

Human Health Risk Assessment of Mercury Vapors in Wilder Hall

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Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ATSDR	Agency for Toxic Substances and Disease Registry
EMF	Electric and Magnetic Field
EPC	Exposure Point Concentration
HASP	Health and Safety Plan
MRL	Minimal Risk Level
NAEL	No Adverse Effect Level
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PPE	Personal Protective Equipment
RfC	Inhalation Reference Concentration
TLV	Threshold Limit Value
TWA	Time-weighted Average
UCLM	Upper Confidence Limit on the Mean
US EPA	United States Environmental Protection Agency

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1 Qualifications

Gradient is well recognized as one of the nation's premier risk assessment firms and has deep expertise in human and ecological toxicology, exposure modeling, and quantitative analyses. Gradient has conducted risk assessments in a wide variety of settings. We excel in communicating complex science to a variety of stakeholders. The expertise of the technical professionals who conducted the analyses herein are discussed below.

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Dr. Boomhower is a principal toxicologist with specialties in metals toxicology, including mercury, and human health risk assessment. He uses his multidisciplinary expertise to evaluate potential chemical exposures and health risks in many contexts, including hazard and risk assessment, food safety, consumer product safety, and regulatory comment. Before joining Gradient, Dr. Boomhower was a postdoctoral fellow in the Department of Environmental Health at the Harvard T.H. Chan School of Public Health, where he conducted *in vitro* and *in vivo* studies of metals exposure. His work in mercury toxicology has received multiple funding awards, including from the National Institutes of Health and National Science Foundation. Dr. Boomhower has authored several book chapters and peer-reviewed scientific articles in toxicology and epidemiology. He also teaches courses in toxicology and pharmacology as an instructor at Harvard University, and has served as an invited adjunct lecturer at Georgetown University.

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2 Introduction

2.1 Background and Objectives

This report provides a summary of a human health risk assessment of residual elemental mercury, including in its liquid and vapor forms, at Wilder Hall on the Dartmouth College campus in Hanover, New Hampshire. Wilder Hall was originally built in the late 1800s to house the Department of Physics. The building has had a number of additions since its original construction. During previous construction activities, elevated vapor mercury readings were detected in the original portions of Wilder Hall, and liquid elemental mercury was visually observed in several areas of the building. The contamination is believed to be the result of historical use of liquid mercury within the building. This risk assessment evaluates potential health risks arising from mercury vapor exposure under two scenarios: 1) normal occupancy of Wilder Hall by students, faculty, and staff, and 2) a destructive repair or renovation scenario in which workers are expected to disturb building materials.

2.2 Risk Assessment Methodology

Human health risk assessment is the systematic process of estimating the nature and probability of potential adverse human health effects resulting from exposure to environmental health hazards, now or in the future (US EPA, 2025). Risk assessment generally involves four steps; since this risk assessment of Wilder Hall involves a single chemical (mercury vapor) and one exposure pathway (inhalation) in a non-residential environment, the risk assessment steps are streamlined, as discussed below.

1. **Hazard Identification:** Identify the potential hazard, *i.e.*, determine whether a chemical has the potential to cause certain health effects, and if so, under what circumstances. The health effects associated with exposure to mercury vapor are described in **Section 3.1**.
2. **Dose-Response Assessment:** Determine the relationship between the nature and magnitude of exposure and the probability of an adverse health effect. The health effects of exposure to varying levels of mercury vapor have been extensively studied, and a number of health agencies have developed exposure limits and guidelines for occupational, commercial, and residential scenarios. These include the United States Environmental Protection Agency (US EPA), the Agency for Toxic Substances and Disease Registry (ATSDR), the American Conference of Governmental Industrial Hygienists (ACGIH), and the Occupational Safety and Health Administration (OSHA). Dartmouth has also adopted a self-imposed exposure limit for mercury vapor. These exposure limits are described in **Section 3.2**.
3. **Exposure Assessment:** Estimate the frequency, timing, and level of exposure to the hazard. **Section 3.3** describes the available data for Wilder Hall that have been collected in the past two decades. This risk assessment relies on recent surveys of mercury vapors conducted in 2024 and 2025 to estimate air concentrations throughout the building. Two scenarios are evaluated: 1) normal occupancy by students, faculty, and staff, and 2) destructive repair or renovation during which building materials are expected to be disturbed. For each exposure scenario, exposure point concentrations (EPCs) are calculated for different areas of Wilder Hall.
4. **Risk Characterization:** Compare the estimated human exposure level to the dose-response assessment for the chemical (*i.e.*, exposure limits). For this risk assessment, the EPCs for each

scenario are compared to the appropriate exposure limit as described in Section 3.2. The results of the risk characterization are presented in **Section 3.4** of this report. Section 3.4 also includes a brief discussion of uncertainties in the risk assessment.

