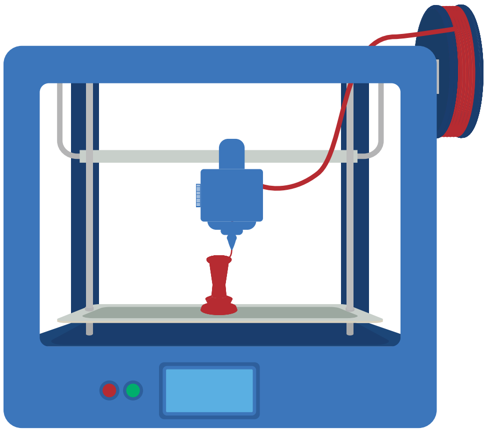
Chemical Insights
An Institute of
Underwriters Laboratories Inc.

3D Printer School Safety: A Guide for Supporting Indoor Air Quality & Human Health

An Overview of 3D Printers

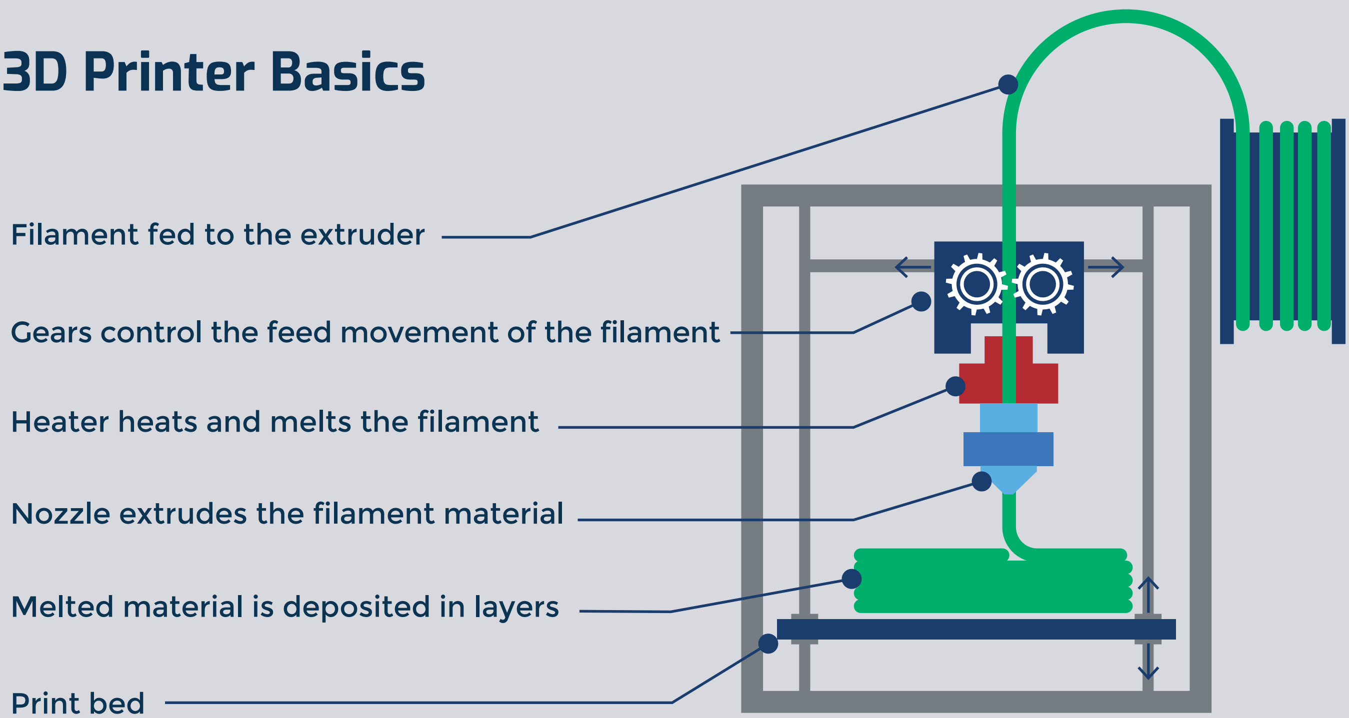


Thanks to the development of affordable, compact, and user-friendly 3D printers, consumer use is booming particularly in classrooms. In fact, a Statista study shows that 3D printer use in education tripled in two years. 3D printers have become a valuable tool in K-12 classrooms because they inspire creativity and problem-solving by bringing students' ideas and designs to life.

