronic exposure (ATSDR 2020). This HHRA evaluates chronic exposure to neighborhood receptors.

To evaluate chronic exposure, the *average daily exposure* for each receptor group is estimated. The average daily exposure (ADE) is represented by the following equation (USEPA 2009):

$$ADE = \frac{\mathrm{C}_a * \mathrm{ET} * \mathrm{EF} * \mathrm{ED}}{\mathrm{AT}}$$

Where:

- ADE = average daily exposure, in units of milligrams per cubic meter (mg/m^3)[3]
- Ca = hydrogen sulfide concentration in air, in mg/m^3
- ET = exposure time, in hours per day
- EF = exposure frequency, in days per year
- ED = exposure duration, in years
- AT = averaging time in hours, which is equivalent to the ED in years multiplied by conversion factors of 24 hours/day and 365 days/year

[3] Hydrogen sulfide monitoring data for neighborhood monitoring points were collected in units of ppbv. Results in ppbv were converted to milligrams per cubic meter (mg/m^3) by multiplying by a factor of 0.0014. For further information on units conversion, please refer to Boguski, 2006.

Both ADE and C_a are presented in units of milligrams per cubic meter (mg/m^3). These units are used instead of ppbv because the toxicity values used to quantify the hazard as exposure increases are in units of mg/m^3, as discussed in Section 4. Because of this, in calculating ADE, Terraphase converted air monitoring data obtained in units of ppbv into mg/m^3.

C_a: As discussed in Section 2, air monitoring for hydrogen sulfide was conducted in summer 2024 at five locations across the neighborhood surrounding the WRF. Monitoring occurred over an approximate two-month period, and monitors read hydrogen sulfide levels approximately every 10 minutes throughout the day. As noted in Section 2, hydrogen sulfide was rarely detected in most readings.

This HHRA evaluates chronic exposures to hydrogen sulfide, and individual monitoring measurements that fluctuate over the course of 24 hours do not represent a long-term, chronic exposure. Because of this, the HHRA used the time-weighted average hydrogen sulfide concentration among all readings across the entire sampling period for each neighborhood monitoring point.

The gas monitors can detect hydrogen sulfide at levels as low as 3 ppbv. Where the hydrogen sulfide concentrations are below this level, the monitor reports the result as zero (0 ppbv). This does not mean that hydrogen sulfide is not present, however. The chemical could be present, but at levels undetectable by the instrument. To accommodate for this uncertainty, Terraphase calculated risks for two different C_a concentrations:

1. Using the zero results as-is in calculating a time-weighted average concentration.
2. Where results were reported as zero, assuming that hydrogen sulfide was present at a concentration of 0.3 ppbv - the upper end of the typical background range (ATSDR 2016). In this case, the time-weighted average concentrations were calculated based on both the detected concentrations and the non-detected concentrations set at a value of 0.3 ppbv.

Evaluating these two scenarios helps reduce the uncertainty associated with using the monitoring dataset and provides a range of potential risks.

Residential Exposure Time, Frequency, and Duration: Residents were assumed to be exposed to hydrogen sulfide in air 24 hours per day for 365 days per year. This HHRA used an exposure duration of six years, which represents the age span of a young child 0-6 years of age and is the USEPA default ED for a resident (USEPA 1991).

These are very conservative assumptions, because most people leave their homes for at least a portion of the day (for example, for work or school) and may occasionally spend days away from their home (such as when on vacation) or may not live in the area for that length of time. These conservative assumptions result in an estimate of potential risk that is biased toward the highest end of exposure.

The uncertainties associated with the exposure assessment include the following:

- People’s activity patterns and corresponding levels of exposure can vary considerably. Many people spend at least a portion of their time outside of their home. This HHRA assumed that residents are exposed to hydrogen sulfide in the WRF neighborhood for the entire monitoring period. This is a conservative estimate of exposure intended to provide high-end estimates of potential health risk.

