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Cleaning and Disinfecting Vehicles and Facilities Technical Advisory Group

Mobility Recovery and Restoration Task Force

Infrastructure & Systems Security Working Group

Cleaning and Disinfecting Transit Vehicles and Facilities During a Contagious Virus Pandemic

Abstract: This white paper discusses current industry practices for cleaning and disinfecting transit vehicles and facilities in response to a pandemic virus. This document will be updated as new information is made available.

NOTE: This document is part of APTA's Toolbox for agencies in their recovery and restoration of service. Other documents in the toolbox are listed in the Reference section.

Keywords: cleaning, contagious virus, COVID-19, disinfecting, facilities, pandemic virus, SARS-CoV-2, transit agency, vehicles

Summary: This white paper is designed to aid transit agencies in the development of viral pandemic response programs for maintenance, cleaning and disinfecting their vehicles and facilities. Transit agencies should consider whether and how the various elements in this white paper apply to their own requirements, plans and policies, and local health departments and regulations. Once a transit agency drafts a cleaning and disinfecting program, it should consider sharing it with the local health department and other stakeholders for review and comment before issuing a final document.

Scope and purpose: SARS-CoV-2 is a virus that causes the disease known as COVID-19, or the novel human coronavirus, that created a global pandemic in 2020 and 2021. This white paper was developed in response to the SARS-CoV-2 pandemic, and therefore many of the procedures and recommendations are aimed at mitigating the spread of that specific virus. This document discusses current efforts being implemented in transit and related industries and focuses on mitigation of COVID-19 spread within public transportation systems. While this white paper may be applicable to other viral pandemics, it should be carefully reviewed for applicability prior to use in response to other viral outbreaks. This white paper does not provide background information on pandemic viruses, human factors associated with the viral pandemic, or operational considerations. Background information and answers to frequently asked questions are readily available in a number of guidelines developed by the CDC, other public health departments, the Department of Homeland Security and APTA (see References).

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Introduction

This introduction is not part of APTA SS-ISS-WP-001-20, Rev. 1 "Cleaning and Disinfecting Transit Vehicles and Facilities During a Contagious Virus Pandemic."

This document was developed by a Technical Advisory Group of senior experts from transit systems and other industry stakeholders. This ad hoc group was formed to make recommendations in the focus area of a pandemic virus service restoration checklist and is designed to inform and invite comments and opinions.

This white paper will support the APTA Mobility Recovery & Restoration Task Force's efforts as it develops further guidance.

APTA recommends the use of this document by:

- individuals or organizations that operate transit systems;

- individuals or organizations that contract with others for the operation of transit systems; and
- individuals or organizations that influence how transit systems are operated (including but not limited to consultants, designers and contractors).

Note on alternate practices

Individual bus and rail transit systems may modify the practices in this standard to accommodate their specific equipment and modes of operation. APTA recognizes that some bus, paratransit and rail systems may have unique operating environments that make strict compliance with every provision of this white paper impossible. As a result, certain bus and rail transit systems may need to implement the recommendations and practices herein in ways that are more or less restrictive than this document prescribes. A bus, rail or paratransit system may develop alternates to APTA standards (white papers) as long as the alternates provide safe operations and are described and documented in the agency's System Safety Program Plan (SSPP) or Public Transportation Agency Safety Plan (PTASP) (or another document that is referenced in the SSPP/PTASP).

Documentation of alternate practices shall:

- identify the specific APTA transit safety standard requirements that cannot be met;
- state why each of these requirements cannot be met;
- describe the alternate methods used; and
- describe and substantiate how the alternate methods do not compromise safety and provide a level of safety equivalent to the practices in the APTA safety standard (operating histories or hazard analysis findings may be used to substantiate this claim).

Cleaning and Disinfecting Transit Vehicles and Facilities During a Contagious Virus Pandemic

1. Program overview

NOTE: The best-practice recommendations provided in this section are not prescriptive but are intended to provide information about possible approaches to developing a cleaning and disinfecting program. Not every suggestion will be applicable to every pandemic outbreak, every community or every transit agency.

Transit agencies should develop programs to clean and disinfect their facilities and vehicles properly during viral disease outbreaks. The intent of these programs should be to reduce the spread of the viral outbreak and to mitigate risks to transit employees and passengers associated with viruses. While this information is based on current industry practices, every transit agency must tailor its program to ensure compliance with local regulations and its own internal policies and safety requirements. Given the difference in transit operating environments across the industry, there will be variations in each transit agency's maintenance, cleaning and disinfecting programs. The intent of this document is solely to provide information and guidance to a transit agency in the development of its own program. As a result, APTA strongly encourages transit agencies to employ risk-based assessments to determine appropriate courses of actions for their particular environment.

1.1 Program scope

The scope of this program focuses on the maintenance, cleaning and disinfecting of transit vehicles and facilities during an infectious virus pandemic. While this document was specifically developed in response to the COVID-19 pandemic of 2020, it may have relevance to other similar infectious viral outbreaks. Applicability of this document during other viral outbreaks should be carefully assessed by transit agencies.

1.2 Program schedule

The Centers for Disease Control and Prevention (CDC) has developed procedures for cleaning and disinfecting facilities and vehicles, which includes recommendations on minimum requirements for scheduling of certain activities. These are summarized in **Table 1**. It should be noted that local governments, health departments and product manufacturers may have other requirements or recommendations that should be considered and complied with by transit agencies. It is recommended that each transit agency conduct an analysis to determine the appropriate schedule frequencies for its program.

TABLE 1
Program Schedule

Activity	Frequency
Facility and vehicle routine cleaning	At least daily
Pesticide disinfecting high touch points in facilities and vehicles	EPA: at least daily [1], Health Canada at least twice daily [2]
Partial facility and vehicle cleaning (high-touch areas)	During shift changes
Deep facility and vehicle cleaning (all surfaces cleaned)*	At least weekly
HVAC filter change*	Per manufacturer's recommendations, ASHRAE: Consider letting filters load further than usual by reducing the frequency of filter changes. Measure pressure drop to ensure increased loading does not disrupt room pressure differentials. Frequently confirm filters remain snug in their frames [2].

* No recommendations provided by the CDC.

1.3 Equipment and materials management

All equipment and products used as part of a cleaning and disinfection program should be thoroughly reviewed, assessed and approved by each transit agency's safety, engineering, operations, maintenance and any other applicable departments. Safety data sheets (SDS) for all materials and products used as part of the program should be carefully reviewed and made available for review by agency staff who will be working with them.

Many of the materials used against contagious viruses have significant safety risks if not mitigated adequately. Furthermore, the equipment and materials discussed in this section could cause damage to agency property if not used properly. Therefore, it is recommended that each agency assess the materials and equipment discussed herein for short- and long-term effects of using these materials and equipment on the agency's facilities and vehicles.

Further, it is likely that during pandemics, materials and equipment will be in limited supply. This document provides recommendations for material and equipment selection. Should these materials and equipment not be available to a transit agency during a pandemic, there may be suitable alternatives, but each product should be thoroughly reviewed and evaluated to determine its effectiveness in protecting against the spread of the virus.

A matrix showing examples of what equipment and processes transit agencies are using is provided in Appendix B.

1.4 Cleaning products

The CDC recommends the use of soap and water for cleaning surfaces [1]. Transit agencies can also use other detergents and cleaning products that are currently used as part of their routine cleaning programs. Cleaning products should be nontoxic and selected with the intent of cleaning away all dirt, grime and debris from surfaces ahead of the disinfection process. Cleaning products can be applied using mops, rags, spray bottles or other common application methods. Use of dry-cleaning methods may cause infectious particulates to become airborne. Therefore, it is recommended that sweeping, vacuuming and other dry cleaning methods be kept to a minimum [1]. Instead, it is recommended that wet cleaning methods (such as mopping and spraying) be used as much as possible. When dry cleaning is required, the American Industrial Hygiene Association (AIHA) recommends the use of vacuums with HEPA filters [3].

1.5 Surface disinfecting products and methods

1.5.1 Pesticide surface disinfectants

The primary disinfectant products being used against COVID-19 are pesticides. It is recommended that transit agencies use disinfectant pesticides registered with the EPA and specifically formulated to mitigate against virus transmission. The EPA defines all chemical solutions used to mitigate viruses and disinfect surfaces as pesticides. The EPA registered product list can be found at EPA's List N here [4].