But, as with so many new technologies, there are also unintended consequences to consider. There's a growing need to better understand human health and environmental risks associated with 3D printing, specifically as it relates to chemical exposure.

Until recently, few scientific studies had been done to evaluate the impact of 3D printers on indoor air quality. So, Chemical Insights (an Institute of Underwriters Laboratories), a not-for-profit organization dedicated to scientific research, along with researchers from Georgia Institute of Technology (Georgia Tech), embarked on a multi-year research initiative on 3D printer emissions.

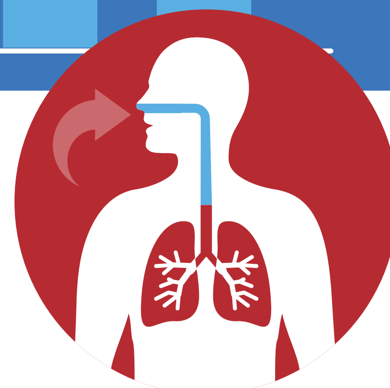
3D Printer Basics



Fundamentally, 3D printers take a digital file and use it to build a three-dimensional solid object. The most common consumer-level 3D printers use a method called fused filament fabrication, or FFF. That simply means that the printer heats up a material, forces it through a nozzle, and then deposits – or prints – that material layer by layer to build an object.

The material that gets heated up and layered to create the object is known as the filament. The two most common types are acrylonitrile butadiene styrene (or ABS) and polylactic acid (or PLA). These are both types of thermoplastics.

Chemical Insights' Research Findings



In order to begin to understand the potential human health impacts of 3D printers, we needed a standard way to identify, measure, and compare 3D printer emissions. This was the focus of Chemical Insights and Georgia Tech's initial research.

Chemical Insights discovered that during operation (which can last for hours), 3D printers generate a complex mixture of airborne particles and volatile organic compounds (VOCs) that are released into indoor air.

VOCs are chemical compounds that evaporate into the air and can be breathed. They pose a number of health risks, including eye, nose, and throat irritation; headaches, loss of coordination, and nausea; damage to the liver, kidney, and central nervous system; cardiovascular disease; cancer; and asthma.

Particles are a mixture of very small solids and liquid droplets suspended in the air. The smaller the particle, the greater the health risk. Fine and ultrafine particles (UFPs) can penetrate deep into the lungs; UFPs, the primary type generated by 3D printers, can enter your bloodstream. Particles can cause eye, nose, and throat irritation; aggravate coronary and respiratory disease symptoms; and contribute to premature death in people with heart or lung disease.

Unfortunately, 3D printers are often used in small-scale indoor environments like classrooms, where there are no regulated indoor air quality standards, and, around children, who are particularly vulnerable to health impacts of poor indoor air quality. Children, since they breathe faster than adults and have smaller body masses, receive higher doses of available air contaminants.

