Health Hazard Evaluation Program

Evaluation of Noise Exposure From Equipment and Ventilation in a Clinical Laboratory

HHE Report No. 2023-0087-3401

October 2024

Centers for Disease Control and Prevention
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Authors: **Marie A. Hayden, MS**

Scott E. Brueck, MS, CIH

Desktop Publisher: Shawna Watts

Editor: Cheryl Hamilton

Logistics: Donnie Booher

Literature Review Assistance: Nellie Neal, CDC librarian

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Disclaimer

The Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 [29 USC 669a(6)]. The Health Hazard Evaluation Program also provides, upon request, technical assistance to federal, state, and local agencies to investigate occupational health hazards and to prevent occupational disease or injury. Regulations guiding the Program can be found in Title 42, Code of Federal Regulations, Part 85; Requests for Health Hazard Evaluations [42 CFR Part 85].

Availability of Report

Copies of this report have been sent to the employer, employees, and union at the clinical laboratory. The state and local health departments and the Occupational Safety and Health Administration Regional Office have also received a copy. This report is not copyrighted and may be freely reproduced.

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Introduction

Request

An employer representative from a state government laboratory requested a health hazard evaluation concerning employee noise exposure. The noise came from instruments and equipment in the newborn screening and microbiology laboratories and from the ventilation system in the molecular laboratories.

Workplace

Employees worked in laboratories on the first floor of a multistory building. They used different instruments and equipment to perform assays on specimens from human samples such as blood, sputum (spit), and stool.

To learn more about the workplace, go to Section A in the Supporting Technical Information

Our Approach

We visited the workplace on June 2, 2023, to learn more about noise concerns in the laboratory. We completed the following activities during our evaluation:

- Observed work processes and practices, lab equipment, and workplace conditions.
- Took sound level measurements at employees' work areas in the newborn screening laboratory, microbiology laboratory, and molecular laboratory Rooms 156 and 157.

To learn more about our methods, go to Section B in the Supporting Technical Information

Our Key Findings

Sound levels in the laboratory were below occupational noise exposure limits

- The sound levels we measured in the laboratories were less than 73 decibels, A-weighted. Based on these sound levels, employees' noise exposures would be below the NIOSH recommended exposure limit and the Occupational Safety and Health Administration (OSHA) noise exposure limits for workplaces.

Sound levels in the newborn screening laboratory could be high enough to cause difficulty hearing conversations at times

- Sometimes the sound levels in the newborn screening were above the suggested upper limits for speech to be fully understood.

To learn more about our results, go to [Section B in the Supporting Technical Information]

Our Recommendations

The Occupational Safety and Health Act requires employers to provide a safe workplace.

Potential Benefits of Improving Workplace Health and Safety:

- ↑ Improved worker health and well-being
- ↑ Better workplace morale
- ↑ Easier employee recruiting and retention
- ↑ Enhanced image and reputation
- ↑ Superior products, processes, and services
- ↑ Increased overall cost savings

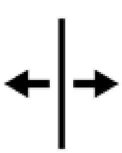
The recommendations below are based on the findings of our evaluation. For each recommendation, we list a series of actions you can take to address the issue at your workplace. The actions at the beginning of each list are preferable to the ones listed later. The list order is based on a well-accepted approach called the "hierarchy of controls." The hierarchy of controls groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or practical, administrative measures and personal protective equipment might be needed. Read more about the hierarchy of controls at https://www.cdc.gov/niosh/hierarchy-of-controls/about/index.html.

We encourage the company to use a health and safety committee to discuss our recommendations and develop an action plan. Both employee representatives and management representatives should be included on the committee. Helpful guidance can be found in *Recommended Practices for Safety and Health Programs* at https://www.osha.gov/safety-management.

Recommendation 1: Reduce employees' noise exposures to improve communication in the laboratories.

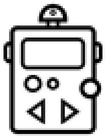
Why? Employees were not overexposed to noise, but a potential exists for employees to have difficulty communicating due to background noise.

How? At your workplace, we recommend these specific actions:



Install noise reducing barriers.

- Install a barrier, such as a wall, in the hallway between the freezers and the employee cubicles in the newborn screening area. This will reduce noise levels at the cubicles.
- Provide antifatigue mats made with sound absorbing material near procedure tables.



Reduce noise from the molecular room ventilation system.

- Consult with a ventilation consultant to evaluate the ventilation system and offer suggestions for noise reduction. While noise from the system does not pose a hazard for hearing loss, the levels could interfere with communication at times.

Begin a Buy Quiet Program.

- Start a "Buy Quiet" program, which is a long-term method to reduce noise exposures. When installing or replacing equipment, purchase equipment that makes less noise. Learn about Buy Quiet programs at https://www.cdc.gov/niosh/noise/prevent/eliminate.html.