3 Human Health Risk Assessment

3.1 Background Information on Mercury

3.1.1 Sources of Mercury

Mercury-related health effects depend upon the form of mercury and the amount, duration, and route of exposure. Mercury occurs in three forms, each of which has different implications for its potential toxicity (Ufelle and Barchowsky, 2019): (1) elemental mercury; (2) organic mercury, which is mercury combined with carbon (*e.g.*, methylmercury); and (3) inorganic mercury, which is mercury (*i.e.*, mercurous [Hg^{+1}] and mercuric [Hg^{+2}] cations) combined with elements other than carbon, such as chlorine, sulfur, and oxygen to form mercury salts (*e.g.*, mercuric chloride) (ATSDR, 2024; Mayfield *et al.*, 2022; Broussard *et al.*, 2002). Elemental mercury exists in a liquid form at room temperature, and it can evaporate to form mercury vapors (ATSDR, 2024). Mercury vapors are denser than air and typically remain close to the ground (ATSDR, 2024). If mercury vapors are near the breathing zone of individuals (*i.e.*, near the nose and mouth), it can be inhaled into the lungs where it is absorbed into the body. Other forms of mercury (*e.g.*, organic mercury or inorganic mercury salts) are typically ingested and absorbed from the gastrointestinal tract.

There are many sources of mercury in the environment. Elemental mercury can be found in air pollution, electrical switches, batteries, thermometers, barometers, dental amalgams, and herbal or religious remedies (ATSDR, 2024). Uses of organic mercury compounds included fungicides for seed grains until the 1970s and antifungal agents in paints (both interior and exterior paints) until 1991 (ATSDR, 2024). Organic mercury (as methylmercury) is commonly found in seafood (*e.g.*, fish) and represents one of the most common sources of mercury exposure in the population (ATSDR, 2024). Uses of inorganic mercury compounds include fungicides, skin-lightening creams, topical antiseptics, disinfectants or antibacterials, and other medicinal products including worming medications, laxatives, and teething powders (ATSDR, 2024). Inorganic mercury compounds are also used in color paints, as a red coloring agent in tattoo dyes (ATSDR, 2024).

This report will focus on elemental mercury in the form of mercury vapors, as this is the form present in Wilder Hall.

3.1.2 Potential Health Effects

The nervous system is the most sensitive target of mercury vapor exposure. Neurological effects are the most common effect associated with chronic exposure to high concentrations of mercury vapor, with tremor and psychological disturbances as the main symptoms (ATSDR, 2024; Clarkson and Magos, 2006; Albers and Bromberg, 1995). Accentuated postural tremor (*i.e.*, a type of tremor that occurs when a person maintains a position against gravity, such as holding arms outstretched) is the most characteristic feature of mercury intoxication, (ATSDR, 2024; Albers, 2012; Albers and Bromberg, 1995). Psychological disturbances associated with chronic exposure to elevated concentrations of elemental mercury include nonspecific neuropsychological symptoms (*e.g.*, shyness, suspicion, mood swings, nervousness, or memory loss) (ATSDR, 2024; Frumkin *et al.*, 2001; Albers and Bromberg, 1995). Other neurological effects include

unsteady walking, irritability, poor concentration, blurred vision, slurred speech, memory deficits, decreased hand-eye coordination, and abnormal nerve conduction (ATSDR, 2024).

3.2 Health-based Exposure Limits

Several health agencies have derived exposure limits for elemental mercury. In developing exposure limits for chemicals, regulatory health agencies often use high-end estimates of exposure and toxicity (which can result in overprediction of potential health risks) to be protective of human health. The aim of the US EPA and other public health agencies is not to precisely define which effects are possible or expected to occur, but to define a level at which health effects are *unlikely* to occur (US EPA, 1993; ATSDR, 2018). Thus, the exceedance of an exposure limit does not mean one should assume it is likely that an adverse health effect will occur; rather, exposures to levels below these criteria means adverse health effects are unlikely to occur. Health-based exposure limits for elemental mercury derived by health agencies are summarized in Table 3.1 below.

Table 3.1 Agency Exposure Limits for Elemental Mercury

Exposure Limit	Value ($\mu\text{g}/\text{m}^3$)	Assumed Exposure Duration	Applicable Population	Source
US EPA RfC	0.3	24 hrs/day, 365 days/year, 70 years	General Population	US EPA (2002a)
ATSDR Chronic MRL	0.3	24 hrs/day, 365 days/year, 70 years	General Population	ATSDR (2024)
ATSDR Action Level	≤ 1	24 hrs/day, 365 days/year, 70 years	Residential Occupants	ATSDR (2012); US EPA (2019)
ATSDR Action Level ^a	≤ 3	8 hrs/day, 240 days/year, 40 years	Commercial Setting Occupants; School Occupants ^b	ATSDR (2012); US EPA (2019)
ACGIH TLV TWA	25	8 hrs/day, 240 days/year, 45 years	Workers	ACGIH (2013)
OSHA PEL	100	8 hrs/day, 240 days/year, 45 years	Workers	OSHA (Undated)

Notes:

ACGIH = American Conference of Governmental Industrial Hygienists; ATSDR = Agency for Toxic Substances and Disease Registry; MRL = Minimal Risk Level; OSHA = Occupational Safety and Health Administration; PEL = Permissible Exposure Limit; RfC = Inhalation Reference Concentration; TLV = Threshold Limit Value; TWA = Time-weighted Average; US EPA = United States Environmental Protection Agency.

(a) Dartmouth has adopted a self-imposed exposure limit of $3 \mu\text{g}/\text{m}^3$ mercury vapor.

(b) Assuming that all visible mercury has been removed from the area. Further, pregnant occupants or pregnant students should be offered temporary alternatives to working or attending the contaminated area (ATSDR, 2012; US EPA, 2019).