All EPA-registered pesticides must have an EPA registration number, which consists of a company number and a product number (e.g., 123-45). Alternative brand names have the same EPA registration number as the primary product. Therefore, if a transit agency has difficulty procuring a product from List N, then that agency should seek to purchase other brands that have the same EPA registration number that are targeted at human coronaviruses. The CDC states that when disinfectants with List N product numbers are not available, alternative disinfectants can be used (for example, ⅓ cup of bleach added to 1 gallon of water, or 70 percent alcohol solutions) [5]. However, use of disinfectants not included in List N should be carefully reviewed to determine their efficacy against SARS-CoV-2, health and safety considerations, and potential damage they may cause to transit assets. Disinfectant pesticides should be used only in accordance with the product labeling. Each pesticide label will list approved application method(s), surface types it is prescribed for and required contact time for the target pathogen.

Pesticides can be applied with a spray bottle or fogger device, as shown in **Figure 1** and **Figure 2**, but transit agencies should follow manufacturers' requirements for application methodology. Some pesticides cannot be used in foggers or spray bottles. If spray bottles and foggers are used, they should be set to distribute as a fine mist, as to not oversaturate surfaces and materials within the vehicle or facility. According to AIHA, fogging is not the preferred method of application, as it can create many human health hazards [3]. More advanced methods of application are available, such as robotic units, spray distribution ports and turbine distribution, but these units typically cost tens of thousands of dollars and are not ideally suited for transit facilities and vehicles where there are many obstructions that can block automated disinfectant flow. The CDC also recommends that transit agencies provide disinfectant wipes and disinfecting hand sanitizer at high-touch locations such as work stations or operator areas [6].

FIGURE 1
Fogger for Disinfecting and Antimicrobial Shielding

FIGURE 2
Spray Bottle for Disinfecting and Antimicrobial Shielding

1.5.2 Ultraviolet surface disinfectants

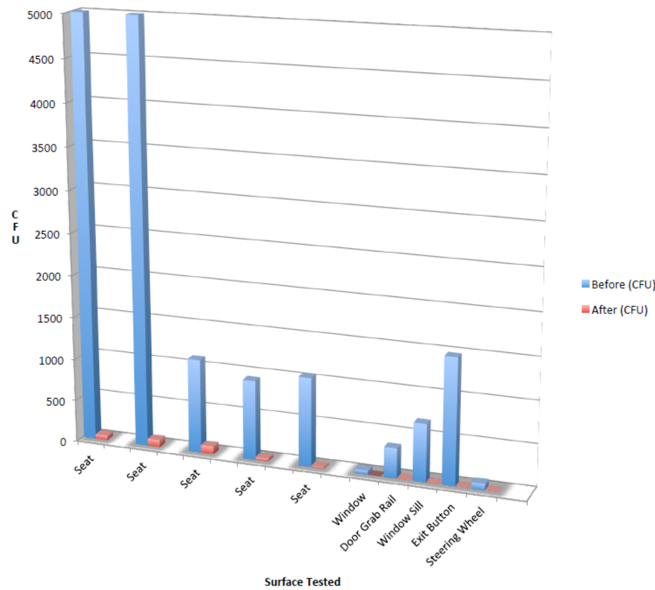
Ultraviolet (UV) light is another form of surface disinfecting that is now being used in many locations, including at airports, food processing plants and hospitals. UV lamps are used to kill bacteria, viruses and molds. UV is light from 100 to 400 nm in wavelength and is invisible to the human eye. UV light is divided into three types: UVA (320 to 400 nm), UVB (280 to 320 nm) and UVC (100 to 280 nm) based on wavelength. UVA and UVB disinfect by oxidizing virus cells, killing them, while UVC disinfects by mutating the DNA of the virus cell, eliminating its ability to reproduce or infect a person. According to ASHRAE, UVC lights are the most effective wavelength for disinfecting surfaces [7]. There have not been any test results published to date verifiably proving that UV lights are effective against SARS-CoV-2. However, as early as the 1970s, the efficacy of UV light against other forms of coronavirus has been proven in laboratory tests. For example, a study conducted at Columbia University found that UV lights were effective in killing human coronaviruses HCoV-229E and HCoV-OC43 [8].

New York MTA, IndyGo, TriMet, NCTD and GCRTA tested UV lights on top of pesticide methods for interior surface disinfection, as shown in **Figure 3**. UV disinfecting has also been used in Russia and China to disinfect transit vehicles and facilities [9] [10]. A study conducted on the Russian metro system determined that UV light was up to 99 percent effective in killing the bacteria that cause staph infections in rail vehicles and on escalator handrails within facilities.

FIGURE 3
UV Disinfecting Light Device During Setup

A study conducted at NCTD also found that UV lights were effective in disinfecting rail vehicles. **Figure 4** shows measurements of bacteria on surfaces throughout the rail vehicle before (blue) and after (pink) UV light treatment was applied. The study found that UV lights were nearly 100 percent effective in eliminating bacteria, measured as colony-forming units (CFUs), on various surfaces throughout the vehicle. The light was slightly less effective on porous seating materials, as the UV light could not fully penetrate the surface. NYCTA and IndyGo are using UV lights that operate across the UV spectrum (UVA, UVB and UVC). Using UV lights that operate across the spectrum may offer improved results but can lead to additional hazards to mitigate, such as ozone production if the lights operate at wavelengths near 200 nm. At these wavelengths UV light has the ability to modify oxygen molecules, forming ozone. Ozone can assist in disinfection by oxidizing bacteria and virus molecules in an area, but is also harmful to humans and the environment.

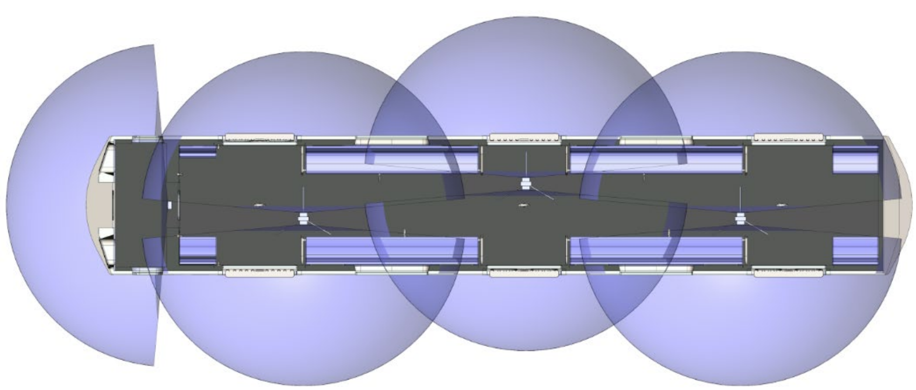
FIGURE 4
NCTD Bacterial Load Before and After UV Light Treatment on a Railcar



When used against other viruses, UV lights are selected based on "total irradiation" or "dosage," which is a measure of the UV energy that will irradiate a unit area. Many studies have been published demonstrating the efficacy of UV against SARS-COV-2 on surfaces. One study reported that UVC light with a dosage of 0.1 mW/cm^2 reduced viable SARS-CoV-2 by 2.51 log10 in 30 seconds [1].

Based on experience there are some processes that transit agencies can follow to select UV equipment and to design a UV disinfecting process. A survey of the area should be completed and mapped to determine the number and type of UV products required to sufficiently disinfect the area. UV irradiation is affected by shadowing, contaminants and distance from a source, as well as the duration of irradiation and power of the source. An example of a UV map for a rail vehicle is shown in **Figure 5**.

FIGURE 5
UV Light Map Example for a Rail Vehicle



There are drawbacks with UV light disinfection, including costs, time associated with the process, operational requirements, maintenance and safety concerns. UV lights have higher upfront costs than pesticide disinfectants. The New York MTA, for example, purchased devices for approximately $6,500 per unit and required 150 units for the pilot program, bringing the total cost of the pilot equipment to roughly $1 million

[12]. At NYCTA, several lights must operate for 30 minutes to disinfect a train car. Setting up and taking down the lights can add as much as an additional hour to the process. Vehicle or facility downtime associated with the process may render UV surface disinfection not feasible in a transit environment. Furthermore, in order to disinfect entire fleets, some of the disinfection typically needs to be performed in yard or storage areas where power for the UV lights is not available. As a result, generators may be required that can add safety issues when working in a transit environment. Finally, UV lights require that surfaces be cleaned ahead of treatment, which eliminates any operational efficiencies that would have been gained by reduced maintenance efforts to disinfect the space compared with pesticides.

UV light is also known to cause damage to materials such as plastic and rubbers that are commonly found in transit vehicles and facilities. Prolonged use of UV light for disinfection may cause rapid deterioration of transit assets and should be considered. Protective coatings and material selection during design of new facilities and vehicles should be considered with this in mind.