Supporting Technical Information

Evaluation of Noise Exposure From Equipment and Ventilation in a Clinical Laboratory

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Section A: Workplace Information

Building

The laboratories for newborn screening, microbiology, and molecular and radiation chemistry are on the first floor of a multistory building. A new air handling unit installed in molecular laboratory Rooms 156 and 157 increased the background noise from the ventilation system. In addition, the amount of equipment in the newborn screening, microbiology, and molecular laboratories has increased while the building space remained the same. This led to an increase in overall background noise levels within those areas. Laboratory employees often worked throughout their assigned lab. Some of the laboratory employees in the newborn screening and microbiology laboratories worked in cubicles along the periphery of the laboratory and some worked in enclosed offices.

Equipment

Employees used a variety of equipment and worked on multiple different tasks throughout an 8-hour workday. Potential noise sources included fume hoods, mass spectrometers, nitrogen generators, genetic screening processors, dried blood spot (DBS) punchers, biological safety cabinets, and freezers. Some tasks were short, such as prepping samples in the fume hoods, and could be completed in 15 minutes. Other tasks took longer, such as running DBS punchers, and could last 3–4 hours. Most of the equipment had internal cooling fans that continuously ran. The sound from these fans contributed to noise within the laboratory. Employees wore safety glasses, nitrile gloves, and laboratory coats when handling samples in the laboratories.

Section B: Methods, Results, and Discussion

Methods: Noise Exposure Assessment

We used two Larson Davis Model 831 Type 1 integrating sound level meter and frequency analyzers. These were equipped with a 0.5-inch random incidence microphone for sound level measurements. The sound level meters were calibrated before and after measurements were taken. During measurements, we held the sound level meters at a height of about 5 feet above floor level. Most measurements were taken for 30–60 seconds within 3–6 feet of the employees' workspaces or lab equipment. No employee conversation was occurring during measurements so we could properly characterize ambient background noise in the workspace.

We measured sound levels at each one-third octave band center frequency from 6.3 to 20,000 hertz (Hz) (corresponding to frequencies of 5.62–22,400 Hz). The instrument sampled at a rate of 51,200 Hz (i.e., 51,200 measurements per second) and integrated using linear averaging at 1-second time history intervals. One-third octave band sound levels were measured using a slow weighting (1,000 millisecond) time constant and Z-weighting (flat or unweighted) response. Following measurements, the noise measurement data stored on the instruments were downloaded, exported, and analyzed using Larson Davis G4® software and Microsoft® Excel® for Office 365®.

When analyzing the data to assess potential employees' noise exposures, we excluded one measurement taken between mass spectrometers and genetic screening processors equipment in the newborn screening area. This measurement did not represent noise exposure at a location an employee would occupy but had been taken for the purpose of measuring equipment fan noise.

We used the ANSI/ASA tangency method to rate the speech interference level for comparison to room noise criterion [ANSI/ASA 2019].

Results: Noise Exposure Measurements

The highest sound level we measured in the laboratory was 77.4 decibels, A-weighted (dBA), generated by mass spectrometer cooling fans. This measurement was taken at the back of the QS1 and QS2 mass spectrometers in the newborn screening area; however, employees would not actually work in that space. The highest sound level measurement at an employee workstation was 72.6 dBA. This was in the newborn screening near the mass spectrometers and genetic screening processors. Based on the sound levels we measured, employees' time-weighted average noise exposures would be well below the OSHA permissible exposure limit (PEL) of 90 dBA, the OSHA Action Level (AL) of 85 dBA, and the NIOSH recommended exposure limit (REL) 85 dBA.

The range of sound levels across laboratory areas was small. Specifically, the range was 6.5 dBA for mass spectrometers and genetic screening processors, 3.3 dBA for DBS punchers, 3.5 dBA for newborn screening staff cubicles, 7.5 dBA for microbiology, 3.7 dBA for Room 156, and 3.7 dBA for Room 157.

One-third octave band measurements provide information about the frequency distribution of noise. Because the energy from noise is usually widely distributed over many frequencies, the frequency range is broken into a smaller range of frequencies (called bandwidths). The one-third octave band is defined as a frequency band where the upper band edge frequency is the lower band edge frequency multiplied by the cube root of two. Analysis of one-third octave band sound levels allows for determination of the dominant noise frequencies in a work area and can be useful for identifying potential engineering controls. For example, if low frequency noise is dominant (i.e., the highest sound levels occur in frequencies of 500 Hz or less), the sound might be generated by vibration or air turbulence. Noise controls that reduce, isolate, or diminish vibration might decrease low frequency noise. If high frequency sound is dominant (i.e., the highest sound levels occur in frequencies of 2,000 Hz or greater), using enclosures, barriers, or sound absorption systems is typically an effective approach for noise reduction [Driscoll 2022]. For the laboratories, sound at some of the low frequencies (31.5 Hz, 63 Hz, 125 Hz, 250 Hz) tended to be predominant.