- The HHRA assumed that a resident is exposed at each monitoring location. Several of the locations (such as the marina and museum), however, are not located in residential areas. This assumption provides a conservative estimate of exposure and potential health risk for receptors such as workers or visitors who are expected to be exposed for less time than a resident.
- The value used for C_a is based on a time-weighted average to provide an estimate of the exposure a receptor could incur over the entire monitoring period. While hydrogen sulfide levels based on singular readings were higher than the average concentration, using the time-weighted average captures both high and low exposure periods, providing a more accurate assessment of exposure and potential chronic health risk.
- Results were reported by the monitoring instrument as zeros for readings where hydrogen sulfide was not detected. The exact concentration of hydrogen sulfide (below 3 ppbv, the instrument detection limit) is unknown for these non-detect values. For non-detect (zero) results, Terraphase assumed that hydrogen sulfide was present at the upper end of the typical background concentration (i.e., 0.3 ppbv), which is more conservative than using a zero value, but this assumption could either under- or over-predict the actual time-weighted average concentrations.

4 Toxicity Assessment

A toxicity assessment describes how exposure to certain chemicals can harm health and determines how much exposure is needed to cause harmful effects. Section 2.1 described the general health effects associated with a person’s exposure to hydrogen sulfide. This section presents the toxicity information used in this HHRA to quantify potential health risk.

4.1 Chronic Toxicity

This HHRA evaluated long term, chronic exposures[4]. The type of toxicity value used to assess systemic health effects (non-cancer effects) is referred to as the chronic reference concentration (RfC). The chronic RfC is the concentration of a particular chemical in the air that a person can be exposed to continuously and not be subject to harmful effects (USEPA 2025a). RfCs are used by government agencies to set air quality standards and to perform risk assessments, the result of which can be used for risk management decision-making. In general, the higher the RfC is, the less toxic the chemical.

The USEPA has developed a chronic RfC for hydrogen sulfide of 0.002 mg/m^3 (or 1.4 ppbv) (USEPA 2025a). The RfC is based on nervous and respiratory system effects and is intended to be used in risk assessments that evaluate chronic, long-term exposures. This RfC was used in this HHRA to estimate chronic health risk to residents in the neighborhood of the WRF.

[4] An HHRA also typically includes evaluation of cancer risk. However, because hydrogen sulfide is not classified as a carcinogen (cancer-causing), an evaluation of cancer risk is not included in this report.

4.2 Acute and Subchronic Toxicity

Other toxicity values are available for hydrogen sulfide but are intended to evaluate shorter-term exposures than those applicable to the RfC.

USEPA issued Acute Exposure Guideline Levels (AEGLs) for hydrogen sulfide (USEPA 2025b). AEGLs are safety limits used by emergency planners and responders to protect people from harmful chemicals in air following a chemical accident. There are three levels of AEGLs based on the severity of health effects. AEGL-1 is the lowest level, at which exposed populations could experience temporary, mild discomfort (such as eye irritation), but no long-lasting effects. The AEGL-1 values vary depending on the length of exposure, ranging from 10 minutes to eight hours. The lowest AEGL-1 for hydrogen sulfide of 330 ppbv (0.46 mg/m^3) is based on an 8-hour exposure duration. **None of the detected concentrations in the neighborhood, over the entirety of the monitoring period, exceeded the AEGL-1; the highest recorded reading in neighborhood samples of 61 ppbv (at Chesapeake Harbor-pool) was five times lower than the AEGL-1.**

The ATSDR provides Minimal Risk Levels (MRL) for hydrogen sulfide (ATSDR 2016). MRLs are a screening tool developed by ATSDR in a manner similar to RfCs, in that they are an estimate of daily exposure to a chemical that is not expected to cause adverse health effects. ATSDR has published an acute-duration MRL of 70 ppbv (0.097 mg/m^3) for hydrogen sulfide based on respiratory and metabolic effects and an intermediate-duration MRL of 20 ppbv (0.028 mg/m^3), both based on nervous and respiratory effects (ATSDR 2016). The acute MRL is applicable to exposures that occur from 1-14 days, whereas the intermediate MRL applies to exposures 15 to 364 days. While both acute and intermediate MRLs are applicable, they were not used in this HHRA since the USEPA RfC is a more conservative (health-protective) value. **No individual hydrogen sulfide concentration exceeded the acute MRL of 70 ppbv at any neighborhood monitoring point, and no daily average concentration exceeded the intermediate MRL of 20 ppbv at any neighborhood monitoring point (see Table 2).**

4.3 Uncertainties with the Toxicity Assessment

The main uncertainty for the Toxicity Assessment is the toxicity values used to assess health risk. Chemical sensitivity varies among people since some are more sensitive than others, depending on various factors such as age, sex, genetics, diet, smoking status, and general state of health. The RfC used in this assessment is designed to be protective of health across a broad population, including the most sensitive groups in the population.