UV light is also dangerous to humans and can cause skin cancer and damage to eyesight; it is typically recommended to be used in controlled environments where human access is restricted. OSHA has two standards regarding human exposure to UV light: "Nonionizing radiation" (29 CFR 1910.97) and "Ionizing radiation: (29 CFR 1910.1096). Furthermore, the National Institute for Occupational Safety and Health (NIOSH) recommends that the time of exposure to UV lights should not exceed 1 minute [13]. UV lights can pass through windows, so should transit agencies elect to use UV lighting as a method of disinfecting, special precautions should be taken to keep employees and passengers away from the area being disinfected during the process. Furthermore, UV products that include motion sensors for automatic deactivation when a person enters an area are recommended.

Columbia University recently conducted research testing specific wavelengths (220 nm) of UV light that may be safe for human exposure but are still lethal to viruses [14]. At these frequencies, the rays may not penetrate the surface of the skin or the eye. That means they could potentially be used in closed and crowded spaces where contamination risks run high, including in public transportation. The Columbia University Study states:

> Far-UVC light is anticipated to have about the same anti-microbial properties as conventional germicidal UV light, but without producing the corresponding health effects. Should this be the case, far-UVC light has the potential to be used in occupied public settings to prevent the airborne person-to-person transmission of pathogens such as coronaviruses.

Further research, however, should be conducted to validate this study before any transit agency considers adopting the use of UV lights in occupied areas.

UV surface disinfection pilot studies conducted at transit agencies during the COVID pandemic have mostly determined that the process is not suitable for transit application. Agencies have reported that the lights are fragile, time consuming to set up, draw a lot of power, and have difficulty irradiating all surfaces within the transit space due to shadowing and obstructions. Furthermore, it is difficult to contain irradiation in a way that ensures that passengers of transit workers are not accidentally exposed to the harmful ultraviolet light.

1.5.3 Alternative surface disinfectants

There are other disinfectant technologies and methodologies being used in response to the COVID-19 pandemic, but these are less prevalent in North American transit environments. These alternatives are provided as information only, are *not* recommended by APTA, and should be carefully investigated before application by any agency.

High-temperature steam-cleaning has long been known to kill bacteria, viruses and other pathogens. The primary advantage of steam-cleaning is that it does not use chemicals, which eliminates certain hazards and disposal concerns associated with pesticides. Polish regional railway operator Koleje Śląskie and Italian operator Azienda Trasporti Verona are using high-temperature steam devices to disinfect transit vehicles [15]. Steam-cleaners typically operate at temperatures at or above 225 °F, which can cause damage to certain surfaces. Steam-cleaning is not recommended for the following surfaces:

- electronics
- porous surfaces
- carpet
- thin plastics and upholstery

Nebulizers are devices that use ultrasonic technology to create a fog that contains disinfectant pesticides. According to manufacturers, this method can create a finer mist than a typical fogger device, allowing for a greater coverage area. These devices are currently being used in Austria and Romania to disinfect transit vehicles [16]. These devices are more expensive than typical spray bottle applications and have not been tested in a North American transit environment.

1.5.4 Selection of surface disinfectant methodologies and technologies

The selection of disinfection technology and methodology should be carefully assessed by each transit agency. In general, foggers, nebulizers and UV lights are best suited for treatment of open areas. These methodologies have not been endorsed by the CDC or EPA, are more expensive, take longer to set up, and can present difficult hazards for transit agencies to mitigate. Therefore, these methodologies are *not* recommended by APTA at this time and should be used only to supplement more traditional pesticide disinfectant approaches.

1.6 Antimicrobial shielding products

Antimicrobial shields are chemicals that adhere to surfaces and possess a positive charge that attracts virus molecules to the surface. Once a virus molecule makes contact with the surface, the antimicrobial shield kills it with disinfectant pesticides, such as ammonia quaternary or metal oxides, in the same way as the pesticides described in Section 1.5.1. Manufacturers claim that these shields can remain effective for days after application; however, no manufacturer has provided data confirming these claims.

While the EPA has not yet developed a list of registered antimicrobial shields or thoroughly evaluated industry claims that they are effective in protecting against SARS-CoV-2 transfer to surfaces, one company is claiming to have independent test results showing that its product is effective in shielding surfaces from SARS-CoV-2 [17]. Despite the lack of EPA registration, the New York MTA, TTC, GO Transit, Prague Public Transit, and Polish regional railway operator Koleje Śląskie have begun applying the antimicrobial shields to their stations and vehicles, in addition to disinfectants, based on manufacturer claims.

Furthermore, the FDA has approved antimicrobial shields for use on food surfaces to prevent bacteria growth. The length of time that these antimicrobial shields remain effective varies by product and has not yet been thoroughly assessed with respect to SARS-CoV-2, but some manufacturers claim their products remain effective for up to one year. Antimicrobial shields can be applied with a spray bottle or fogger device, but many require specific spray sizes. Transit agencies should follow manufacturers' recommendations on application methodology should they choose to implement these types of products. However, without published test results confirming efficacy, or the endorsement of the EPA and CDC, APTA does *not* recommend the use of these products at this time.

1.7 Personal protective equipment

Transit agency personal protective equipment (PPE) programs should comply with OSHA guidance 3990 and 29 CFR 1910.132. It is important that PPE programs also comply with internal transit agency policy and manufacturers' recommendations. Agencies should reference safety data sheets and manufacturers' recommendations in selection of PPE. Special care should be taken in selection of PPE for use with UV or fogging equipment. When cleaning and disinfecting with pesticides, individuals typically are required to wear disposable gloves compatible with the products being used, as well as any other PPE required according to the product manufacturer's instructions. Typically, masks, N95 respirators, face shields, and coveralls or gowns will be required PPE for the cleaning and disinfecting process.

APTA's white paper APTA WP-SEM-016-20, "Developing a Pandemic Virus Service Restoration Checklist," and APTA's document "The COVID-19 Pandemic, Public Transportation Responds: Safeguarding Riders and Employees," provide further details on developing a PPE program during a pandemic.

1.8 Personal hygiene products

The CDC recommends that transit operators provide adequate supplies to support healthy hygiene behaviors for transit operators, employees and passengers in stations, including non-touch or personal containers of liquid soap, hand sanitizer with at least 60 percent alcohol, paper towels, tissues and trash cans [18]. Adequate supplies should be provided so workspaces and equipment can be wiped down and disinfected after each person finishes using them.

1.9 Material and equipment disposal

Transit agencies should comply with local regulations and requirements and manufacturers' recommendations regarding the disposal of products and waste materials associated with the cleaning and disinfection program. Transit agencies should consult safety data sheets for the products being used; some pesticides should not enter transit agency sanitary sewer or storm draining systems.

1.10 Data management and quality checking

It is recommended that each transit agency develop a data management and quality assurance plan as part of its program. The data management system should be designed to assist the agency in scheduling and tracking the status of cleaning and disinfecting efforts. If possible, a data management system that allows for live access to data regarding cleaning and disinfection status of vehicles and facilities is recommended to allow the transit agency to quickly access information. It is recommended that transit agencies develop quality assurance programs, based on the FTA's "Quality Management System Guidelines" document, to ensure proper administration of the program [19].

1.10.1 Field quality checking equipment

Adenosine triphosphate (ATP) is a common testing method used in the food and health industries to verify the. cleanliness of surfaces. ATP is present in all organic material and is the universal unit of energy used in all living cells. ATP is produced and/or broken down in metabolic processes in all living systems (e.g., viable fungi, molds, biofilms and other biological matter). Since viral particles do not contain or produce ATP, performing such testing will not directly confirm either the presence or the absence of viruses on surfaces. It can, however, be used as a surrogate quality check to provide an indication of the cleanliness of surfaces. It should be noted that ATP readings can be obscured by the presence of certain cleaners, pesticide disinfectants and antimicrobial shields, especially before they dry. It is important that this be considered when using ATP as a quality check.

There are no lists of certified or standardized ATP test equipment. The CDC, however, does recognize ATP testing as a method for environmental testing [20]. Should transit agencies decide to implement ATP testing, they should select equipment designed for surface, and not water, testing. **Figure 6** shows an example of an ATP testing unit being used on a bus.

FIGURE 6
Example ATP Unit (Left) and Test Being Performed on a Bus (Right)

2. Vehicle and facility surface cleaning and disinfecting processes

> **NOTE:** The best-practice recommendations provided in this section are not prescriptive but are intended to provide information about possible approaches to developing a cleaning and disinfecting program. Not every suggestion will be applicable to every pandemic outbreak, every community or every transit agency.

2.1 Vehicle and facility cleaning

Cleaning of transit vehicles and facilities should always be completed prior to disinfection. Cleaning procedures should be designed to remove all dirt, grime and debris from surfaces so they can be disinfected during a subsequent process.