In 1995, US EPA derived an inhalation reference concentration (RfC) for elemental mercury of $0.3 \mu\text{g}/\text{m}^3$ (US EPA, 2002a). The RfC is an estimate of a daily inhalation exposure of the human population, including sensitive subgroups, that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfC for elemental mercury was derived from an occupational study by Fawer *et al.* (1983), who measured tremors that occurred at the initiation of voluntary movements in workers exposed to mercury vapor in various occupations. The average exposure concentration was $26 \mu\text{g}/\text{m}^3$ and average exposure duration was 15.3 years. The value of $26 \mu\text{g}/\text{m}^3$ was designated by US EPA (2002a) as the lowest observable adverse effect level (LOAEL), and adjusted to $9 \mu\text{g}/\text{m}^3$ for continuous exposure of the general population (*i.e.*, converted from an 8-hour workday exposure to a 24-hour continuous exposure). An uncertainty factor of 30 was used to derive the RfC of $0.3 \mu\text{g}/\text{m}^3$ (US EPA, 2002a).¹

¹ US EPA also considered other studies in deriving the RfC. For example, US EPA considered occupational studies of neurological effects in chloralkali workers, who were exposed to an estimated 25 to $30 \mu\text{g}/\text{m}^3$ mercury from vapors for an average of 13.7 to 15.6 years (Piikivi and Tolonen, 1989; Piikivi and Hanninen, 1989; Piikivi, 1989). Other studies that US EPA considered included

In 2024, ATSDR derived a chronic minimal risk level (MRL) for elemental mercury of $0.3 \mu\text{g}/\text{m}^3$ (ATSDR, 2024). A chronic MRL is a daily estimate of human exposure to a chemical that is likely to be without an appreciable risk of health effects over a lifetime. The chronic MRL for elemental mercury was derived using an air concentration of $2.84 \mu\text{g}/\text{m}^3$, which represents a pooled, lower-bound estimate of a no adverse effect level (NAEL) that was calculated from multiple studies of workers (*i.e.*, Bast-Pettersen *et al.*, 2005; Boogaard *et al.*, 1996; Chapman *et al.*, 1990; Ellingsen *et al.*, 2001; Fawer *et al.*, 1983; Langworth *et al.*, 1992; Wastensson *et al.*, 2006, 2008). Across the studies, the average estimated air concentration ranged from 4.43 to $8.74 \mu\text{g}/\text{m}^3$, and the average estimated exposure duration ranged from 5.3 to 15.3 years (ATSDR, 2024). An uncertainty factor of 10 was applied to $2.84 \mu\text{g}/\text{m}^3$, resulting in a chronic MRL of $0.3 \mu\text{g}/\text{m}^3$ after rounding (ATSDR, 2024).

Both ATSDR and US EPA have acknowledged that cleaning any area in a typical residence to make indoor air concentrations meet $0.3 \mu\text{g}/\text{m}^3$ (*i.e.*, the ATSDR chronic MRL and US EPA RfC) may not be necessary because the response actions (*e.g.*, loss or destruction of contaminated items or property) may be disruptive enough to cause more harm than benefit (ATSDR, 2012; US EPA, 2019). Therefore, ATSDR developed action level guidelines for indoor air concentrations of elemental mercury (as mercury vapor) in collaboration with US EPA and the state of Michigan (ATSDR, 2012). An action level is an indoor air concentration that is health protective and used to consider whether response actions (*e.g.*, whether to evacuate a building, clean an area, or remove contaminated items) should be implemented by public health and environmental officials. ATSDR (2012) cautioned that action levels "should not be considered as 'bright line' indicators of toxicity or predictors of adverse health effects." The action levels were developed using the ATSDR chronic MRL or US EPA RfC and adjusted using site-specific considerations related to presumed exposures at residences, commercial settings, schools, and other locations (ATSDR, 2012; US EPA, 2019).

ATSDR recommends an action level of $\leq 1 \mu\text{g}/\text{m}^3$ for normal occupancy of residential settings (*e.g.*, homes). The action level applies to the breathing zone of individuals and when no visible elemental mercury is present.² ATSDR (2012) stated that "[u]nder almost all conditions, removing visible mercury from the indoor environment until a residual concentration of $1 \mu\text{g}/\text{m}^3$ is reached would be protective of even the most sensitive population." As further justification, ATSDR stated that the action level of $1 \mu\text{g}/\text{m}^3$ is 10 times lower than the air concentration (*i.e.*, $10 \mu\text{g}/\text{m}^3$) predicted to result in an increase in urinary levels of mercury (*i.e.*, indicative of increased retention of mercury in the body) and is 26 times lower than the air concentration (*i.e.*, $26 \mu\text{g}/\text{m}^3$) expected to result in potential neurological effects that formed the basis of the US EPA RfC (ATSDR, 2012; US EPA, 2019).

ATSDR also has developed an action level of $\leq 3 \mu\text{g}/\text{m}^3$ for normal occupancy of commercial settings (*e.g.*, during the normal course of work), which includes schools and educational settings. The action level applies to the breathing zone of individuals and when no visible elemental mercury is present. ATSDR (2012) stated that $1-3 \mu\text{g}/\text{m}^3$ is an "acceptable level for schools to resume normal operations." The action level of $3 \mu\text{g}/\text{m}^3$ is based on the residential action level of $1 \mu\text{g}/\text{m}^3$ adjusted for a typical work day or school day (*i.e.*, adjusting from an assumed 24-hour daily exposure to an 8-hour workday, five days per week). According to ATSDR (2012), pregnant workers or pregnant students should be offered temporary alternatives to working or attending the contaminated area in the school or educational setting when air concentrations are $>1 \mu\text{g}/\text{m}^3$ and $\leq 3 \mu\text{g}/\text{m}^3$. The ATSDR action level of $\leq 3 \mu\text{g}/\text{m}^3$ is consistent with Dartmouth's self-imposed exposure limit of $3 \mu\text{g}/\text{m}^3$.