Newborn Screening Laboratory

Tables C1 and C2 show the sound level measurements taken at employee workstations and near equipment where employees worked within the newborn screening laboratory. Sound levels at employee workstations in the area with mass spectrometers and genetic screening processors ranged 66.1 dBA to 72.6 dBA. Sound levels in employee office cubicles near the DBS punchers ranged 55.7 dBA to 59.2 dBA.

Figures B1 and B2 show the median octave band sound levels across frequencies ranging 16 Hz to 8,000 Hz in the newborn screening laboratory. Figure B1 shows the measurements near the mass spectrometers and genetic screening processors, and Figure B2 shows the measurements near the staff cubicles. Comparisons of frequency dependent sound levels with noise criterion (NC) curves can help determine whether the noise in a room or workspace exceeds acceptable levels. Room noise in the mass spectrometers and genetic screening processors area exceeded the NC-60 curve, and room noise near the staff cubicles exceeded the NC-45 curve. This indicates that background noise levels could be high enough to interfere with speech.

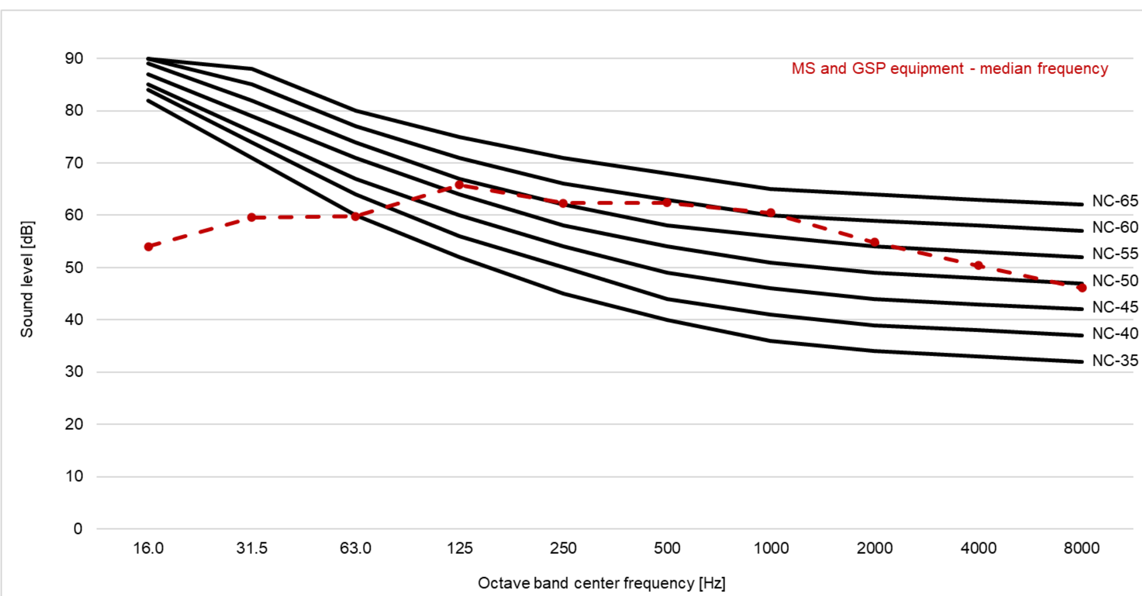

Figure B1. Median octave band sound levels in the newborn screening area near mass spectrometers and genetic screening processors equipment compared with noise criteria curves.