5 Risk Characterization

The information from the exposure assessment and toxicity assessment are combined to determine the potential for health risk, in a process called risk characterization. Risk characterization is the final step of the HHRA process. The outcome of the risk characterization helps decision makers determine if the levels of chemicals in the environment warrant further action.

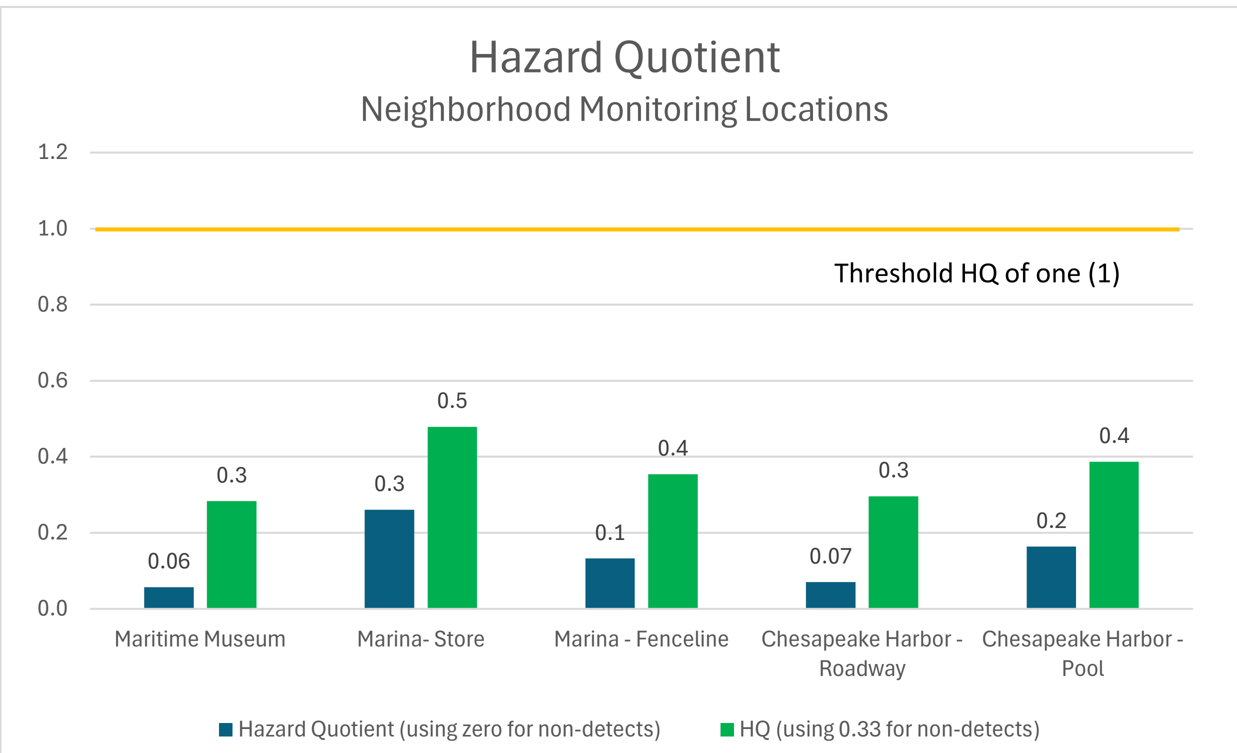
The potential for health risks from exposure to a chemical is evaluated using a term called a Hazard Quotient (HQ). The HQ is calculated by comparing the receptor's average daily exposure to the RfC:

$$HQ = \frac{ADE}{RfC}$$

HQ is a unitless value. If the HQ is less than or equal to a value of one (the exposure dose is the same as or lower than the RfC), then it means the exposure is considered to be safe. If the HQ is greater than one, then it means that there may be a *potential* health risk (although it does not mean there is an actual health risk; it is only a theoretical estimate of risk). **Appendix B** presents the calculation of HQs for each monitoring point.