Ngim *et al.* (1992) and Liang *et al.* (1993). Ngim *et al.* (1992) observed deficits in neurobehavioral performance in dentists exposed to mercury at an average concentration of $14 \mu\text{g}/\text{m}^3$ for an average duration of 5.5 years. Liang *et al.* (1993) observed alterations in mood and neurobehavioral performance in workers exposed to an average mercury concentration of $33 \mu\text{g}/\text{m}^3$ for an average duration of 10.4 years.

² "Visible" mercury refers to elemental mercury in its liquid form (*i.e.*, shiny, silver beads that appear fluid-like when handled) (ATSDR, 2012).

In 1994, ACGIH recommended a threshold limit value (TLV) time-weighted average (TWA) of 25 $\mu\text{g}/\text{m}^3$ for elemental mercury. A TLV is an air concentration of a chemical at which nearly all workers can be repeatedly exposed over a working lifetime without adverse health effects (ACGIH, 2020). ACGIH considered multiple studies in humans to support their recommended TLV of 25 $\mu\text{g}/\text{m}^3$, including studies of neurological effects in workers exposed to elemental mercury (*e.g.*, Piikivi and Tolonen, 1989; Piikivi and Hanninen, 1989; Piikivi, 1989; ACGIH, 2001). ACGIH also indicated that dermal contact with elemental mercury should be minimized to reduce potential dermal absorption.

In 1972, OSHA recommended a permissible exposure limit (PEL) TWA and a ceiling limit PEL of 100 $\mu\text{g}/\text{m}^3$ for mercury vapor. A PEL is a maximum air concentration for a chemical that a worker can be exposed to in the workplace without experiencing adverse health effects. The PEL was developed based on reported symptoms in felt hat and fur-cutting workers exposed to mercury vapor concentrations ≥ 100 $\mu\text{g}/\text{m}^3$ (Neal *et al.*, 1937, 1941). OSHA also indicated that dermal contact with elemental mercury is a potential hazard. According to US EPA (2019), dermal exposure to elemental mercury (which is not a significant pathway of exposure) may produce skin irritations and allergic reactions.

3.2.1 Exposure Limits Appropriate for Wilder Hall

An exposure limit of 3 $\mu\text{g}/\text{m}^3$ is appropriate for protecting against potential health effects from mercury vapor exposure under normal occupancy of Wilder Hall by non-pregnant students, faculty, and staff. 3 $\mu\text{g}/\text{m}^3$ is also the upper limit of the ATSDR's action level for normal occupancy of commercial buildings, including schools and educational institutions, and is the self-imposed exposure limit used by Dartmouth. An exposure limit of 3 $\mu\text{g}/\text{m}^3$ is supported for the following reasons:

- 3 $\mu\text{g}/\text{m}^3$ is nearly 10-fold lower than the air concentration of mercury vapor (*i.e.*, 26 $\mu\text{g}/\text{m}^3$) associated with health effects in workers exposed over 15 years (US EPA, 2002a).
- 3 $\mu\text{g}/\text{m}^3$ is approximately equal to the air concentration of mercury vapor (*i.e.*, 2.84 $\mu\text{g}/\text{m}^3$) associated with no adverse effects in workers exposed for approximately 5 to 15 years (ATSDR, 2024).
- When no visible elemental mercury is present, ATSDR (2012) stated that 1-3 $\mu\text{g}/\text{m}^3$ is an "acceptable level for schools to resume normal operations."
- 3 $\mu\text{g}/\text{m}^3$ allows for the normal operations of schools that have experienced elemental mercury contamination without requiring the loss or destruction of contaminated items or property, which may be disruptive enough to cause more harm than benefit (ATSDR, 2012; US EPA, 2019).

According to ATSDR (2012) and out of an abundance of caution, pregnant workers or pregnant students should be offered temporary alternatives to working or attending the contaminated area in the school or educational setting when air concentrations are greater than 1 $\mu\text{g}/\text{m}^3$ and ≤ 3 $\mu\text{g}/\text{m}^3$. However, ATSDR (2012) stated that "[u]nder almost all conditions, removing visible mercury from the indoor environment until a residual concentration of 1 $\mu\text{g}/\text{m}^3$ is reached would be protective of even the most sensitive population," which includes pregnant individuals.

An exposure limit of 25 $\mu\text{g}/\text{m}^3$ is appropriate for protecting against potential health effects from mercury vapor exposure under a destructive repair or renovation scenario in which workers are expected to disturb building materials in Wilder Hall. This action level is applicable to "industrial settings where mercury exposure is expected in normal course of work" and assumes that hazard communication programs, engineering controls, and medical monitoring measures are in place (ATSDR, 2012; US EPA, 2019).