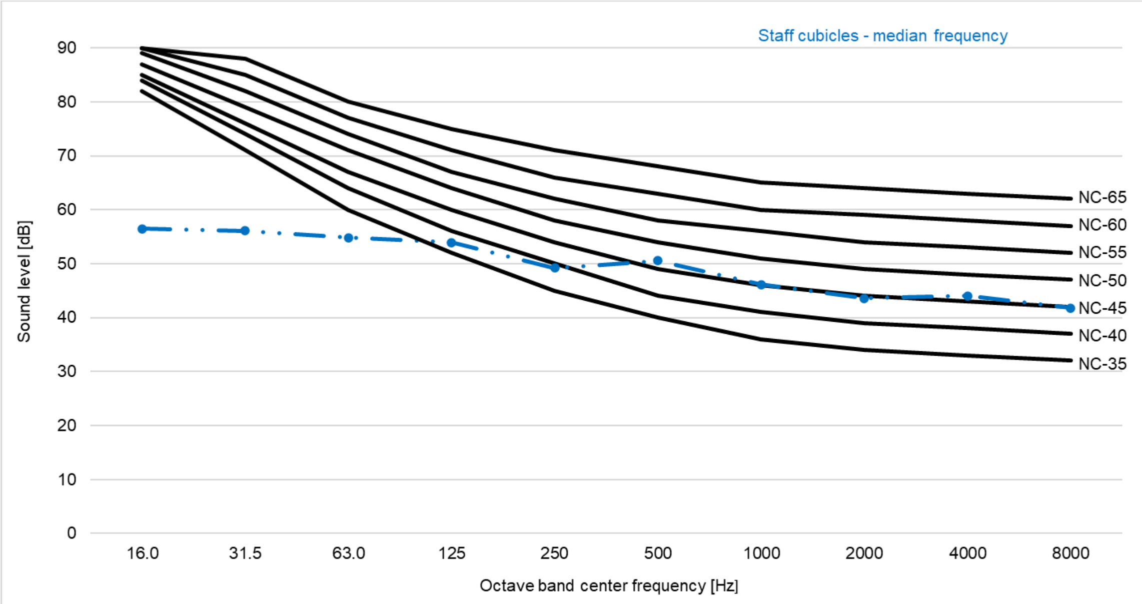

Figure B2. Median octave band sound levels in the newborn screening area near staff cubicles compared with noise criteria curves.

Dried Blood Spot Punchers in the Newborn Screening

The DBS punchers are automated devices that screen dried blood prepped on sample plates. The process requires employees to monitor and move samples into place while the equipment automatically presses down to collect the blood sample off the plate. Table C2 shows the sound level measurements ranged 66.3 dBA to 69.6 dBA while the DBS punchers were screening. Figure B3 shows sound levels were the highest (60.8 dB) at 4,000 Hz during the DBS screening process.

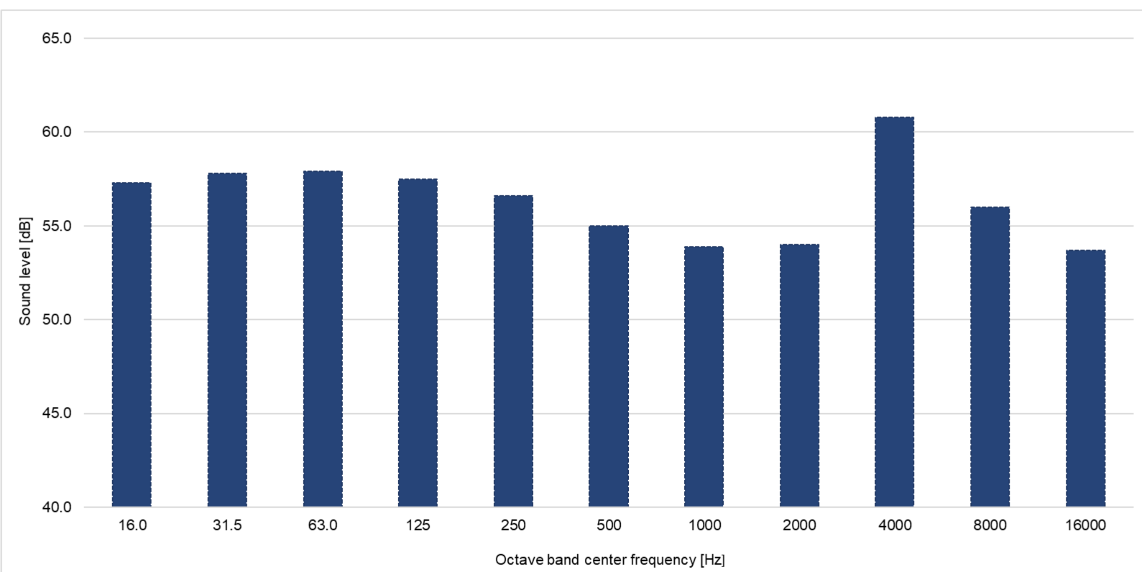

Figure B3. Median octave band sound levels during DBS screening.

Microbiology Laboratory

Table C3 shows the sound level measurements taken at employee work areas and near equipment within the microbiology laboratory. This area was unoccupied at the time of sound level measurements with only internal fans from equipment and ventilation system running. The sound levels ranged from 58.7 dBA near the staff cubicles to 66.2 dBA near the biological safety cabinet equipment. Figure B4 shows the median octave band levels in the microbiology laboratory exceeded the NC-50 curve.