The CDC and The Transportation Research Board (TRB) recommend that transit facilities and vehicles be cleaned at least daily [1] [21]. The entirety of the vehicle or facility area should be cleaned, but efforts should be focused on high-touch surfaces such as workstations, operator controls, seats, kiosks, ticket machines, turnstiles, benches, handrails, garbage cans, door handles, pay phones, restroom surfaces (e.g., faucets, toilets, counters), elevator buttons and system maps. For soft or porous surfaces, remove any visible contamination, if present, and clean with appropriate cleansers indicated for use on these surfaces. Again, for porous surfaces manufacturer's recommended soak times should be strictly adhered to by agencies to ensure mitigation. The

EPA recommends that transit agencies consider eliminating soft and porous materials, such as area rugs and seating, within facilities to reduce the challenges of cleaning and disinfecting them. Surfaces should be cleaned with agency-approved detergent or soap and wash mittens, rags or mops. Special care should be taken when cleaning electronics to not damage them. TRB recommends that damp mops or wet vacuums should be used to clean floors, as shown in **Figure 7**.

FIGURE 7
Wet Vacuum Being Used to Clean Railcar Floor

Some transit agencies have elected to clean their facilities and vehicles more frequently than once a day. These agencies have chosen to periodically perform minor cleaning procedures throughout the day, such as wiping down high-touch surfaces and removing trash and debris from vehicles and facilities. The CDC recommends that transit operators wipe down vehicle controls between shifts, and that counters and other hard surfaces be wiped down between customer interactions at customer service locations within facilities [18].

Dry cleaning methods, such as vacuuming and sweeping, are not recommended. However, if necessary, this should be performed with only minimal staff present, and proper PPE should be worn at all times. AIHA recommends the use of vacuums with HEPA filters when dry cleaning is required.

2.2 Vehicle and facility disinfecting

Vehicle and facility disinfecting are very important to offer transit employees as well as passengers protection against contagious viruses. Cleaning and disinfecting are two different procedures that should be used together to remove and kill germs, bacteria and contagious viruses. Once the cleaning process described in Section 2.1 is completed, the disinfecting process can begin. Disinfecting should be conducted as thoroughly as possible and can be accomplished by using disinfecting pesticides.

2.3 Pesticide disinfecting

The CDC recommends that transit vehicles and facilities be disinfected with pesticides from EPA's List N found here [1]. The process for applying the disinfectant pesticides varies by product and manufacturer directions but may include wiping, spray or fogger applications (as shown in **Figure 8**). The disinfectant pesticides should sit wet on the surface for the directed wet contact kill time and then be allowed to air dry and not be wiped off. Disinfecting pesticides should be applied to high-touch surfaces such as workstations, operator controls, seats, kiosks, ticket machines, turnstiles, benches, handrails, garbage cans, door handles, pay phones, restroom surfaces (e.g., faucets, toilets, counters), elevator buttons and system maps. Special care should be taken to not oversaturate electronics and porous surfaces, as this could damage equipment.

FIGURE 8
Disinfection of Rail Vehicle Cab Area

Some transit agencies have elected to disinfect their facilities and vehicles with pesticides more frequently than once a day. These agencies have chosen to periodically perform minor disinfecting procedures throughout the day, such as applying disinfectant to high touch surfaces on vehicles and in facilities.

A generic example of a pesticide disinfecting procedure for a public transit vehicle is provided in Appendix A.

2.4 UV light disinfecting

As previously mentioned UV light has been proven to be effective against SARS-CoV-2, but there are no established procedures for using UV light for disinfecting transit vehicles and facilities. If a transit agency chooses to use UV lights for disinfection of its vehicles and facilities, APTA recommends that the agency consult with UV lighting experts to develop operating and maintenance procedures and to ensure that proper safety precautions are taken.

2.5 Antimicrobial shielding

Antimicrobial shields have not been proved effective against SARS-CoV-2. Some antimicrobial shields contain disinfectant pesticides similar, or identical, to those that would be used in Section 2.2. In those cases, the processes described in Section 2.2 would be replaced with those described in this section. Antimicrobial shields, however, have not been recommended thus far by the EPA or the CDC for use during the COVID-19 pandemic, and therefore transit agencies should carefully consider using them exclusively for disinfection.

3. Management of areas where infected people have been present

> **NOTE:** The best-practice recommendations provided in this section are not prescriptive but are intended to provide information about possible approaches to developing a cleaning and disinfecting program. Not every suggestion will be applicable to every pandemic outbreak, every community or every transit agency.

According to the CDC, areas where people confirmed to be infected have been present should be handled with special care. The CDC recommends that the areas be closed off as soon as possible. If possible and feasible, the area or vehicle should not be accessed by staff or passengers for 24 hours. If possible, the area should be ventilated by opening windows. Once the 24-hour period has passed, cleaning, disinfecting and antimicrobial shielding (if available), as described in Section 2, should be conducted. Dry cleaning methods such as vacuuming and sweeping are not recommended but, if necessary, should be performed with minimal staff present and with proper PPE worn at all times.

APTA's document "The COVID-19 Pandemic Public Transportation Responds: Safeguarding Riders and Employees" provides further details on management of areas where infected people have been present.

4. Facility and vehicle design and modification considerations

> **NOTE:** The best-practice recommendations provided in this section are not prescriptive but are intended to provide information about possible approaches to developing a cleaning and disinfecting program. Not every suggestion will be applicable to every pandemic outbreak, every community or every transit agency.

Due to the magnitude of the COVID-19 pandemic, it is likely that transit agencies will want viral outbreak considerations to be included in future vehicle and facility designs and modifications. This section includes modifications that could be made to transit facilities and vehicles in either a temporary or permanent fashion.

4.1 Designing facilities and vehicles for ease of cleaning and disinfecting

When designing or modifying facilities and vehicles, transit agencies should consider future cleaning efforts.

We Go Public Transit in Nashville published a transit facility design guidelines manual that provides details on how facilities can be designed to improve cleaning activities [23]. The manual states that facilities should be designed with minimal joints and exposed corners where dirt and debris can accumulate. Surfaces should be selected for ease of cleaning, and protective coatings should be used to reduce maintenance and cleaning needs. The document also states that fabrics should be avoided within facilities. Finally, facilities should be designed with cleaning equipment access in mind. If wet vacuums are to be used, for example, space must be allocated for access. Furniture and other structures should be movable or designed to not allow for dirt and debris accumulation.

TRB published a bus cleaning guidebook that would be applicable to most transit vehicles [21]. The guide states that vehicle designs that incorporate cantilevered seating will improve interior cleaning. The guide also recommends the use of sealed floor seams, clear-coat floor finishes, nonribbed flooring, rot-resistant subflooring material, dark interior colors, modesty panels with 1 in. clearance above the floor, nonslip floor material to eliminate the need for sand in the winter, and holes drilled into plastic seat bottoms to allow water drainage. Cloth and porous materials should be avoided, if possible, in vehicle designs.

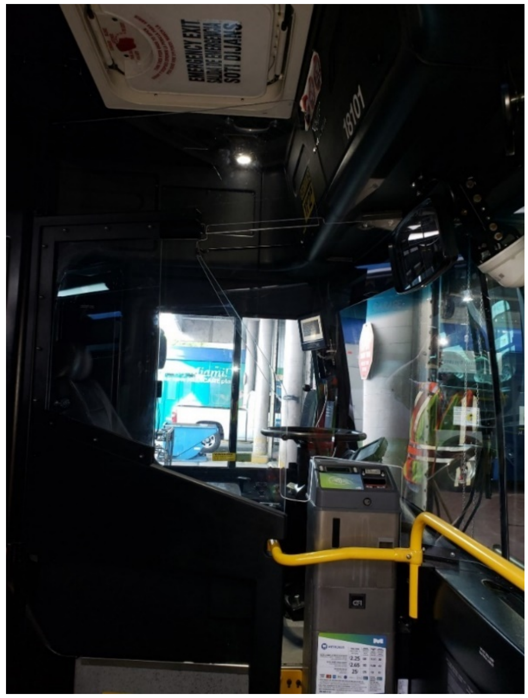
Longitudinal bench-style seating can help to reduce cleaning effort on vehicles compared with segmented transverse arrangements. Examples of these seating arrangements are shown in **Figure 10**. Longitudinal seating, however, is not suitable for all vehicles, so an analysis should be conducted to determine if it is suitable for each application. Other innovative designs have been used; for example, TTC has specified floor-mounted piping in its vehicles, which can be connected to a hose to distribute water on the floor of the buses to quickly wash away debris.

FIGURE 10
Longitudinal Seating (Left) and Transverse Seating (Right)

4.2 Employee barriers

According to the CDC, it is recommended that transit agencies install barriers surrounding work stations where transit employees will have face-to-face interaction with other people on a regular basis [24]. These locations include operator areas within vehicles and workstations within transit facilities. The intent of these barriers is to provide a sneeze and cough shield for the transit employees. Many transit agencies have installed temporary barriers made from plastic during the recent pandemic; an example is shown in **Figure 11**. When installing barriers in vehicles it is important that operator sight lines are not obstructed. Transit agencies may elect to install permanent barriers in their facilities and vehicles going forward. Testing and research should be conducted to assess the feasibility and effectiveness of permanent solutions at individual transit agencies.