3.3 Exposure Assessment

3.3.1 Mercury Vapor Data Collected in Wilder Hall

Historically, visible liquid mercury as well as elevated mercury vapor readings were documented in Wilder Hall during construction activities occurring in the original building. The liquid mercury had reportedly been observed in various building materials, such as wood flooring, beneath vinyl floor tiles, and on the top surface of plaster ceilings (Woodard & Curran, 2024). However, liquid mercury has *not* been observed during more recent surveys conducted in Wilder Hall. For example, a 2022 limited pre-construction survey in three first-floor classrooms noted that no visual evidence of liquid mercury was observed (Woodard & Curran, 2022). Subsequent mercury surveys conducted throughout all floors of Wilder Hall did not state that liquid mercury was observed (Woodard & Curran, 2024; EHI, 2025a,b). Therefore, for purposes of this human health risk assessment, it is assumed that Wilder Hall remains free of visible liquid mercury.

In 2024 and 2025, three additional surveys were conducted to assess the extent of mercury impacts throughout Wilder Hall, as summarized in Table 3.2 below. The following sections describe these sampling efforts in more detail.

Table 3.2 Summary of 2024-2025 Mercury Sampling Events in Wilder Hall

Survey Date	Survey Locations	Disturbance of Building Materials?	Sample Type	Number of Samples or Readings	Range of Mercury Vapor Concentrations Detected ($\mu\text{g}/\text{m}^3$)
Nov 2024	All floors	Yes	Instantaneous	30	0.1 – 43.2
Sep 2025	All floors	No	Instantaneous	529	0.01 – 0.8
Nov 2025	All floors	Yes	Instantaneous	11	0.4 – 106
Nov 2025	All floors	Yes	Personal ^a	4	1.5 – 5.2

Notes:

$\mu\text{g}/\text{m}^3$ = Micrograms per Cubic Meter.

a) Personal breathing zone air samples were collected by four workers over the course of several hours to simulate exposures for a work shift.

3.3.1.1 November 2024 Vapor Survey

On November 25, 2024, a screening assessment was performed within the original sections of Wilder Hall and the south addition to screen for mercury using a Jerome J405 mercury vapor analyzer with a detection limit [DL] of 0.0 mg/m^3 (Woodard & Curran, 2024). The areas surveyed were selected based on planned locations for installation of new pipes. A total of 30 readings were taken from all four floors of Wilder Hall. The survey was conducted using "minimally invasive sampling methods," including removing a small piece of floor finish, and, if mercury vapors were not detected, drilling a ¼-inch hole through wood flooring systems (Woodard & Curran, 2024). Vapor readings were taken directly after floor material removal or drilling.

Summary statistics for readings collected on each floor are presented in Table 3.4 in Section 3.3.2. Out of the 30 locations surveyed, 27 showed detections above the DL at concentrations ranging from 0.0001 to 0.0432 mg/m^3 (0.1 to 43.2 $\mu\text{g}/\text{m}^3$). The maximum concentration (43.2 $\mu\text{g}/\text{m}^3$) was reported on the third floor in the southwestern portion of Room 302, while all of the rest of the readings collected on that floor were at or below 2.0 $\mu\text{g}/\text{m}^3$ (see floor plan M-W-104 in Woodard & Curran, 2024). Based on this survey, the second floor had a higher average mercury concentration (14.5 $\mu\text{g}/\text{m}^3$) compared to the other floors

(range: 1.5-8.0 $\mu\text{g}/\text{m}^3$; see Table 3.4). Three of four highest readings reported for the second floor were taken near locations where cores had been drilled through the wall.³

3.3.1.2 September 2025 Vapor Survey

On September 10 and 11, 2025, another survey was conducted to assess the extent of mercury impacts throughout Wilder Hall. A total of 529 mercury readings were taken from all floors of Wilder Hall using a Jerome J505 vapor analyzer (EHI, 2025a). In contrast to the previous survey, these measurements were taken without active disturbance of building materials (*e.g.*, removing floor tiles, drilling holes, *etc.*). The report notes that some readings were taken "at locations of the wall or floor damage or where wall cavities were open" (EHI, 2025a).

Summary statistics for readings collected on each floor are presented in Table 3.3 in Section 3.3.2. Of the 529 locations surveyed, readings above the DL of 0.01 $\mu\text{g}/\text{m}^3$ were observed at 378 locations, at concentrations ranging from 0.01 to 0.8 $\mu\text{g}/\text{m}^3$. Average concentrations were slightly higher in the basement (0.06 $\mu\text{g}/\text{m}^3$) compared to the other floors (0.02-0.04 $\mu\text{g}/\text{m}^3$).

3.3.1.3 November 2025 Vapor Survey and Personal Air Sampling

On November 2, 2025, sampling was conducted to characterize potential mercury concentrations under a simulated work scenario. During this sampling event, four workers performed certain construction activities throughout Wilder Hall, such as removing floor tiles, pulling up carpet, moving furniture, drilling into walls, and vacuuming (EHI, 2025b). A Jerome vapor analyzer was used to record the highest instantaneous reading during each work activity. A total of 11 vapor readings were reported, with concentrations ranging from 0.4 to 106 $\mu\text{g}/\text{m}^3$ (Table 3.4). The maximum concentration was reported from the area of Room 002A/003A in the basement, and the work conducted during this event was described as "HEPA vacuum debris, move furniture/stock, later floor was cleaned with wet rags" (EHI, 2025b). All other readings reported were below 20 $\mu\text{g}/\text{m}^3$.