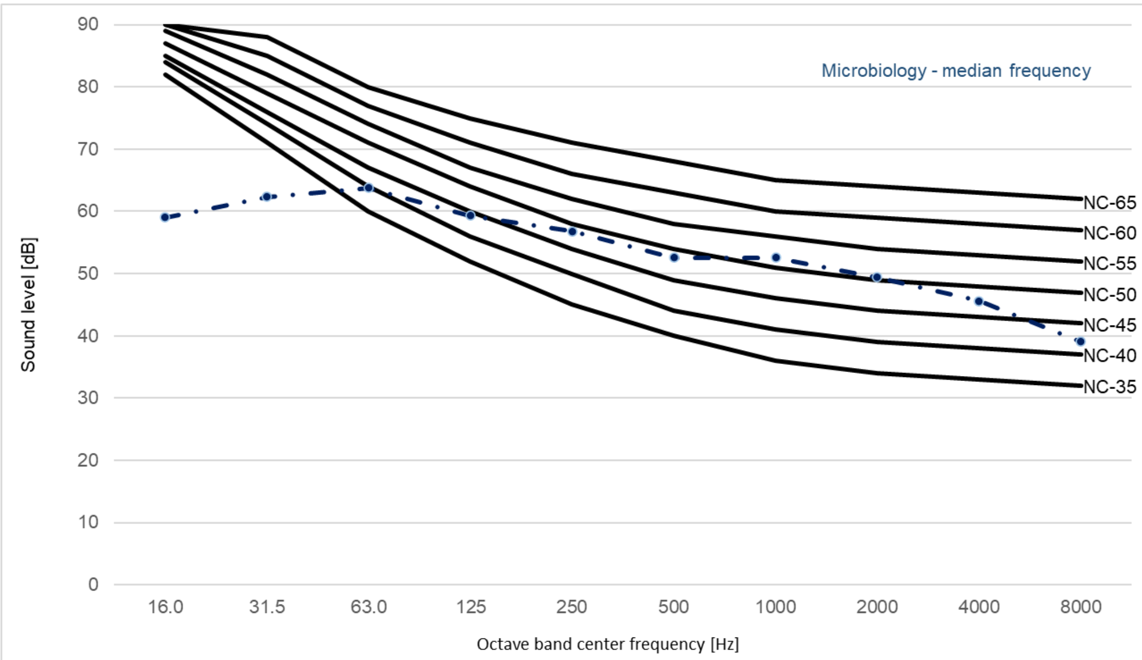

Figure B4. Median octave band sound levels in the microbiology laboratory compared with noise criteria curves.

Molecular Laboratory Rooms 156 and 157

Table C4 shows the sound level measurements taken at employee work areas and near equipment within molecular laboratory Rooms 156 and 157. This area was unoccupied at the time of sound level measurements with only internal fans from equipment and the ventilation system running. Employees reported maintenance recently worked on the air handler and noticed a decrease in noise from the ventilation system. Room 156 had slightly higher sound levels, ranging 62.5 dBA to 66.2 dBA, compared with Room 157, which ranged from 56.6 dBA to 60.3 dBA.

Figure B5 shows the median octave band levels in Rooms 156 and 157. Levels exceeded the NC-50 curve for Room 156 and the NC-45 curve for Room 157.

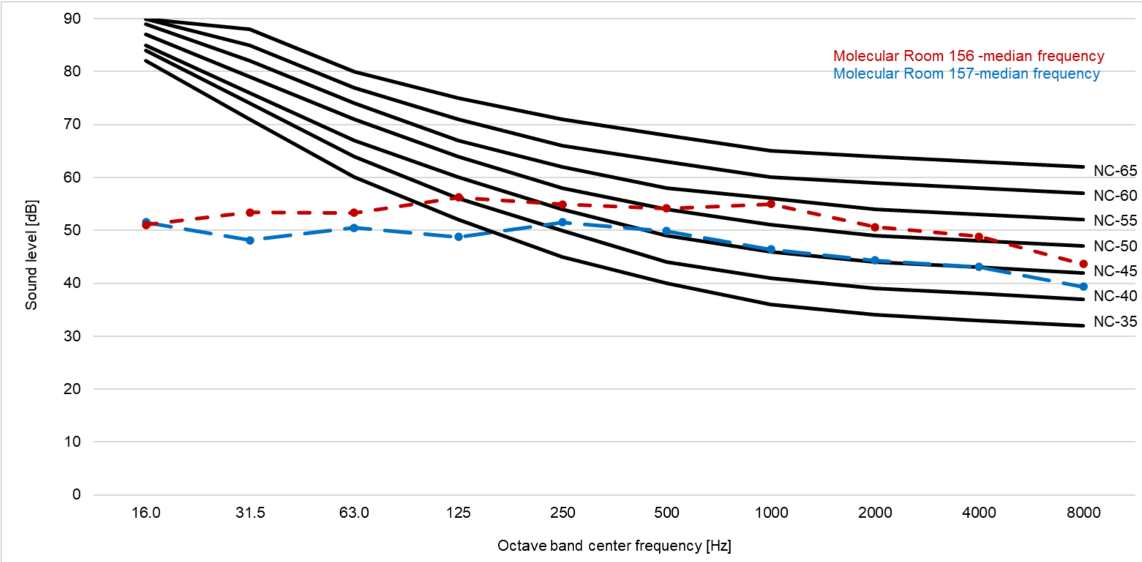

Figure B5. Median octave band sound levels in molecular Rooms 156 and 157 compared with noise criteria curves.