FIGURE 11
Plastic Barrier to Block Off Operator Area in a Bus



4.3 HVAC management

The CDC has stated that airborne transmission of the virus is more likely than transmission through surface contact. As a result, many agencies have begun investigating incorporating disinfection efforts into their HVAC systems. Adequate ventilation and air filtration of HVAC systems can reduce the likelihood of airborne exposure. While air movement throughout a vehicle or facility can provide a means for airborne pathogens to travel, ASHRAE does not recommend that HVAC systems be turned off or operated in a reduced capacity mode during an infectious virus pandemic [25]. The ventilation system has the ability to remove some airborne pathogenic particles and droplets, which decreases the likelihood of exposure. While the controlled movement of air through the facility or vehicle is necessary, ventilation systems should be evaluated for proper diffused and returned airflow.

Additionally, increasing ventilation rates can be considered, but not without first analyzing the effects on overall system performance and the potential to induce additional harmful exterior pathogens. Some transit vehicles are equipped with variable ventilation control systems that decrease ventilation based on passenger load for the sake of energy savings. Where variable ventilation control systems are present, the recommendations of ASHRAE Guideline 23 should be followed to ensure that adequate ventilation is being provided under all operating conditions. For vehicles fitted with operable windows, open windows can provide increased ventilation airflow when conditions allow or when passenger safety, air quality or comfort will not be compromised.

Most transit HVAC systems provide Minimum Efficiency Reporting Value (MERV) 7–10 filtration meeting ASHRAE Standard 52.2. ASHRAE does not recommend the use of filters with MERV ratings higher than 10 or HEPA filters [26]. HEPA filters (identified by H10 through H14 typically having a MERV rating of 16 to 20) have the ability to capture a minimum of 99.97 percent of 0.3 µ–sized particles passing through the filter and can remove pathogens that are particles from the ventilation air. However, the use of these higher-efficiency air filters also results in a significantly higher operating pressure drop. It is not feasible in most cases to simply add higher-efficiency filtration to systems not originally designed for the associated pressure drop, as this can result in reduced performance and potential equipment damage. Ventilation and airflow testing of the vehicle or facility HVAC system is encouraged, to determine whether any increase in MERV rating can be accommodated.

Capturing pathogens with traditional filters, though beneficial from an air quality standpoint, can result in inadvertent contamination when particles and/or droplets separate from the filter when the HVAC system is turned off or when the filters are replaced. Therefore, transit agencies should replace filters prior to cleaning a facility or vehicle and appropriate PPE should be worn during the process.

Outside of ASHRAE recommendations, The CDC and EPA have only endorsed one HVAC disinfection method. In January 2021, the EPA granted emergency exemptions for the use of a pesticide which is not currently included on List N: Grignard Pure. This pesticide, which is in part Triethylene glycol, has been granted emergency approval by the EPA for use in disinfecting air and surfaces within conditioned spaces, including transit vehicles and facilities [2]. Grignard Pure is the only product currently approved for air disinfection by the EPA, and can reportedly be used safely while people are in the conditioned space. Currently emergency exemption has only been granted in Georgia and Tennessee. The EPA requires that distribution of Grignard Pure be done through approved equipment, installed by certified installers, and that concentrations of the pesticide be monitored. The EPA requires that concentrations be kept within the levels identified in Table 1. Distribution systems are available that can be integrated into HVAC system for automatic distribution and concentration monitoring. The EPA notes that Grignard pure may cause irritation to eyes and lungs in some individuals. There are a few transit agencies in North America currently piloting the use of Grignard Pure in their transit vehicles.

Table 1 Grignard Pure Concentration Requirements

Measurement Method	Visual Assessment of Haze Density	Particle Sensor Reading for GP	Equivalent Active Ingredient Concentration
Minimum	Non-visible	1.66 mg/m^3	1.04 mg/m^3
Maximum	Light Moderate	9 mg/m^3	5.62 mg/m^3

Aside from the methods mentioned above, *APTA does not currently recommend* the application of any of the other technologies or methods discussed in this section at this time. The information in this section is provided as information only.To combat the need for increased efficiency filtration mentioned earlier, specialty antimicrobial/antiviral filters, which reportedly break down and inactivate pathogens with silver or copper embedded in the media, are being investigated to be applied either as a pre-filter or as a final pleated filter [27]. Initial claims by the manufacturer of these specialty antimicrobial/antiviral filters, based on internal testing, indicate no significant increase in pressure drop in some applications. Certification in accordance with UL900 is currently in process for final validation. Several transit agencies are currently testing these antiviral filters.

Another filtration methodology being experimented with is electronic filtration, which uses corona wires or ionizers to charge particles and attract them to filter media with opposite charge [4]. ASHRAE reports that these devices can range widely in effectiveness, but in some cases have demonstrated the ability to increase particle arrrestance efficiency without creating pressure drops or damaging the HVAC system. This technology is not intended to eliminate SARS-COV-2 particles, but rather capture them on filter media.

Devices that produce negatively charged ions have also been investigated by transit as a potential mitigation technology. The concept behind this technology is that negatively charged ions are electrically generated by a device and distributed within a conditioned space. The ions can reportedly oxidize bacteria, viruses and other pathogens. Efficacy of these devices against SARS-COV-2 has not yet been proven. There are different methods used by manufacturers to generate ions, such as needlepoint and bi-polar ionization. ASHRAE does not currently have a position on ionization, and the CDC has provided the following quote on the subject [4]:

> *"CDC does not provide recommendations for, or against, any manufacturer or manufacturer's product. While bi-polar ionization has been around for decades, the technology has matured and many of the earlier potential safety concerns are reportedly now resolved. If you are considering the acquisition of bi-polar ionization equipment, you will want to be sure that the equipment meets UL 2998 standard certification (Environmental Claim Validation Procedure (ECVP) for Zero Ozone Emissions from Air Cleaners) which is intended to validate that no harmful levels of ozone are produced. Relative to many other air cleaning or disinfection technologies, needlepoint bi-polar ionization has a less-documented track record in regards to cleaning/disinfecting large and fast volumes of moving air within heating, ventilation, and air conditioning (HVAC) systems. This is not to imply that the technology doesn't work as advertised, only that in the absence of an established body of evidence reflecting proven efficacy under as-used conditions, the technology is still considered by many to be an "emerging technology". As with all emerging technologies, consumers are encouraged to exercise caution and to do their homework. Consumers should research the technology, attempting to match any specific claims against the consumer's intended use. Consumers should request efficacy performance data that quantitively demonstrates a clear protective benefit under conditions consistent with those for which the consumer is intending to apply the technology. Preferably, the documented performance data under as-used conditions should be available from multiple sources, some of which should be independent, third party sources."*

UV lighting systems are another method that has been used for over a decade to disinfect HVAC systems and airstreams. Like UV surface disinfection, transit agencies should carefully assess the technology for potential health, safety and equipment damage concerns before installing UV lighting in the HVAC systems on their vehicles and within their facilities. Ultraviolet systems using short-wave UVC energy can offer increased disinfection to inactivate viral and other bacterial organisms when installed directly within an HVAC system. These systems can be installed either within the supply (conditioned) or return/mixed air sections of the HVAC system, or directly within the vehicle or facility ductwork [28].

UV lamps can be designed to provide adequate total irradiation to continually disinfect the moving airstream. Several types of UV lamps and configurations are readily available; however, design of the system must carefully consider dynamic operation in a transit environment, including the type of lamp, product safety, shock and vibration, and environmental hazards, to avoid lamp failure during service within the airstream and during removal. The irradiance of the light must be sufficient to treat the air in the short period that the air travels through the UV-treated duct section. When determining the location of a UV system, all adjacent materials must be considered, as material degradation could occur. UV systems should be designed to facilitate maintenance and be equipped with AUTO-OFF interlock to avoid personnel exposure to UV radiation.

HVAC applications of UV lights have been tested in transit environments. In 2009, TRB conducted a study on 12 Houston Metro buses that had UV lights installed in their HVAC systems [29]. The study found that the UV light systems were 95 to 99 percent effective in reducing bacteria, fungi and virus particles. The study also found that UV systems helped to improve the efficiency and airflow within the bus systems by up to 31 percent by removing contaminants. A similar study was conducted on a rail system in Russia and found that the use of UV systems reduced air contaminants by a factor of 2.5 [9]. In response to the COVID-19 pandemic, some new bus and train vehicle models manufactured for Russia and China will be delivered with

UV systems installed standard. These types of systems have also been used in buses in Dallas, Toronto, Tampa, Fort Worth, Miami-Dade, Jacksonville and New York City transit vehicles [30].