The chart below shows the HQs calculated for a residential receptor at each of the five monitoring points in the neighborhood. The height of the bars in the chart represents the magnitude of the HQ calculated for each monitoring point (higher bars have higher HQs), and the numbers above each bar are the calculated HQ at each location. Blue bars show the HQ that was calculated using the zero values reported for non-detect results, whereas green bars show the HQ calculated assuming a background value of 0.3 ppbv for non-detect results.

These HQs are compared to the HQ threshold of one, depicted as the horizontal orange line shown in the figure below.



All of the HQs at each of the neighborhood monitoring points, for both scenarios (assuming zero or 0.33 for non-detects), are well below the HQ threshold of one. The highest HQ was calculated for the Marina store location, but even that HQ was one-half of the HQ threshold of one.

HQs less than one at all neighborhood monitoring points indicate that the hydrogen sulfide levels in air in the neighborhood around the WRF are not expected to pose adverse health effects to residents who live or work in the neighborhood and breathe the air.

The uncertainties associated with the risk characterization mainly relate to the uncertainties associated with the exposure and toxicity assessments that were discussed in Sections 3.3 and 4.

The hazard quotient method is a common and straight-forward tool used by environmental managers to compare the estimated dose to the toxicity of a chemical and predict whether that dose is likely to cause health effects. As only an estimation tool, the HQ does not tell us if that exposure has or has not resulted in actual health effects or if health effects will occur from an exposure.

This HHRA evaluated potential health risk for only hydrogen sulfide, which is the primary chemical of potential concern at the WRF. People may be exposed to other chemicals in air, soil, water, and diet throughout their life, which could contribute to overall health risk.

Overall, this HHRA used conservative, health-protective assumptions to estimate HQs. These conservative assumptions, coupled with the low HQ values, indicate that there is little uncertainty associated with the conclusions of the HHRA – **in other words, the hydrogen sulfide concentrations in air of the WRF neighborhood are not expected to cause health effects to local residents.**

6 WRF Worker Scenario

Because the WRF is subject to federal occupational standards and has safety controls and employee training and monitoring in place to control worker exposures, the WRF worker scenario was evaluated separately by discussing their exposure relative to occupational standards and guidelines and safety procedures.

As discussed earlier, WRF workers could potentially inhale hydrogen sulfide inside the headworks building as well as in outside areas of the plant during the course of daily operations. Hydrogen sulfide monitors have been installed across the WRF at a number of locations adjacent to WRF processes as well as at fenceline locations. Monitoring results generally show much higher levels and more frequent detections of hydrogen sulfide at the WRF compared to the neighborhood monitoring locations.

Hydrogen sulfide is a common pollutant in wastewater treatment facilities. As demonstrated by the monitoring data summarized in Section 2.3.1, the levels of hydrogen sulfide fluctuate considerably during the course of the day. Due to this variability and the fact that high levels of hydrogen sulfide in air can be extremely toxic to workers, even over a short timeframe, worker safety precautions are employed to maintain worker health in these types of facilities.

In the United States, there are several measures taken to ensure the health and safety of workers at wastewater facilities where they could be exposed to hydrogen sulfide in the air. To protect workers, facilities follow strict regulations and guidelines set by organizations like the Occupational Safety and Health Administration (OSHA). These measures include monitoring air quality to detect hydrogen sulfide levels and providing proper training for workers to recognize and respond to the presence of the gas. Additionally, facilities must have emergency plans in place in case of a hydrogen sulfide leak, including procedures for evacuating workers and providing medical care if needed. By following these safety measures, wastewater facilities help to protect the health and well-being of their workers.

At the WRF, the only enclosed part of the treatment train is the grit/screen/headworks building, where wastewater is screened and degritted and the highest hydrogen sulfide levels (up to 57,800 ppbv) were routinely seen. This building is equipped with hydrogen sulfide monitors equipped with alarms that are set off when hydrogen sulfide levels exceed 10,000 ppbv, which is the Recommended Exposure Level (REL) set by the National Institute for Occupational Safety and Health (NIOSH). The REL is for a 10-minute ceiling exposure.

According to WRF representatives, these alarms have never been triggered and are all calibrated and in working order. While the Headworks monitoring results occasionally exceeded 10,000 ppbv, the monitors are located directly adjacent to the bar screens and above the grit channel, and not representative of locations within the building where workers are more likely exposed. In addition to the alarmed monitors, all operators who enter this building are required to wear odor monitors. When gas levels increase to unacceptable levels, the building ventilation is increased until levels are acceptable to work in. There is also an enclosed Solids Building, where contractor operators dewater the biosolids. There are no permanently mounted hydrogen sulfide monitors in or sampling data available for this building (monitoring was conducted downstream of the odor control system.)