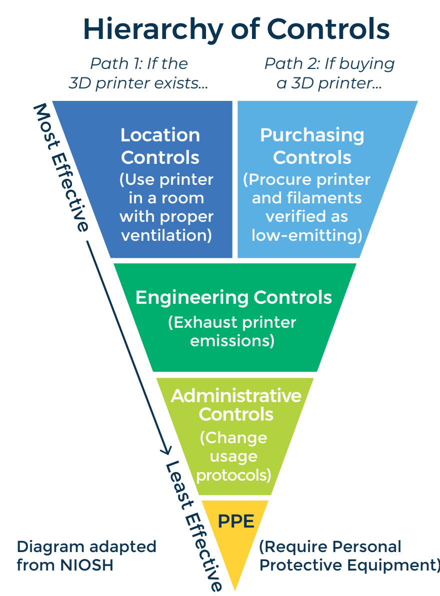
FINDINGS: The research found that 3D printers emit particles, most of which are very small in size, and VOCs, some of which are known irritants, carcinogens, and odorants. This means that exposure may present a human health hazard, in particular when a person stands next to the printer with minimal ventilation. The amount and type of these emissions varied based on factors like printer and filament brand, filament material, and extrusion and build plate temperature.

Strategies to Reduce Exposure to 3D Printer Emissions

Chemical Insights and Georgia Tech's research suggests that we must redefine how 3D printers are used as teaching tools and implement strategies that both mitigate 3D printer emissions and reduce human exposure to these emissions.