Discussion

None of the sound levels we measured in the areas where employees worked were greater than 75 dBA, and most were below 70 dBA. Based on these sound level measurements, employees' time-weighted average noise exposures would be well below the occupational noise exposure limits. Therefore, employees would not be at risk of noise-induced hearing loss from noise exposures in the laboratory. However, the sound could at times reach levels that might interfere with communication, such as speech recognition.

Berglund et al. [1999] noted that for speech intelligibility, a signal-to-noise ratio (i.e., difference speech level and background noise level) should be at least 15 dB. Previous research has found that for listeners with normal hearing, speech intelligibility at a distance of one meter is nearly 100 percent when speaking volume is 15 dB above the background level [Bradley 1986; Houtgast 1981]. Sato et al. [2011] found similar results for speech intelligibility with young and elderly listeners when speaking volume is 15 dB above background noises of 50 dB to 55 dB. Another study found individuals reduced their distance to 0.5 meters between talkers and listeners when background noise exceeded 75 dBA [Brungart et al. 2020].

With measured noise levels in the laboratory ranging 56 dBA to 73 dBA, for a signal to noise ratio of 15 dB needed for high speech intelligibility, a worker would need to speak at a volume of about 71 dBA to 88 dBA. Depending on the setting, speech levels can range from 55 dB to 66 dB [Olsen 1998]. An upper noise limit of 55 dBA in laboratories has been suggested for speech to be adequately recognizable [Froehlich 2013; Griffiths et al. 1970; OSHA 2011].

Negative effects of noise levels high enough in a laboratory to interfere with communication include misunderstanding instructions or laboratory results during conversations in person or on the phone

[OSHA 2011]. A case study by Froehlich [2013] discussed similar issues with communication due to noise from laboratory equipment such as nitrogen generators and external pumps that ranged 50 dBA to 60 dBA. The study suggested that noise reduction solutions should be included as part of the laboratory design and noise controls incorporated into the design. Brungart et al. [2020] noted negative effects for listeners in public spaces, including longer response times and decrease in speech intelligibility, from 95% to 80% from background noises above 60 dBA to 85 dBA.

ANSI/ASA [2019] established noise criterion curves to evaluate background sound levels in buildings. Each noise criterion curve is designated by a single number (which were determined by averaging sound levels across the 500 Hz, 1,000 Hz, 2,000 Hz, and 4,000 Hz octave bands) and approximate speech interference levels. Different types of rooms or building spaces may have different recommended noise criterion levels based on the level at which background noise interferes with the needs or purpose of the room. For example, a concert hall has a lower recommended noise criterion level than a common area in an office.

Comparing measured background sound levels in a room with the noise criterion curves can help determine whether noise levels are high enough to have a negative impact on speech and communication. The ANSI/ASA [2019] recommended noise criteria rating for speech interference levels in unoccupied hospitals and clinical laboratories range from NC-35 and NC-45. For the unoccupied microbiology and molecular rooms, our measurements showed that the one-third octave band levels exceeded the ANSI/ASA recommended noise criteria ratings for satisfactory communication in these types of setting. Similarly, one-third octave band levels in the newborn screening room also exceeded the ANSI/ASA recommended noise criterion ratings.

Mortland and Mortland [2002] noted that acoustical partitions covered with antimicrobial fabric can be placed behind equipment such as analyzers, refrigerators, and freezers to absorb sound and reduce sound reverberation in Biosafety Level 2 (BSL-2) clinical laboratories. Additional noise reduction strategies include the use of rubber flooring or antifatigue mats, which have sound-absorbing properties and do not promote bacterial or fungal growth [Mortland and Mortland 2002]. Noise reduction should be part of an overall long-term noise reduction strategy. For example, Buy Quiet is a concept by which companies can reduce hazardous noise levels through their procurement process. Through this process, buyers are encouraged to consult with equipment and tool manufacturers, compare noise emission levels for differing models of equipment, and, whenever possible, choose equipment that produces less noise.

Limitations

This evaluation was subject to limitations. Exposure assessment could only document exposures and conditions in the locations evaluated and on the day this evaluation occurred. These results may not represent conditions during other times. Measurements were taken while instruments were in use for the newborn screening laboratory. Not all the instruments were in use during measurements taken in the microbiology and molecular laboratory Rooms 156 and 157.