A newer UV technology for treatment of both air and surfaces is called photocatalytic oxidation (PCO). PCO works by shining UVC light on a metal oxide catalyst. The PCO creates a photochemical reaction that alters water vapor in the air, converting it to hydrogen peroxide. When installed in an HVAC system, this technology circulates aerosolized hydrogen peroxide throughout the conditioned space, disinfecting both surfaces and the air. According to manufacturers, the hydrogen peroxide particles produced are safe for humans. OSHA 29 CFR 1910.1000 sets a permissible hydrogen peroxide exposure limit of 1 part per million as an 8-hr time weighted average. ASHRAE states that PCOs can also produce ozone, which can be hazardous to humans and damaging to equipment [31]. OSHA guidelines sets an ozone exposure limit of 0.1 part per million as an 8-hr time weighted average. Should transit agencies deploy this technology, a thorough analysis should be conducted to ensure that the hydrogen peroxide and ozone limits set by OSHA are not exceeded.

This technology has been used in occupied building spaces in the healthcare, food processing, aviation and hospitality industries for 20 years, but was installed for the first time on transit vehicles during the COVID-19 pandemic. Currently SEPTA and another transit agency are piloting PCO installs on buses and rail vehicles. In these pilot installs, the PCO has been placed on the clean air side of the HVAC unit, as shown in **Figure 12**. According to the manufacturer, the hydrogen peroxide flows into the passenger compartment to disinfect the air and surfaces within the vehicle constantly as the vehicle is in service. Long-term testing in a transit environment is required to validate the concept and to determine any negative health and material effects of the technology.

FIGURE 12
PCO Device Installed on a Transit Bus

Another method of using UV light to disinfect both the air and surfaces is the use of low-wavelength UVC to produce ozone. As explained in Section 1.5.2, UVC operated at approximately 200 nm can modify oxygen molecules, converting them into ozone. Ozone acts as an oxidizer, which can kill bacteria and viruses in the air and on surfaces. However, ozone is harmful to humans and can cause irritation and damage to lungs, skin and eyes. Furthermore, ozone's oxidizing reactions can cause damage to the equipment and materials within a transit facility or vehicle. IndyGo is currently piloting and adopting a system that uses both UV light and ozone to disinfect its buses. Unfortunately, due to the hazards associated with ozone and UV light, this device cannot be used while the buses are in service. ASHRAE provides the following recommendations regarding the use of ozone to disinfect [4]:

> *Devices that use the reactivity of ozone for the purpose of cleaning the air should not be used in occupied spaces because of negative health effects that arise from exposure to ozone and its reaction products. Extreme caution is warranted when using devices that emit a significant amount of ozone as by-product of their operation, rather than as a method of air cleaning. These devices pose a potential risk to health.*

Stand-alone air purification and air disinfection units are also being investigated. These units are totally enclosed and fitted with an integral fan, UV lighting apparatus and air filtration system. The units can be configured either horizontally or vertically within the passenger compartment; will be visible to passengers; and can be potentially installed under seats, adjacent to equipment lockers, as part of the sidewall structure or at the ends of the vehicle. The type and number of units must be carefully selected based on vehicle size, geometry, seating configuration, passenger occupancy, maintenance requirements and susceptibility to vandalism. New social distancing behaviors may provide an opportunity for the unit(s) to take the place of some passenger seating. These units typically require 120 or 230 VAC supply power and could be integrated with the vehicle HVAC system controls or through a dedicated power source operable by a device located in the cab or operator area.

A critical characteristic of an HVAC system that could be altered by a transit operator to potentially disinfect facilities and vehicles is heat. Research indicates that exposure to prolonged temperatures above 130 °F may be effective in killing a virus. Recently Ford completed software modifications to police automobiles that would allow the system thermostats to maintain temperatures above 133 °F. While this approach has not been tested on SARS-CoV-2, Ford claims it is 99 percent effective in reducing viral concentrations within the vehicles [32]. While this approach has not been tested in a transit environment, some transit agencies have begun investigating the feasibility of modifying HVAC systems to create similar heated conditions. Excessive heat can, however, create hazards for humans and potentially damage transit agency equipment. Transit agencies should carefully investigate this method and its potential effects on both employees and customers before applying it.

Another critical characteristic that transit operators may be able to alter in response to a viral pandemic is the relative humidity of the interior air. Bacteria in an airborne state remains infectious longer when traveling through dry air; therefore, to potentially reduce infection rates and reduce microbial virulence, ASHRAE recommends that interior relative humidity be kept between 40 to 60 percent year-round [33]. On subway-type vehicles, streetcars or light rail vehicles that do not typically contain onboard water systems, and where the side and/or front doors frequently open, achieving this level of humidity becomes a challenge, especially during the colder months. By naturally applying interior heating to maintain the interior design temperature, the interior relative humidity is continually reduced. On intercity or commuter vehicles, where station stops are less frequent, and which contain onboard water systems, the desired interior humidity level could be achieved through the use of a humidifier within the air stream of the ventilation system. There are additional challenges for applications in drier climates. Special design considerations will need to be made in these locations.

4.4 Antimicrobial surface materials

Going forward, transit agencies will likely seek to use materials in their facilities and vehicles that offer antimicrobial properties. Copper has long been known to be a material that can reduce the dwell time of pathogens due to its multi toxicity to microorganisms. While the method in which this occurs is complex and multifaceted, a recent article has stated the primary inactivation of pathogens on copper is through an "electrochemical process where copper cations are produced during aqueous corrosion" [9] [The article goes on to state, "copper is also oxidized at very low relative humidity (RH) by oxygen in the atmosphere. However, surfaces containing debris and/or chemical deposits form a thin film of aqueous solution at most RH levels aided by dew point condensation, capillary condensation, and/or deliquescence of salt deposits. These enable aqueous corrosion processes to proceed even when surfaces appear dry." These copper ions directly damage the cell wall, produce oxygen radicals causing oxidative degradation, interfere with key enzymes, and disrupt the osmotic balance of the organism. The healthcare industry has been incorporating antimicrobial materials into facilities for years. Extensive testing has been performed on antimicrobial materials and has resulted in EPA registration of materials for antibacterial activity (Reg. Nos. 82012-1 to -6) as well as Health Canada registration (RD2014-15) for copper alloys with as low as 60% copper. These materials are typically tested under ISO standard 22196:2011. Antimicrobial materials have been proved effective against Staphylococcus aureus (ATCC 6538), Enterobacter aerogenes (ATCC 13048), methicillin-resistant Staphylococcus aureus (MRSA-ATCC 33592), Escherichia coli O157:H7 (ATCC 35150) and Pseudomonas aeruginosa (ATCC 15442).

Recently a number of tests have been performed to determine the efficacy of antimicrobial materials in providing surface protection against human coronavirus:

- One study reported antimicrobial efficacy against one strain of coronavirus (HuCoV-229E) [34].
- The National Institutes of Health (NIH) and the CDC conducted a study that found that SARS-CoV-2 could live on copper surfaces for only approximately four hours, versus three days on plastics and steels [35].

While antimicrobial materials have not been widely applied in transit applications to date, agencies may look to incorporate them into facility and vehicle designs in the future. Transit agencies should continue to gather information about the effectiveness of these materials against infectious viruses and to determine whether they are suitable for transit applications. A few transit agencies, such as TransLink in Vancouver, began testing antimicrobial material retrofits on their vehicles in 2020.

TransLink's pilot was in partnership with Teck Resources Limited, completed in collaboration with their local heath authority (Vancouver Coastal Health) and the University of British Columbia, and built on previous testing of copper surfaces in local hospitals. The pilot looked at three different types of copper surfaces: copper/resin, copper alloy spray, and solid copper decals. The testing assessed microbial kill of materials, material durability, and unique considerations for the successfully implementation of these materials in transit.

Overall, the pilot showed that copper can play a role in improving the safety of public transit by reducing pathogens on surfaces with minimal cost or impact to cleaning programs. The pilot also provided key considerations for transit groups when looking at the various types of copper surfaces available:

Surface	Advantages	Disadvantages
Copper/resin coating	- Minimal risk of vandalism/theft. - Can be retroactively applied to fleet.	- Resin in mixture does not have antimicrobial properties. Effectiveness depends on level of copper exposed at the surface.
Copper alloy spray	- Can be effective without having a "copper appearance", minimizing risk of vandalism/theft. - Can be applied with varying surface roughness.	- May require specialized process for application that makes retroactively applying to fleet difficult.

Solid copper decals	- Can easily be retroactively applied to fleet.	- Potential for sharp metal edges. - Considerations to protect against vandalism should be taken when installing on transit vehicles. - Difficult to apply to curved surfaces.