Luckily, there are steps schools can take to minimize exposure risks, balancing the exciting innovations that 3D printers offer with a precautionary approach to human health and safety. Whether a school is considering purchasing 3D printers for the first time or already has a robust program, there are common sense measures that can mitigate exposure risks.

When mitigating risk, there is a hierarchy of controls to consider, with smart purchasing and proper building location as the most effective courses of action and personal protective equipment as the least. Consider this hierarchy when evaluating strategies related to purchasing, location, and operation.



Purchasing:

To eliminate or greatly reduce potential hazards, purchase 3D printers and supplies that have been independently verified or certified to produce lower emissions. Purchase and use only filaments recommended by the printer manufacturer.

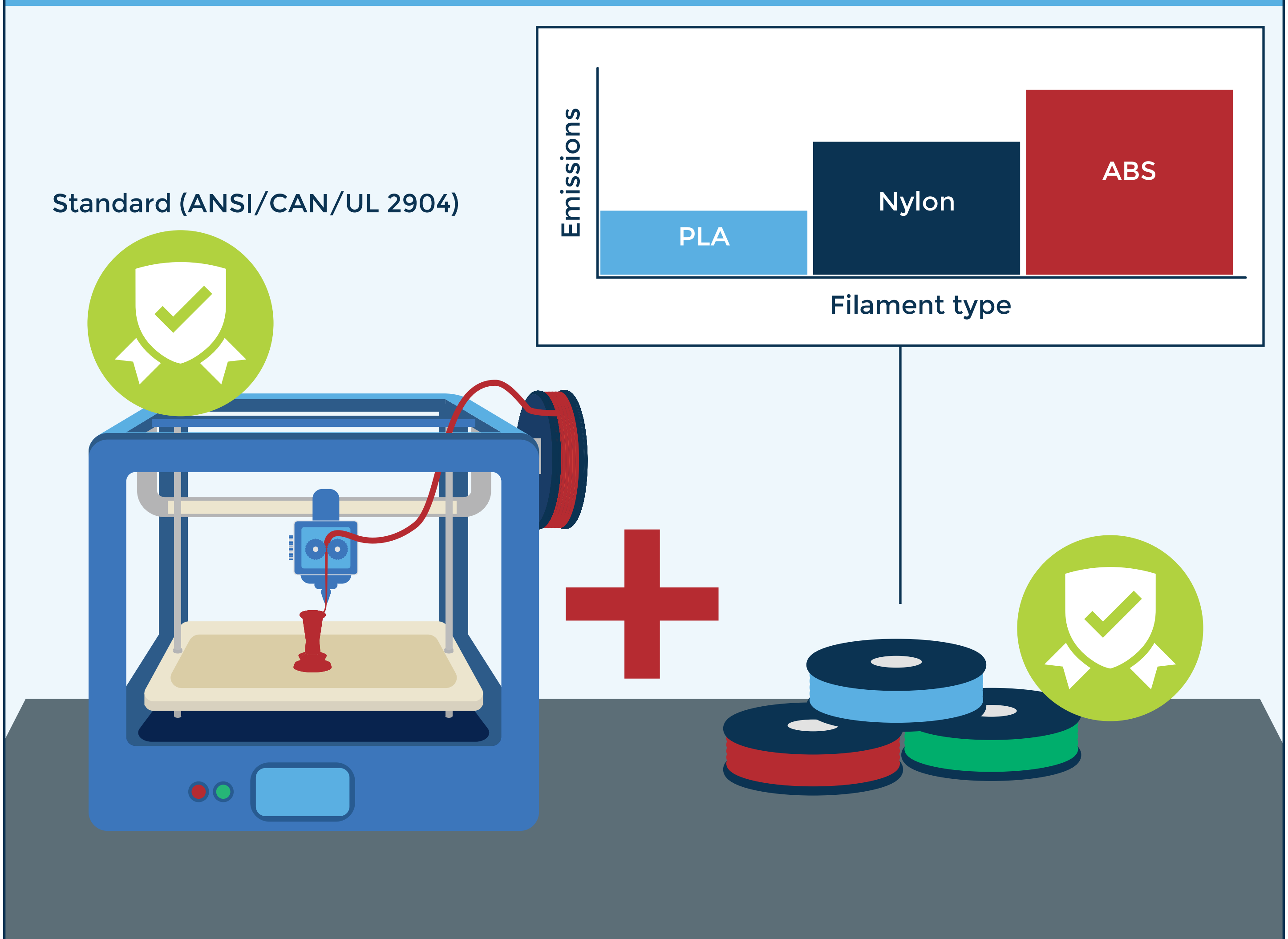
Location:

Utilize engineering controls by selecting appropriate locations with good room ventilation, operable windows, or local exhaust fans that can be placed above the printers. Place so that users cannot hover over the printer while it is operating.

Operation:

Implement administrative controls by operating printers according to manufacturer's instructions and safety recommendations, and operate the printer nozzle at the lowest recommended temperature.

Strategies: Purchasing



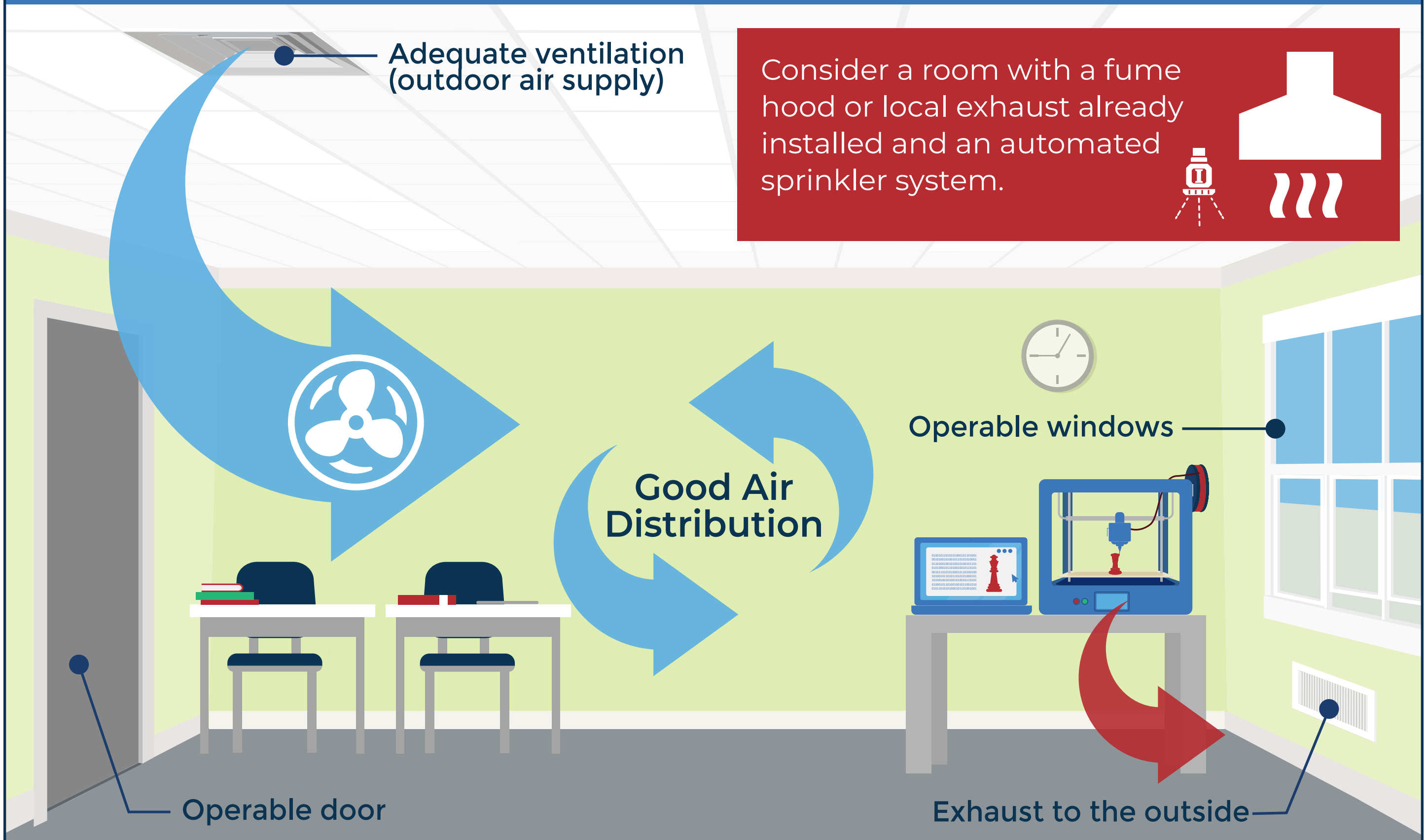
There are several key steps schools can take to mitigate risks when purchasing 3D printers. As a result of Chemical Insights and Georgia Tech's research, a Standard (ANSI/CAN/UL 2904) was developed to certify printers proven to have reduced emissions. Consider selecting printers that meet ANSI/CAN/UL 2904 and requiring compliance with the Standard in the bidding/purchasing process.

Other printer features to consider include integrated enclosures, direct exhaust lines, and a filtration system, but only if these features have been verified to be effective in collecting or removing emissions from the environment.

In addition to the printer itself, schools also need to consider the type of filament to purchase. Most 3D printer manufacturers specify the filament that should be used with their printers. Only purchase the filament brand specified by the printer manufacturer. There is little reliable information about the chemical additives that lower-cost filaments contain.

Of the common filament types, ABS filaments typically have higher emissions, followed by Nylon, and then PLA. But each filament type emits a different mix of VOCs and particles, so assessing the health risks of exposure can be complicated. If you have a choice, consider printers that use PLA filaments.

Strategies: Location



Once a school has purchased a 3D printer, it needs to decide where to put it. Locate 3D printers away from heavy-traffic areas and building occupants to minimize their exposure to pollutants. It is best to put the 3D printer in an isolated room away from classrooms and administrative offices, with an operable door to keep students and staff out of the room when printers are operating.

Make sure that the 3D printer is placed in a well-ventilated space with a well-mixed outdoor air supply and returns that vent contaminants from the room to the outside without recirculating them within the building. The room needs to have the recommended ventilation according to ASHRAE 62.1.

At the very least, keep 3D printers away from return air vents. Consider locating 3D printers near operable windows. If there is already a room with a fume hood or local exhaust installed, consider locating the 3D printer there. If such a room does not exist, consider building a vented enclosure for the printer. Finally, a location with a sprinkler system is always recommended for fire safety concerns.