Conclusion

Overall, the noise levels were below OSHA and NIOSH occupational noise exposure limits and are not considered to present a risk of hearing loss. However, the noise levels we measured in the laboratory could be high enough to interfere with employee communication and speech recognition. We recommend strategies to reduce noise such as installing noise control barriers, implementing a Buy Quiet program, and working with a ventilation consultant to reduce noise from air handling systems.

Section C: Tables

Table C1. Noise measurements for the newborn screening laboratory near mass spectrometers in June 2023

Measurement location	Sound Level (dBA)
Workstation fume hood #1 closed with fan running at minimum flow rate	68.7
Workstation fume hood #2 closed with fan running at minimum flow rate	69.2
Workstation fume hood #1 open with fans running at higher flow rate	71.0
Workstation fume hood #1 open with fans running at higher flow rate	70.4
Workstation computer next to the Waters™ XEV01 MSMS	70.4
Waters™ XEV01 MSMS equipment with internal cooling fan running	71.0
Centrifuge and eyewash station	68.7
Centrifuge and eyewash station	68.1
TQD1 MSMS with internal fan running	70.1
TQD1 MSMS while running a sample	69.6
Workstation computer for equipment TQD1 MSMS	69.6
Nitrogen generator #1	70.2
Workstation computer for equipment XEV02	72.6
Walkway between XEV02 MSMS & QS1 LC-MSMS	71.0
Speci-mix™ and LSD shaker both running samples	70.4
Speci-mix™ running samples	71.0
Workstation computer for equipment TQD2 MSMS	70.5
Workstation computer for equipment TQD2 MSMS	68.7
TQD2 MSMS while running a sample	69.2
Workstation computer for equipment GSP1. Equipment alarm going off in the background	68.8
Nitrogen generator #2	69.0
Computer workstation for equipment QS2 LC MSMS	70.3
Refrigerator #2 with auto pipet, LSD shaker, and Speci-mix™ equipment running in the background	70.3
Refrigerator #2	69.9
GSP3 equipment	66.1

Table C2. Noise measurements for the newborn screening laboratory near dried blood spot punchers* and freezers in June 2023

Measurement location	Sound Level (dBA)
Employee workstation at DBS puncher #4	69.6
Employee workstation at DBS puncher #3	68.0
Walkway behind DBS punchers #3 & #4 and in front of DBS puncher #1	67.9
Employee workstation at DBS puncher #1	66.3
Employee workstation at DBS puncher #2	69.0
Hallway next to freezer NBS-2 with internal fans running in background	63.1
Staff cubicles southeast with internal fans inside the freezers running in background	55.7
Staff cubicles southeast with internal fans inside the freezers and DBS punchers running in the background	59.2

* All four dried blood spot (DBS) punchers were running in the background for measurements at puncher locations.

Table C3. Noise measurements for microbiology laboratory in June 2023

Measurement location	Sound Level (dBA)
NuAire™ fume hood across the entry to Room 141	64.2
Middle of aisle way	61.1
End of aisle way near cubicles and Office 149	58.7
Between Micro 4/5 workstations	61.8
Middle of aisle way	61.9
End of aisle way outside Office 149	59.6
Biological safety cabinet	66.2
Micro #3 Freezer	62.5
Micro I.S. and fume hood	64.4
Centrifuge 5430	60.8

Table C4. Noise measurements for molecular laboratory in June 2023

Measurement location	Sound Level (dBA)
Room 157 near window side next to pipets and automated machines	57.4
Room 157 near window side	57.1
Room 157 near centrifuge machine and EZ1	56.6
Room 157 near entrance in front of the MicroLab® STAR equipment across from the refrigerator	60.3
Room 156 near workstation, sink and centrifuge 5430	62.5
Room 156 window side of room between workstation and central work island	64.3
Room 156 near Illumina MiSeq™ sequence equipment	66.2
Room 156 near speed vacuum ~6 feet inside entry door	63.7

NOTE: No lab samples were running when collecting measurements. For some equipment, an internal cooling fan was running. In both rooms, the ventilation system for return air was running

Section D: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended occupational exposure limits (OELs) for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects.

However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a preexisting medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limits (STEL) or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These legal limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the NIOSH Pocket Guide to Chemical Hazards [NIOSH 2007]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, PPE, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Another set of OELs commonly used and cited in the United States is the ACGIH® TLVs®. The TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2023].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at https://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm (Occupational Safety and Health Act of 1970; Public Law 91-596, sec. 5[a][1]). This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions.