Another key consideration for copper in transit is how surface properties could be optimized for application on vehicles. Copper alloys could be used to reduce visible tarnishing while maintaining effective kill rate. Additionally, surface roughness may have an impact on antimicrobial performance. While these factors were identified as properties that could be used to optimize copper coatings for transit, they would have to be further explored over a longer study to confirm potential benefits.

TransLink is expanding their pilot with a yearlong study to better understand the impact of copper surfaces in transit and the key factors to be implemented successfully. So far no studies have been published regarding the effectiveness of antimicrobial materials within a transit environment.

4.5 Permanent facility and vehicle UV lighting

In addition to the temporary UV lighting measures mentioned in Section 2, some transit agencies are considering installing UV lights permanently in their transit facilities and vehicles. The hazard and safety concerns already mentioned would also be applicable to permanent installations. This is new technology to the transit industry, but the healthcare industry has been permanently installing UV lights in its facilities for years. Currently there are no established standards or recommended practices for transit agencies to follow, but the CDC and NIOSH have published guidelines for permanent installation of UV lights to protect healthcare facilities from the spread of tuberculosis [36]. Guidelines and studies like this may help the transit agency to develop standards for more permanent measures in the future. At this time, APTA *does not recommend* installing UV lights permanently on vehicles or in facilities.

4.6 Antimicrobial coverings

Antimicrobial films have been used in the health industry for the past several years. Similar to antimicrobial materials, the films are embedded with metallic materials that can kill bacteria that contact the surface. These films are typically applied to screens and other high-touch points within the healthcare facilities, and they have been applied to transit buses in Europe. These films have been proven effective against bacteria and viruses such as influenza, E. coli, MRSA and Staph [37].

The healthcare industry has also implemented germicidal paints, which also leverage metallic properties to neutralize bacteria on surfaces [38]. When the paint is exposed to light, it breaks down water vapor in the air to produce free radicals that attack bacteria. These paints can be applied to stainless steels and other metallic surfaces.

Both antimicrobial films and paints may provide benefits to transit agencies, but no test results have yet been published confirming their effectiveness against SARS-CoV-2. If proven effective, the films may be suitable for application on touch screens such as fare kiosks, and the paint could be applied to high-touch surfaces such as handrails. Unlike biocidal materials, however, the effectiveness of these materials lessens over time and would need to be reapplied periodically. Without published test results relating to SARS-CoV-2, or endorsement by the EPA or CDC, APTA *does not recommend* the use of these products at this time. Should an agency decide to use any of these antimicrobial products, however, it should select products that are formulated to kill viruses.

4.7 Pesticide distribution systems

In response to the Ebola outbreak in 2014, ambulance operators adopted disinfectant distribution systems. The Department of Homeland Security conducted a product review of these technologies in 2015 and identified that they offer the advantage of reducing human exposure while disinfecting vehicles [39]. The systems require distribution ports to be installed on the vehicles, and the decontamination system pumps disinfectant through the ports, which mists the pesticides on the vehicles' internal surfaces. These systems can be costly (roughly $50,000 per unit) and are not able to distribute disinfectant to areas of the vehicle that are blocked by obstruction. These devices are currently being used in transit systems in Prague and Italy and have been considered by several transit agencies in North America [40].

Should a transit agency choose to use these systems within its facilities or vehicles, the placement of the distribution ports should be carefully designed to provide sufficient coverage of disinfectants.

4.8 Sanitization provisions

Indian Railways has begun using a fumigation tunnel outside of its rail maintenance facility in Jagadhari to disinfect employees prior to their work shifts [41]. The fumigation tunnel sprays diluted hydrogen peroxide on employees. This approach has also been implemented in China, but it has not been tested in North America. Health officials around the world have been critical of this practice, and APTA *does not recommend* that transit agencies experiment with this approach.

4.9 Screening provisions

Chinese and Taiwanese public transportation operators have also begun using imaging technology in their facilities to identify passengers within the system that have a fever or are not wearing masks [40]. Furthermore, a Chinese bus manufacturer has integrated imaging technology on its new line of buses to identify passengers who are not wearing masks or have fevers and report the issue to the operator. These types of technologies have been met with criticism due to privacy concerns.

The CDC does recommend that transit agencies consider conducting temperature screenings for employees before they enter facilities, but it is emphasized that discretion and confidentiality of information about those who are believed to be sick must be maintained to meet legal requirements. Many U.S. transit agencies, such as GCRTA, MBTA, San Diego MTS, Houston METRO and Sacramento RT have begun these employee screenings at their facilities [42]. APTA's white paper APTA WP-SEM-016-20, "Developing a Pandemic Virus Service Restoration Checklist," provides further details on screening provisions that transit agencies can implement.

5. Damage to Equipment

As previously mentioned, transit agencies should complete a thorough review of all products used within their transit systems to reduce wear and damage caused to agency property due to cleaning and disinfection. During the pandemic many transit agencies have reported accelerated degradation of equipment and surfaces within their vehicles and facilities. Figure 1 shows surface degradation experienced by one bus operator due to pesticide disinfection, this type of damage is emblematic of the types of damage cleaning and disinfection has caused during the pandemic.

Figure 1 Surface degradation caused by pesticide disinfectants

6. Testing and Validation

NOTE: The best-practice recommendations provided in this section are not prescriptive but are intended to provide information about possible approaches to developing a cleaning and disinfecting program. Not every suggestion will be applicable to every pandemic outbreak, every community or every transit agency.

6.1 ATP quality check

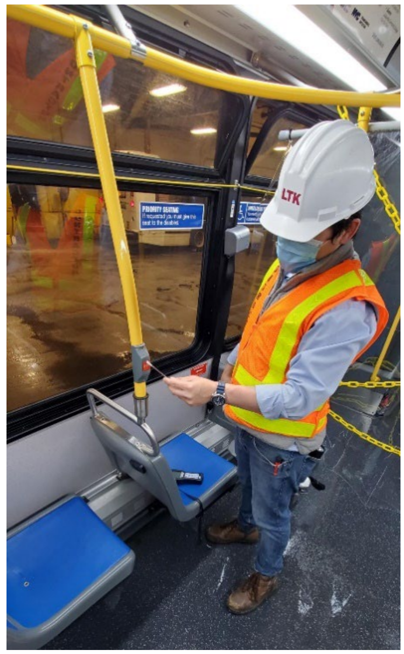
As discussed in Section 1.10.1, an ATP quality check can provide transit agencies with a relative check of cleanliness within a facility or vehicle. ATP testing *does not confirm* whether SARS-CoV-2 or other viruses are currently present on surfaces.

Prior to cleaning, disinfecting and applying antimicrobial shields to surfaces, a baseline test can be performed. This will be necessary for every environment sampled, as some non-microbial residue will be present on nearly any surface. It is recommended that ATP tests be performed on high-touch areas throughout the facilities and vehicles by swabbing areas as shown in **Figure 9**. Example test locations include the following:

- seating area surfaces
- handrails and stanchions
- operator areas
- counters
- tables
- fare collection equipment
- vehicle chime cords/stop requests

Readings are taken by swabbing an approximately 10-by-10 cm area using a crisscross pattern for even coverage, rotating the swab tip and applying sufficient pressure to maximize sample collection. When swabbing irregular areas, the procedure should be performed in a consistent manner, ensuring a large enough area is swabbed to collect a representative sample. Special care should be taken to not touch the swab tip and contaminate the results. ATP devices present results in relative light units (RLUs). RLUs may vary between manufacturers' systems and even among models. Lower RLU readings indicate cleaner surfaces. Multiple readings should be taken from each location, and the results should be averaged and recorded.

FIGURE 9
ATP Test Swab Being Performed on Bus Stanchion Post



Following cleaning and before disinfecting of the surfaces, the ATP testing should be repeated in the same locations. Comparing average ATP results before and after the cleaning process can provide the transit agency with a check of relative cleanliness of the surface. Transit agencies should aim to reduce the average RLU values following cleaning.

Specific ATP testing procedures should be based on manufacturers' recommendations.

6.2 Testing and Validation

Periodic laboratory surface testing for SARS-CoV-2 can be conducted to provide audits of a transit agency's disinfecting process. The most widely used lab testing process used for SARS-CoV-2 is a quantitative fluorescence-based reverse transcription polymerase chain reaction (RT-qPCR). The American Association of Clinical Chemistry (AACC) maintains a list of laboratories that can conduct SARS-CoV-2 testing [22]. Transit agencies should consult with laboratories regarding sample collection procedures. It should be noted that during a pandemic laboratory testing will likely be primarily dedicated to patient testing, and not surface testing, so delays in receiving results should be expected.