Figure 1: Particle Concentration

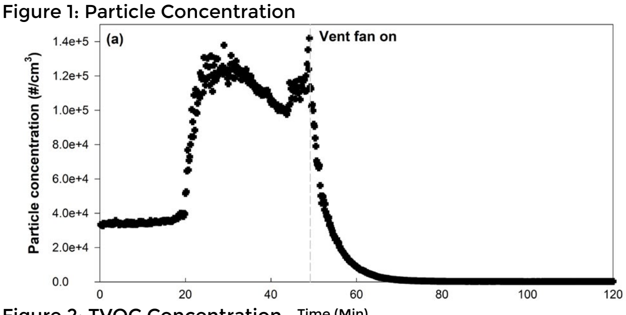
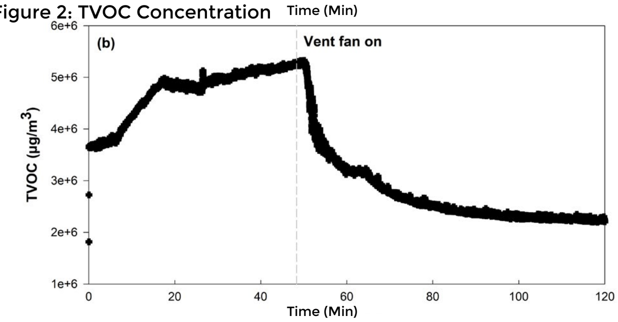
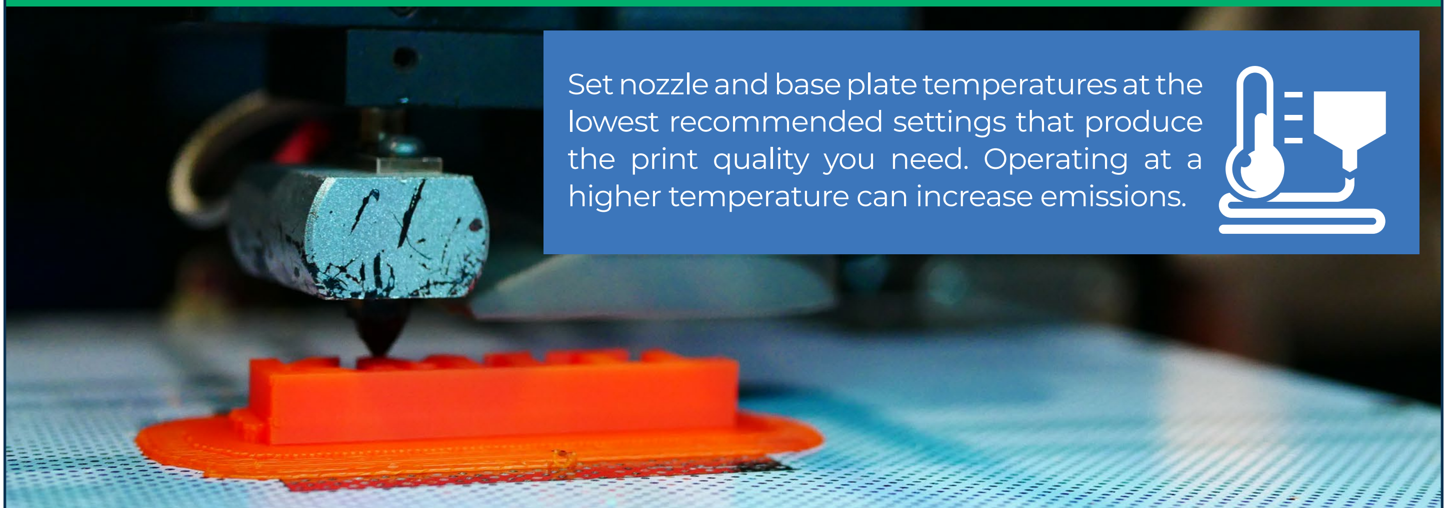


Figure 2: TVOC Concentration



Figures 1 and 2 show a significant drop off in particle and TVOC emissions after a vent fan is turned on. **Credit: NIOSH.**

Strategies: Operation



Set nozzle and base plate temperatures at the lowest recommended settings that produce the print quality you need. Operating at a higher temperature can increase emissions.