The table below summarizes the available occupational standards for hydrogen sulfide in air. These limits help protect workers from the acute and chronic health effects of hydrogen sulfide exposure, including respiratory irritation, central nervous system effects, and potential asphyxiation at higher concentrations. Of these, the OSHA Permissible Exposure Limit (PEL) is the only enforceable standard that must be met. OSHA PELs are federal standards, many of which were issued decades ago. Because of this, PELs may not be adequate for ensuring the protection of worker health and in fact, OSHA recommends that employers use alternative occupational health guidelines and limits for evaluating worker safety (OSHA 2025[5]).

Table 3 below includes the PEL as well as alternative guidelines recommended by other occupational health agencies, including the National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH). NIOSH is a federal agency who has issued Recommended Exposure Limits (RELs). ACGIH is a private, non-profit, non-governmental scientific organization that develops occupational guidelines that are entirely based upon health and safety considerations.[6]

[5] https://www.osha.gov/annotated-pels

[6] See https://www.osha.gov/annotated-pels for a detailed description of each of the above guidelines/standards.

Table 3. Hydrogen Sulfide Occupational Exposure Standard & Guidelines

Agency	Exposure Limit	Value (ppbv)	Notes
OSHA	Permissible Exposure Limit (PEL)	20,000	Ceiling. Allows for peak of 50,000 ppbv for 10 minutes, if no other exposure occurs
NIOSH	Immediately Dangerous to Life and Health (IDLH)	100,000	Not to exceed
	Recommended Exposure Limit (REL)	10,000	10-minute ceiling
ACGIH	Threshold Limit Value, time-weighted average (TLV-TWA)	1,000	8-hour time-weighted average
	Threshold Limit Value, short-term exposure limit (TLV-STEL)	5,000	15-minute exposure limit

Refer to the HDR December 2024 report for detailed discussion and presentation of WRF data.

Table 4 presents the detection frequency and range of detected hydrogen sulfide concentrations at the WRF by monitoring point.

Table 4. Frequency and Range of Detected Hydrogen Sulfide Concentrations at WRF Monitoring Locations[a]

Monitoring Location	Spring		Summer	
	Detection Frequency	*Range of Detected Concentrations (ppbv)*	*Detection Frequency*	*Range of Detected Concentrations (ppbv)*
Uncontrolled Sources (Emitted directly to atmosphere)				
Influent Pump Station (effluent)	-	-	81%	400– 15,300
Headworks (Building Space)	-	-	98%	400– 57,800
Headworks (Effluent)	56%	400 – 19,900	89%	400– 12,500
Solids Building (after odor control)	1%	400 – 900	0%	0.0 – 0.0
Aeration Tank	0%	0	-	-
Secondary Clarifier Launder	0.04%	400	-	-
Mudwell	-	-	43%	400– 60,000

Table 4. Frequency and Range of Detected Hydrogen Sulfide Concentrations at WRF Monitoring Locations[a]

Monitoring Location	*Spring*		*Summer*	
	Detection Frequency	*Range of Detected Concentrations (ppbv)*	*Detection Frequency*	*Range of Detected Concentrations (ppbv)*
Controlled Sources (Sent to Odor Control Treatment)				
Influent Pump Station (influent)	96%	400 – 13,800	98%	400– 36,700
Primary Clarifier Launder #1	79%	400 – 27,500	93%	400– 37,700
Primary Clarifier Launder #2	96%	400 – 26,300	-	-
Odor Control Blowers	46%	400 – 9,500	82%	400– 37,200
Gravity Sludge Thickener #1	32%	400 – 3,500	95%	400– 39,200
Gravity Sludge Thickener #2	54%	400 – 4,200	-	-
Fenceline Locations				
Septic Hauler Discharge	-	-	15%	3 – 2,500
South (PC Distribution Box)	-	-	51%	3 – 700
North (near Mudwells)	-	-	24%	3 – 100

A dash (-) indicates monitoring point not sampled during event.

a. Summary data are reproduced from HDR December 2024, Tables 3-1 and 3-2.