In addition to the instantaneous readings, personal breathing zone air samples were collected for each of the four workers while they moved about Wilder Hall conducting the aforementioned construction activities. The air samplers were worn by the workers for 284 to 292 minutes (4.7 to 4.9 hours) and were meant to represent exposures that an individual may encounter while performing different construction activities throughout the building. As shown in Table 3.5, mercury concentrations in personal air ranged from 1.5 to 5.2 $\mu\text{g}/\text{m}^3$ (Liberty Mutual Industrial Hygiene Laboratory, 2025). During this time period, each of the workers moved through various locations in the building and performed different activities, so it is not possible to attribute the results of these personal breathing zone air samples to any particular location within Wilder Hall.

3.3.2 Estimated Exposure Concentrations

EPCs provide an estimate of the average concentration of a chemical that someone may be exposed to over the course of the exposure period. Due to the uncertainties associated with estimating the "true average" concentration of any chemical at a site, US EPA recommends using the 95% upper confidence limit on the mean (UCLM) concentration as the EPC when possible (US EPA, 2002b). The 95% UCLM provides an upper-bound estimate of the average concentration of a chemical that a person may expect to encounter at

³ These readings are: 1) Hallway near copier in the southern portion of the building next to a wall core (31.6 $\mu\text{g}/\text{m}^3$); 2) Room 220 southwestern corner (30.7 $\mu\text{g}/\text{m}^3$); 3) Room 217 near a wall core (23.4 $\mu\text{g}/\text{m}^3$); and 4) Room 219 near a wall core (23.4 $\mu\text{g}/\text{m}^3$) (see floor plan M-W-103 in Woodard & Curran, 2024).

the site and is therefore conservative while being reasonable. It bears noting, however, that calculation of a reliable 95% UCLM depends on the sample size and sample distribution of the dataset (among other factors). When a 95% UCLM cannot be calculated, or when the calculated value exceeds the maximum observed value in a dataset, the maximum observed concentration can be applied as the EPC. In this risk assessment, 95% UCLMs are calculated using the statistical software ProUCL version 5.2 (US EPA, 2022). The EPCs for the normal occupancy and destructive repair/renovation scenarios are described in the following sections.

3.3.2.1 Normal Occupancy Scenario

The normal occupancy scenario applies to occupants such as students, faculty, and staff who are assumed to spend up to 8 hours each day in Wilder Hall.⁴ It is assumed that normal occupants would not be engaging in activities requiring significant disturbance of building materials (e.g., drilling, pulling up flooring materials). Therefore, the data collected during the September 2025 survey, where readings were obtained without disturbing building materials, were applied to evaluate a normal occupancy scenario. Summary statistics and EPCs for the data collected in the September 2025 survey are provided in Table 3.3 below.

Table 3.3 Summary Statistics for Mercury Vapor Instantaneous Readings Collected in September 2025

Floor	Frequency of Detection	Mercury Vapor Concentrations ($\mu\text{g}/\text{m}^3$)					
		Minimum Detected	Maximum Detected	Average ^a	Median	95% UCLM	EPC
All Locations	378/529	0.010	0.80	0.068	0.040	0.078	0.078
Basement	95/122	0.010	0.67	0.099	0.060	0.12	0.12
1 st Floor	80/104	0.010	0.79	0.088	0.040	0.12	0.12
2 nd Floor	116/176	0.010	0.80	0.051	0.020	0.064	0.064
3 rd Floor	87/127	0.010	0.27	0.046	0.030	0.056	0.056

Notes:

EPC = Exposure Point Concentration; $\mu\text{g}/\text{m}^3$ = Micrograms per Cubic Meter; UCLM = Upper Confidence Limit on the Mean.

a) In the calculation of arithmetic average concentrations, readings reported as below the detection limit (DL) were assigned a value equal to one-half of the DL.

3.3.2.2 Destructive Repair/Renovation Scenario

The destructive repair/renovation scenario is intended to capture potential vapor inhalation exposures to workers who are engaging in construction activities in the building, which can entail significant disturbance of building materials. It is assumed that such work would be conducted under a site-specific Health and Safety Plan (HASP) that includes exposure mitigation measures, such as dust mitigation controls, ventilation, and personal protective equipment (PPE), which would minimize exposures from dermal contact and incidental ingestion. Therefore, the mercury readings collected during the November 2024 and November 2025 surveys were applied to evaluate a destructive repair/renovation scenario. Summary statistics and EPCs for the instantaneous readings collected during these surveys are provided in Table 3.4.

In addition, the results from personal air samples collected during the November 2025 survey event are presented in Table 3.5. As the personal samplers were operating for less than a full 8-hour period, the sample results also were converted to 8-hour TWA concentrations in which zero exposure (*i.e.*, $0 \mu\text{g}/\text{m}^3$)

⁴ Because some occupants may spend more than 8 hours per workday in Wilder Hall, Gradient also considered mercury vapor exposure limits protective of longer exposure durations (e.g., 24 hours per day). As discussed in Section 3.4.1, the EPCs that were calculated for all floors of Wilder Hall, the highest of which is $0.12 \mu\text{g}/\text{m}^3$, fall below the residential action level of $1 \mu\text{g}/\text{m}^3$, and even the US EPA RfC and the ATSDR MRL of $0.3 \mu\text{g}/\text{m}^3$.

was assumed during the unsampled period, consistent with OSHA policy (OSHA, 2023). For purposes of risk characterization, the 8-hour TWA concentration is applied as the EPC for personal air samples.