There are several strategies for operating 3D printers that can mitigate emissions. First of all, always follow manufacturer instructions for both material selection and base plate glue or tape application. Set the nozzle and base plate temperatures at the lowest recommended settings that produce the print quality you need. The research found that operating at a higher temperature can increase emissions.

Next, limit observation during 3D printer observations. While students enjoy watching 3D printers in operation, being close to an operating printer significantly increases exposure to emissions. So, it's best to keep students and staff away from 3D printers. Instead, rely on tools like cameras or observation windows looking into enclosed rooms for observation. Also consider operating the printer when fewer people are present, but only operate printers if the building's heating, ventilation and air conditioning (HVAC) system is running. Many schools automatically shut down HVAC systems on nights and weekends. Because of fire risk, do not run 3D printers unattended.

If you're operating the printer and need to check it periodically, always wear protective safety glasses and minimize the amount of time you are near the printer. Standard protective dust masks are not effective at preventing inhalation of the VOCs and UFPs emitted by 3D printers. Some commercial respirators approved by the National Institute for Occupational Safety and Health (NIOSH) provide adequate protection from chemical and particle contaminants, but they can be cumbersome and expensive.

Finally, make sure to clean the 3D printer and the surrounding space. Specifically, clean the nozzle before each use and the build plate after each use.

Dust all surfaces around the printer, such as the counter or floor, frequently with a disposable wet cloth. Vacuum floors, surfaces and furniture frequently with a vacuum with high efficiency particulate filtration (HEPA). Finally, wash your hands, and students' hands, to avoid hand-to-mouth transfer of chemicals and particles, especially before eating.

Mitigation Strategy Checklist

Purchasing

- Select printers that meet the requirements of ANSI/CAN/UL 2904
- Require compliance with ANSI/CAN/UL 2904 in the bidding/purchasing process
- Consider integrated enclosures, direct exhaust lines, and filtration systems, only if these features have been verified to be effective
- Purchase the filament brand specified by the printer manufacturer
- Consider printers that use PLA filaments

Location

- Locate 3D printers away from heavy-traffic areas and building occupants in an isolated room away from classrooms and offices, with an operable door
- Place 3D printers in a well-ventilated space (that meets ventilation rates according to ASHRAE 62.1) with a well mixed outdoor air supply and returns that vent contaminants to the outside
- Keep 3D printers away from return air vents
- Consider locating 3D printers near operable windows
- Consider locating the 3D printer in a room with a fume hood or local exhaust installed or consider building a vented enclosure for the printer
- Ensure location has a sprinkler system (for fire safety concerns)

Operation

- Follow manufacturer instructions for material selection and base plate glue or tape application
- Set the nozzle and base plate temperatures at the lowest recommended settings that produce desired print quality
- Limit time spent observing the 3D printer while it is operational
- If you need to check it periodically, always wear protective safety glasses
- Consider operating the printer after hours when fewer people are present (only if the building's HVAC system is running)
- Due to risk of fire, do not leave operational 3D printers unattended
- Do not rely on standard protective dust masks, only commercial respirators approved by the National Institute for Occupational Safety and Health (NIOSH)
- Clean the 3D printer nozzle and build plate before each use
- Dust all surfaces around the printer frequently with a disposable wet cloth
- Vacuum floors, surfaces and furniture frequently with a vacuum with high efficiency particulate filtration (HEPA)
- Wash your hands, and students' hands, to avoid hand-to-mouth transfer of chemicals and particles, especially before eating

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