Comparison of data to these limits indicates the following:

- **OSHA:** There have been sporadic individual hydrogen sulfide measurements exceeding the PEL ceiling of 20,000 ppbv and the 10-minute peak of 50,000 ppbv. These detections have occurred at least once at most monitoring locations within the WRF. As mentioned, workers are typically not present in these monitoring locations on a routine or frequent basis. Of the monitoring locations, the only interior location is the Headworks facility, which is equipped with hydrogen sulfide alarms.
- **NIOSH:** There have been sporadic individual hydrogen sulfide measurements at WRF locations exceeding the REL of 10,000 ppbv. These detections have occurred at least once at most monitoring locations within the WRF. No detected concentration at fenceline monitors exceeded the REL. No detected concentration at any location exceeded the IDLH.
- **ACGIH**: Detections exceeded the TLV-TWA and TLV-STEL at most locations in the WRF and at the septic hauler discharge monitoring point (western fenceline).

As discussed, workers are infrequently present at the equipment and monitoring locations and are required to wear odor monitors while working in the Headworks building, which also contains hydrogen sulfide alarms. Nevertheless, precautions should be taken by workers when entering these areas, in accordance with OSHA requirements, due to the occasional peaks of hydrogen sulfide above the OSHA standard and recommended exposure levels and guidelines.

7 Conclusions

This HHRA was conducted by Terraphase to evaluate potential health risks associated with breathing hydrogen sulfide in air at the WRF and at various points around the WRF neighborhood. The HHRA used hydrogen sulfide monitoring data generated from the Odor Control Project in conjunction with conservative assumptions about residents' exposure to estimate HQs. Results of the risk assessment for residential receptors indicated that all HQs at all neighborhood monitoring sites were below the threshold of one, meaning that the levels of hydrogen sulfide in the air are not expected to pose a health risk to neighborhood workers, visitors, or residents.

A separate evaluation of worker safety was conducted for the WRF workers by comparing air monitoring results at the WRF to occupational safety standards and guidelines. This worker safety evaluation is distinct from the residential HHRA because the WRF is required by federal regulations to provide training and safety measures to protect worker exposure. The comparison indicated that hydrogen sulfide periodically reaches levels at various points in the WRF that could be hazardous to employees working in those areas, and that safety measures and monitoring should be continued.

While there are uncertainties and limitations associated with this risk assessment, the HHRA was designed to be a conservative and health-protective evaluation of potential health risk. However, it is important to note that the HHRA provides only an estimate of *theoretical* risk and is not intended to evaluate actual or future health effects that have or could result from exposure.

8 Limitations

This document was prepared solely for Tidewater in accordance with professional standards at the time the services were performed and in accordance with the contract between Tidewater and Terraphase dated December 24, 2024. We have relied on information or instructions provided by Tidewater and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

9 References

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Figures

Aerial imagery source: Nearmap (October 25, 2024)

0 75 150 225 300 Feet

1 inch = 150 feet

N

SAFETY FIRST

terraphase engineering

CLIENT: Tidewater

PROJECT: Annapolis Water Reclamation Facility, Annapolis, MD

PROJECT NUMBER: H004.001.001

Winter/Spring Monitoring Locations

FIGURE 1

File: N:\GIS\Prj\H004.001_Annapolis Water Reclamation Facility\Pro Project\(20250227) Site Figures.aprx Layout:Figure 1 - Winter Locations 3/31/2025 Created by: Resource Coordinate System: NAD 1983 StatePlane Maryland FIPS 1900 Feet

Aerial imagery source: Nearmap (October 25, 2024)

0 125 250 375 500 Feet

1 inch = 250 feet

N

SAFETY FIRST

terraphase engineering

CLIENT:	Tidewater
PROJECT:	Annapolis Water Reclamation Facility, Annapolis, MD
PROJECT NUMBER:	H004.001.001

Summer Monitoring Locations

FIGURE 2

File: N:\GIS\Prj\H004.001_Annapolis Water Reclamation Facility\Pro Project\(20250227) Site Figures.aprx Layout:Landscape_11x17 3/31/2025 Created by: Resource Coordinate System: NAD 1983 StatePlane Maryland FIPS 1900 Feet

Appendix A

ATSDR ToxFAQ

Hydrogen Sulfide - ToxFAQs™

CAS # 7783-06-4

This fact sheet answers the most frequently asked health questions (FAQs) about hydrogen sulfide. For more information, call the CDC Information Center at 1-800-232-4636. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It's important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Hydrogen sulfide occurs naturally and is also produced by human activities. Very high levels (>500 ppm) can result in sudden unconsciousness or death. Lower, longer-term exposure (around 10 ppm or less) can cause eye irritation, headache, and fatigue. Hydrogen sulfide has been found in at least 34 of the 1,832 National Priorities List sites identified by the Environmental Protection Agency (EPA).