Table 3.4 Summary Statistics for Mercury Vapor Instantaneous Readings Collected in November 2024 and November 2025

Floor	Frequency of Detection	Mercury Vapor Concentrations ($\mu\text{g}/\text{m}^3$)					EPC
		Minimum Detected	Maximum Detected	Average ^a	Median	95% UCLM ^b	
November 2024							
All Locations	27/30	0.10	43.2	7.31	0.80	13.7	13.7
Basement	8/8	0.10	26.5	3.84	0.20	NC	26.5
1 st Floor	6/7	0.10	5.60	1.49	0.40	3.12	3.12
2 nd Floor	7/9	1.90	31.6	14.5	16.2	22.9	22.9
3 rd Floor	6/6	0.20	43.2	8.00	1.20	NC	43.2
November 2025							
All Locations	11/11	0.40	106	14.3	1.40	31.4	31.4
Basement	6/6	0.40	106	22.0	1.30	56.6	56.6
1 st Floor	2/2	1.40	17.0	9.20	9.20	NC	17.0
2 nd Floor	2/2	2.20	3.00	2.60	2.60	NC	3.00
3 rd Floor	1/1	1.30	1.30	1.30	1.30	NC	1.30

Notes:

EPC = Exposure Point Concentration; $\mu\text{g}/\text{m}^3$ = Micrograms per Cubic Meter; NC = Not Calculated; UCLM = Upper Confidence Limit on the Mean.

a) In the calculation of arithmetic average concentrations, readings reported as below the detection limit (DL) were assigned a value equal to one-half of the DL.

b) "NC" indicates that the ProUCL software was not able to recommend a 95% UCLM, either due to the skewness of the dataset or insufficient sample size.

Table 3.5 Personal Mercury Air Sample Results and 8-Hour Time-Weighted Average Concentrations from November 2025

Sample ID	Sampling Time (min)	Sample Result ($\mu\text{g}/\text{m}^3$)	8-Hour TWA Concentration ^a ($\mu\text{g}/\text{m}^3$)
106	292	1.50	0.91
53	291	5.20	3.15
08	287	2.50	1.49
12	284	2.70	1.60

Notes:

Min = Minutes; $\mu\text{g}/\text{m}^3$ = Micrograms per Cubic Meter; TWA = Time-weighted Average.

a) Sample results were converted into 8-hour TWA concentrations assuming no mercury exposure occurred during the remainder of the 8-hour shift.

3.4 Risk Characterization

3.4.1 Normal Occupancy Scenario

As discussed in Section 3.2, the exposure limit of $3 \mu\text{g}/\text{m}^3$, which is both Dartmouth's internal limit as well as the action level set by US EPA and ATSDR for commercial and school settings, is applicable to the normal occupancy scenario in Wilder Hall. Use of this action level is supported by the lack of observations of free liquid mercury during the recent surveys conducted throughout the building. Should any visible

liquid mercury be later discovered, it should be removed because its presence can result in elevated air mercury concentrations (US EPA, 2019).

As shown in Table 3.3 above, all of the mercury vapor readings obtained during the September 2025 survey are below the action level of 3 µg/m³, and the maximum reading of 0.8 µg/m³ falls even below the residential action level of 1 µg/m³ set by US EPA and ATSDR. The EPCs that were calculated for all floors of Wilder Hall, the highest of which is 0.12 µg/m³, fall below even the US EPA RfC and the ATSDR MRL of 0.3 µg/m³.

Therefore, based on these data, potential mercury exposures in Wilder Hall under a normal occupancy scenario are unlikely to pose an adverse health risk, including for sensitive subgroups such as pregnant persons.

3.4.2 Destructive Repair/Renovation Scenario

As discussed in Section 3.2, the ACGIH TLV of 25 µg/m³ is applicable to the destructive repair or renovation scenario, where significant disturbance of building materials is expected to occur as part of normal work activities. It is assumed that any destructive repair or renovation activities would be conducted using appropriate engineering controls (e.g., ventilation, dust mitigation measures) and other industrial hygiene measures (e.g., use of PPE) recommended by agencies such as ACGIH and National Institute for Occupational Safety and Health (NIOSH).

As shown in Table 3.6 below, a minority of instantaneous mercury vapor readings collected during the November 2024 and November 2025 surveys exceed 25 µg/m³. However, it bears noting that the ACGIH TLV of 25 µg/m³ is based on an 8-hour TWA concentration (ACGIH, 2013) rather than instantaneous or maximum readings.

Table 3.6 Comparison of Mercury Vapor Readings with the ACGIH TLV

Floor	Proportion of Readings >25 µg/m ³	Maximum Detected Concentration (µg/m ³)
November 2024		
All Locations	4/30 (13%)	43.2
Basement	1/8 (13%)	26.5
1 st Floor	0/7 (0%)	5.60
2 nd Floor	2/9 (22%)	31.6
3 rd Floor	1/6 (17%)	43.2
November 2025		
All Locations	1/11 (9%)	106
Basement	1/6 (17%)	106
1 st Floor	0/2 (0%)	17.0
2 nd Floor	0/2 (0%)	3.00
3 rd Floor	0/1 (0%)	1.30

Note:

ACGIH = American Conference of Governmental Industrial Hygienists;
TLV = Threshold Limit Value; µg/m³ = Micrograms per Cubic Meter.