Noise

Noise induced hearing loss (NIHL) is an irreversible condition that progresses with noise exposure. NIHL is caused by damage to the nerve cells of the inner ear and, unlike some other types of hearing disorders, cannot be treated medically [AIHA 2022]. Approximately 25% of U.S. workers have been exposed to hazardous noise [Kerns et al. 2018], and more than 22 million U.S. workers are estimated to be exposed to workplace noise levels above 85 dBA [Tak et al. 2009]. NIOSH estimates that workers exposed to an average daily noise level of 85 dBA over a 40-year working lifetime have an 8% excess risk of material hearing impairment. This excess risk increases to 25% for an average daily noise exposure of 90 dBA [NIOSH 1998]. NIOSH defines material hearing impairment as an average of the hearing threshold levels for both ears that exceeds 25 dB at frequencies of 1,000 Hz; 2,000 Hz; 3,000 Hz; and 4,000 Hz.

Although hearing ability commonly declines with age, exposure to excessive noise can increase the rate of hearing loss. In most cases, NIHL develops slowly from repeated exposure to noise over time, but the progression of hearing loss is typically the greatest during the first several years of noise exposure [Rosler 1994]. NIHL can result from short duration exposures to high noise levels or even from a single exposure to an impulsive noise or a continuous noise, depending on the intensity of the noise and the individual's susceptibility to NIHL [AIHA 2022]. Noise exposed workers can develop substantial NIHL before it is clearly recognized. Even mild hearing losses can impair one's ability to understand speech and hear many important sounds. In addition, some people with NIHL also develop tinnitus. Tinnitus is a condition in which a person perceives hearing sound in one or both ears, but no external sound is present. Persons with tinnitus often describe hearing ringing, hissing, buzzing, whistling, clicking, or chirping like crickets. Tinnitus can be intermittent or continuous and the perceived volume can range from soft to loud. Currently, no cure for tinnitus exists.

Noise measurements are usually reported as dBA. A-weighting is used because it approximates the "equal loudness perception characteristics of human hearing for pure tones relative to a reference of 40 dB at a frequency of 1 kHz" and is considered to provide a better estimation of hearing loss risk than using unweighted or other weighting measurements [Murphy et al. 2022]. The dB unit is dimensionless, and it represents the logarithmic ratio of the measured sound pressure level to an arbitrary reference sound pressure 20 micropascals, which is defined as the threshold of normal human hearing at a frequency of 1 kilohertz (kHz). Because the dB is logarithmic, an increase of 3 dB is a doubling of the sound energy, an increase of 10 dB is a 10-fold increase, and an increase of 20 dB is a 100-fold increase in sound energy. Noise exposures expressed in dB or dBA cannot be averaged using the arithmetic mean.

The NIOSH REL for noise is 85 dBA as an 8-hour TWA. For calculating exposure limits, NIOSH uses a 3-dB time/intensity trading relationship, or exchange rate. Using the NIOSH criterion, an employee can be exposed to 88 dBA for no more than 4 hours, 91 dBA for 2 hours, 94 dBA for 1 hour, 97 dBA for 0.5 hours, etc. Exposure to impulsive noise should never exceed 140 dBA. For extended work shifts, NIOSH adjusts the REL to 84.5 dBA for a 9-hour shift, 84.0 dBA for a 10-hour shift, 83.6 dBA for an 11-hour shift, and 83.2 dBA for a 12-hour work shift. NIOSH recommends the use of hearing protection and the implementation of a hearing loss prevention program when noise exposures exceed the REL [NIOSH 1998].

The OSHA noise standard specifies a PEL of 90 dBA and an AL of 85 dBA, both as 8-hour TWAs. OSHA uses a less conservative 5-dB exchange rate for calculating the PEL and AL. Using the OSHA criterion, an employee may be exposed to noise levels of 95 dBA for no more than 4 hours, 100 dBA for 2 hours, 105 dBA for 1 hour, 110 dBA for 0.5 hours, etc. Exposure to impulsive or impact noise must not exceed 140 dB peak noise level. OSHA does not adjust the PEL for extended work shifts. However, the AL is adjusted to 84.1 dBA for a 9-hour shift, 83.4 dBA for a 10-hour shift, 82.7 dBA for an 11-hour shift, and 82.1 dBA for a 12-hour work shift. OSHA requires implementation of a hearing conservation program when noise exposures exceed the AL [29 CFR 1910.95].

An employee's daily noise dose, based on the duration and intensity of noise exposure, can be calculated according to the formula: Dose = $100 \times (C_1/T_1 + C_2/T_2 + ... + C_n/T_n)$, where C_n indicates the total time of exposure at a specific noise level, and T_n indicates the reference exposure duration for which noise at that level becomes hazardous. A noise dose greater than 100% exceeds the noise exposure limit.

Section E: References

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