What is hydrogen sulfide?

Hydrogen sulfide is a flammable, colorless gas that smells like rotten eggs. People usually can smell hydrogen sulfide at low concentrations in air ranging from 0.0005 to 0.3 parts per million (ppm). It is often referred to as sewer gas or stink damp.

Hydrogen sulfide occurs naturally in crude petroleum, natural gas, volcanic gases, and hot springs. It can also result from bacterial breakdown of organic matter. Bacteria found in your mouth and digestive tract produce hydrogen sulfide during the digestion of food containing vegetable or animal proteins. Industrial sources of hydrogen sulfide include petroleum refineries, natural gas plants, petrochemical plants, coke oven plants, food processing plants, and tanneries.

It is used primarily in the production of sulfur and sulfuric acid.

What happens to hydrogen sulfide when it enters the environment?

- Hydrogen sulfide can be released into air, water, and soil at places where it is produced or used.
- It is released primarily as a gas and spreads in the air. It can remain in the air from 1 to 42 days, depending on the season.
- In air, it can change into sulfur dioxide and sulfates.
- Levels in water are very low because it readily evaporates.
- In soil, hydrogen sulfide will be consumed by bacteria and changed to sulfur.

How might I be exposed to hydrogen sulfide?

- You might be exposed to hydrogen sulfide from breathing contaminated air or drinking contaminated water. Because the gas is heavier than air, risk of exposure is greater at ground level and in enclosed spaces when there are releases into the environment.
- You can be exposed to hydrogen sulfide when living near facilities that generate and release it into the environment, like a wastewater treatment plant, a gas and oil drilling operation, a farm with manure storage or livestock confinement facilities, or a landfill.
- You can be exposed at work if you work in rayon textiles, petroleum and natural gas drilling and refining, or wastewater treatment industries. Workers on farms with manure storage pits or landfills can be exposed to higher levels of hydrogen sulfide.

How can hydrogen sulfide affect my health?

The effects of hydrogen sulfide exposures in humans varies and depends on concentration levels, exposure duration, affected tissues and co-exposures to other toxic gases. Inhaling the gas quickly affects vital systems such as the respiratory, cardiovascular, and nervous systems during short term (up to about 1-2 weeks) exposure to high concentrations (>150 ppm) and can cause long-term health effects or death.

The odors emitted from the gas become noticeable at low levels (0.0005 ppm). But people lose the ability to smell the gas after about 2 to 15 minutes of exposure at about 100 ppm, which makes the odor an ineffective hazard warning for the presence of hydrogen sulfide gas.

Eye, nose, or throat irritation can occur to long term (exposures (a year or more) at low exposure concentrations of H_2S (ranging from 5 to 50 ppm). Some asthmatics may have difficulty breathing and experience headaches, nauseas, and vomiting. Some of these symptoms may resolve when the exposure is removed.

People can lose their sense of smell or lose consciousness from short exposures (up to about 1-2 weeks) at moderate or high concentrations (greater than 100 ppm). In some cases, the effects go away when exposure is removed. However, in some individuals, long-term or permanent effects may occur.

Hydrogen Sulfide

CAS # 7783-06-4

How likely is hydrogen sulfide to cause cancer?

Hydrogen sulfide has not been shown to cause cancer in humans, and its possible ability to cause cancer in animals has not been studied thoroughly.

The Department of Health and Human Services (DHHS) and the International Agency for Research on Cancer (IARC) have not classified hydrogen sulfide as to its carcinogenicity. The EPA has determined that data for hydrogen sulfide are inadequate for carcinogenic assessments.

How can hydrogen sulfide affect children?

There is very little information on possible health problems in children who have been exposed to hydrogen sulfide. Exposed children probably will experience effects similar to those experienced by exposed adults. Whether children are more sensitive to hydrogen sulfide exposure than adults is not known.