As discussed in Section 3.3.2, personal air samples were collected in addition to instantaneous readings during the November 2025 survey, which better represent potential full-shift worker exposures. As shown in Table 3.5 (see Section 3.3.2.3), mercury concentrations in the personal air samples range from 1.5-5.2 $\mu\text{g}/\text{m}^3$, corresponding to 8-hour TWA concentrations of 0.91-3.2 $\mu\text{g}/\text{m}^3$. Both the time-averaged and unaveraged concentrations are well below the ACGIH TLV. It should be noted that the personal air concentrations reflect exposure that would occur in the absence of respiratory protection, as the personal air monitors were worn outside of a worker's respirator.

Together, the instantaneous readings and personal air samples from the November 2025 survey demonstrate that elevated instantaneous readings do not necessarily indicate that workers experience average mercury vapor concentrations above 25 $\mu\text{g}/\text{m}^3$ for an 8-hour workday. Further, in the documentation associated with the instantaneous readings, it was noted that mercury levels in all workspaces, including the basement area that had the highest reading of 160 $\mu\text{g}/\text{m}^3$, returned to level of 3 $\mu\text{g}/\text{m}^3$ or lower after the work activities were completed (EHI, 2025b). This suggests that mercury levels rise when building materials are actively disturbed, but quickly return to baseline after the disturbance ceases. Furthermore, the survey events generally show that mercury vapor concentrations are highly variable across different spaces in Wilder Hall, and therefore if a worker visits different areas during the work shift, the resultant exposure would be better reflected by an average of the concentrations in those areas.

Collectively, the data collected for Wilder Hall indicate that potential worker exposures under a destructive repair/renovation scenario are generally below the ACGIH 8-hour TWA TLV of 25 $\mu\text{g}/\text{m}^3$. Importantly, the personal air samples, which better represent potential worker exposures, were also below 25 $\mu\text{g}/\text{m}^3$. As stated previously, this assumes that such work is being performed under conditions that meet recommended industrial hygiene guidelines, such as use of proper engineering controls, PPE, and monitoring.

3.4.3 Uncertainty Assessment

One uncertainty of this assessment is that the majority of available data are instantaneous survey instrument readings, rather than samples collected over a longer period of time that would better represent a daily average exposure concentration. In general, uncertainties were addressed in this risk assessment by adopting conservative assumptions that tend to overestimate rather than underestimate exposures (*e.g.*, use of statistics higher than the average to represent the EPC).

For the normal occupancy scenario, all of the data are instrument readings. However, the large number of readings collected (over 500) and the coverage of all four floors in Wilder Hall help mitigate uncertainties associated with the lack of time-averaged sample data. Additionally, the EPCs evaluated in this scenario are all based on 95% UCLMs, which represent an upper bound estimate of average exposures, and are therefore conservative.

For the destructive repair/renovation scenario, there are 41 instantaneous instrument readings and four personal samples. With respect to the survey instrument readings, in several cases UCLMs could not be calculated due to data limitations (*e.g.*, low sample size or skewed data); in these cases, the EPC was set to the maximum observed reading, which would overestimate the degree of exposure. While the availability of personal air samples helps to characterize potential full-shift worker exposures, the small sample size ($n = 4$) is one source of uncertainty, as the construction activities performed during this survey event may not be generalizable to other construction activities. Therefore, additional personal sampling may be warranted for workers engaging in activities that differ in nature from the ones already evaluated.

4 Conclusions

Gradient conducted a risk assessment using US EPA methodology to evaluate potential health risks arising from mercury vapor exposure under two scenarios: 1) normal occupancy of Wilder Hall by students, faculty, and staff, and 2) a destructive repair or renovation scenario in which workers are expected to disturb building materials.

Gradient evaluated multiple exposure limits for mercury vapor from health agencies and determined that an exposure limit of $3 \mu\text{g}/\text{m}^3$ is appropriate for protecting against potential health effects from mercury vapor exposure under normal occupancy of Wilder Hall by non-pregnant students, faculty, and staff. $3 \mu\text{g}/\text{m}^3$ is also the upper limit of the ATSDR's action level for normal occupancy of commercial buildings, including schools and educational institutions, and is the self-imposed exposure limit used by Dartmouth. Further, an exposure limit of $25 \mu\text{g}/\text{m}^3$ is appropriate for protecting against potential health effects from mercury vapor exposure under a destructive repair or renovation scenario in which workers are expected to disturb building materials in Wilder Hall.

Under conservative assumptions that erred on overestimating exposure to mercury vapors, Gradient determined that potential mercury exposures in Wilder Hall under a normal occupancy scenario are unlikely to pose an adverse health risk, including for sensitive subgroups such as pregnant persons. This is supported by mercury vapor readings obtained in building surveys that all fall below the action level of $3 \mu\text{g}/\text{m}^3$ and EPCs that all fall below more conservative exposure limits, such as the US EPA RfC and ATSDR chronic MRL of $0.3 \mu\text{g}/\text{m}^3$.

Under a destructive repair/renovation scenario, Gradient determined that potential mercury exposures in Wilder Hall are unlikely to pose an adverse health risk to workers. This is supported by data that indicate that potential worker exposures, including personal air samples, are generally below the ACGIH 8-hour TWA TLV of $25 \mu\text{g}/\text{m}^3$. This assumes that destructive repair/renovation work is being performed under conditions that meet recommended industrial hygiene guidelines, such as use of proper engineering controls, PPE, and monitoring.

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