It is not known whether hydrogen sulfide causes birth defects in people. The results of studies in animals suggest that exposure to low concentrations of hydrogen sulfide during pregnancy does not cause birth defects.

How can families reduce the risk of exposure to hydrogen sulfide?

- Hydrogen sulfide is part of the natural environment; the general population will have some exposure to hydrogen sulfide. Families can be exposed to more hydrogen sulfide than the general population if they live near natural or industrial sources of hydrogen sulfide, such as hot springs, manure holding tanks, or pulp and paper mills. However, their exposure levels are unlikely to approach those that sicken people exposed at work.
- Families can reduce their exposure to hydrogen sulfide by avoiding areas that are sources of hydrogen sulfide. For example, individuals of families that live on farms can avoid manure storage areas where high concentrations of hydrogen sulfide may be found.

Is there a medical test to show whether I've been exposed to hydrogen sulfide?

Hydrogen sulfide and its breakdown products (metabolites) can be measured in blood and urine. However, the detection of hydrogen sulfide or its metabolites cannot predict the kind of health effects that might develop from that exposure. Because hydrogen sulfide and its metabolites leave the body fairly rapidly, the tests need to be conducted soon after exposure.

Has the federal government made recommendations to protect human health?

The Occupational Safety and Health Administration (OSHA) set an acceptable ceiling limit of 20 ppm for hydrogen sulfide in workplace air.   The ceiling limit is a 15-minute time-weighted average that cannot be exceeded at any time during the working day.

The National Institute for Occupational Safety and Health (NIOSH) recommends a 10-minute ceiling limit of 10 ppm. NIOSH also determined that 100 ppm is immediately dangerous to life or health of workers.

References

This ToxFAQs™ information is taken from the 2016 Toxicological Profile for Hydrogen Sulfide and Carbonyl Sulfide produced by the Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Public Health Service in Atlanta, GA.

Where can I get more information?

For more information, contact the Agency for Toxic Substances and Disease Registry, Office of Innovation and Analytics, 1600 Clifton Road NE, Mailstop S106-5, Atlanta, GA 30329-4027.

Phone: 1-800-232-4636.

ToxFAQs™ on the web: www.atsdr.cdc.gov/toxFAQs.

ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

Appendix B

Neighborhood Residential Hazard Quotient Calculations

APPENDIX B

Noncancer Hazard Quotient Calculations for Exposure of Residents to Hydrogen Sulfide in Outdoor Air via Inhalation
Annapolis Wastewater Reclamation Facility
Annapolis, Anne Arundel County, Maryland

EQUATIONS (USEPA 1989):

$$\text{Average Daily Exposure: } \frac{Ca * EF * ET * ED}{AT * CF}$$

$$\text{Hazard Quotient: } \frac{ADE}{RfC}$$

Parameter	Value	Units
Concentration in air (Ca)	Time-weighted average (TWA)	micrograms per cubic meter (μg/m^3)
Exposure Frequency (EF)	365	days/year
Exposure Duration (ED) - child	6	years
Exposure Time (ET)	24	hours/day
Averaging Time (AT)	52,560	hours [ED x 365 days/year x 24 hours/day]
Reference Concentration - Inhalation (RfC)	2.00E-03	milligrams per cubic meter (mg/m^3), from USEPA 2025a
Conversion Factor (CF)	1.00E+03	micrograms per milligram (μg/mg)
Hazard Quotient (HQ)	Calculated	unitless

Parameter	Maritime Museum	Marina- Store	Marina - Fenceline	Chesapeake Harbor - Roadway	Chesapeake Harbor - Pool
TWA (ug/m3) ND = 0	0.11	0.52	0.27	0.14	0.33
TWA (ug/m3) ND = 0.33	0.57	0.96	0.71	0.59	0.77
HQ (using zero for non-detects)	0.1	0.3	0.1	0.1	0.2
HQ (using 0.33 for non-detects)	0.3	0.5	0.4	0.3	0.4

Notes:
Time-weighted average across entire summer monitoring period.
ND =0: results reported as zero were used as-is in TWA calculation.
ND = 0.33: a value of 0.33 ppbv, representing background concentrations, was substituted for all results reported as zero in calculation of the TWA

Sources:

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