The EPA, ASTM and the Department of Homeland Security have identified MS2 and Phi-6 bacteriophages as surrogates that can be used to test the efficacy of mitigation approaches outside of a laboratory setting [2], [6]. Bacteriophages are viruses that only infects and harms bacteria, but are not dangerous to humans. The concept behind these surrogate tests is that the bacteriophages are similar in size and makeup to SARS-COV-2 and behave in similar manner when exposed to common controls. Surrogate testing of many common controls being implemented during the pandemic has been conducted on transit vehicles by various research groups such as Fresno State University [7]. In the Fresno State study mitigation measures such as filtration, UV, photocatalytic oxidation, and ionization were found to eliminate up to 99% of bacteriophages released into a transit bus. The Department of Homeland Security is currently conducting a test at NY MTA using inert particle tracers selected to represent SARS-COV-2 virus particle transmission through coughing or sneezing in a subway and bus vehicles [6]. The intent of the study is to evaluate methods for mitigating aerosolized virus particles in a transit environment.

Related APTA standards and reports

APTA WP-SEM-016-20, "Developing a Pandemic Virus Service Restoration Checklist"
APTA SS-S-SEM-005-09, Rev. 1, "Developing a Contagious Virus Response Plan"
"The COVID-19 Pandemic Public Transportation Responds: Safeguarding Riders and Employees"
Moving the Nation Through Crisis: Mobility Recovery & Restoration Task Force Report
Public Transit and the COVID-19 Pandemic: Global Research and Best Practices
Global Practices for Protecting Employees and Customer Health During the COVID-19 Pandemic

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Abbreviations and acronyms

µ	micron
AACC	American Association of Clinical Chemistry
AIHA	American Industrial Hygiene Association
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ATCC	American Type Culture Collection
ATP	adenosine triphosphate
CDC	Centers for Disease Control and Prevention
CFU	colony-forming unit
EPA	Environmental Protection Agency
GCRTA	Greater Cleveland Regional Transit Authority
HEPA	high-efficiency particulate air
HVAC	heating, ventilation, air conditioning
MARTA	Metropolitan Atlanta Rapid Transit Authority (Atlanta)
MBTA	Massachusetts Bay Transportation Authority
MERV	Minimum Efficiency Reporting Value
MRSA	methicillin-resistant Staphylococcus aureus
NATSA	North American Transportation Services Association
NCTD	North County Transit District
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
nm	nanometer

NYCTA New York City Transit Authority
OSHA Occupational Safety and Health Administration
PCO photocatalytic oxidation
PPE personal protective equipment
PTASP Public Transportation Agency Safety Plan
RLU relative light unit
RT-qPCR reverse transcription polymerase chain reaction
SDS safety data sheets
SEPTA Southeastern Pennsylvania Transportation Authority
SSPP System Safety Program Plan
TRB Transportation Research Board
TTC Toronto Transit Commission
UV ultraviolet
UVA ultraviolet A
UVB ultraviolet B
UVC ultraviolet C
VAC volts alternating current

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First published	---	—	—	—	6/22/20
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Note regarding appendixes

The appendixes included with this document are provided as information only. Transit agencies should conduct a thorough analysis of the information contained within the appendixes to determine applicability for their own operating environments. By providing this information, APTA does not endorse the use of these procedures or materials by any transit agency.

Appendix A: Generic procedures for disinfecting public transit vehicles

Cleaning and disinfecting are part of a broad approach to preventing infectious diseases on public transportation vehicles[1]. To help slow the spread of SARS-CoV-2,[2] the following steps may be taken to thoroughly clean and disinfect high-touch areas of public transportation vehicles.

All disinfecting staff should receive an orientation to this procedure, issuance of disinfecting and antimicrobial materials, equipment, and personal protective equipment.

Equipment

It is critical to use an effective disinfectant for killing this form of virus; therefore, use disinfectant chemicals approved by the EPA and listed on List N: Disinfectants for Use Against SARS-CoV-2. Additionally the EPA registration documents should be reviewed to determine what concentrations, dwell times and other provisions were used to achieve the required results. The pathogens tested against should also be evaluated to determine their similarity to SARS-CoV-2.

Personal protective equipment (PPE)

- All PPE as required for working in a transit vehicle in the operating environment including (if required) safety hardhats, vests, safety boots, flashlight, etc.
- Gloves and coveralls (Tyvek suit) should be compatible with the disinfectant and antimicrobial products being used.
- Gloves and coveralls should be removed carefully to avoid contamination of cleaning staff and the surrounding area. Be sure to clean hands after removing gloves.
- If coveralls are not available, aprons or work uniforms can be worn during cleaning and disinfecting. Reusable (washable) clothing should be laundered afterward. Laundering procedures should be carefully developed and adhered to during the program. Clean hands after handling dirty laundry.
- Gloves should be removed after cleaning an area occupied by people assumed to be ill. Clean hands immediately after gloves are removed.
- Cleaning staff should immediately report breaches in PPE, such as a tear in gloves or any other potential exposures to their supervisor.

Removing personal protective equipment

- **Gloves:** Grasp outside of glove with opposite gloved hand, peel off; hold removed glove in gloved hand; slide fingers of ungloved hand under remaining glove at wrist; peel off over first glove; discard gloves in waste container. See **Figure 13**.

1. FTA notes that a public transportation vehicle may include rail, bus, paratransit, maintenance or nonrevenue vehicles, 49 CFR Part 673.
2. Coronavirus Disease 2019 (COVID-19) is a respiratory disease caused by the SARS-CoV-2 virus. OSHA Pamphlet 3990-03 2020.

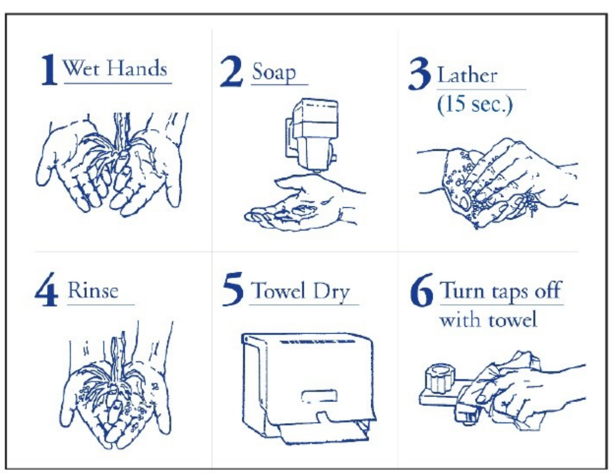
FIGURE 13
Glove Removal Procedure

- **Mask:** Remove by the elastic headband or earpieces; place in waste or decontamination container.
- **Goggles:** Remove handle by head band or earpieces; place in waste container.

Hand-cleaning procedure

Cleaning staff and others should clean hands often, including immediately after removing gloves and after contact with an ill person, by washing hands with soap and water for 20 seconds. If soap and water are not available and hands are not visibly dirty, an alcohol-based hand sanitizer that contains at least 60 percent alcohol may be used. However, if hands are visibly dirty, always wash hands with soap and water. See **Figure 14**.

FIGURE 14
Handwashing Procedure



Record-keeping requirements

- Prior to treatment, consult maintenance management for a list of transit vehicle numbers and track location where vehicles are to be treated are stored.
- During treatment, verify that each number and location is correct.
- After treatment, notify maintenance management of list of transit vehicle numbers that were treated, as well as any vehicles that were not treated.

Disposal

Material, equipment and personal protective equipment can be disposed of as regular waste. Ensure that trash bags are sealed and that proper PPE is used when filling trash bags.

Disinfection notes

- It is intended that treatment of the vehicles is performed after they have been thoroughly cleaned using the agency's approved cleaning procedures and products so that application surfaces are clean and free of dirt.
- Follow the steps in order.
- Use extreme caution when moving through the transit vehicle storage areas. Be aware of vehicle moves and inadvertent contact with the traction power system.

Disinfecting steps

1. Collect all materials and stage in a centralized location where work will be performed, ideally near utilities.
2. Prepare disinfection solution using the manufacturer's recommended dilution ratio, and add solution to disinfection sprayer. Sprayers must be labeled to avoid applying chemicals in wrong order and to prevent the accidental mixing of chemicals.
3. Before entering the first vehicle, confirm that the vehicle number and storage location match the assignment list from Maintenance Management.
4. Enter the vehicle to be cleaned, and turn on HVAC system and interior lights. When the HVAC or lights system automatically shut down, restart both systems.
5. Bring both solution sprayers, ample rags, and a trash bag (for rag disposal and containment) onto the vehicle.
6. Record vehicle number to be treated and verify that it matches the number assignment list.
7. When in the operator area, apply disinfection solution to all surfaces and allow it to rest for the manufacturer's required dwell time. Operator controls must be disinfected; however, do not oversaturate console controls such that the solution creates pools that can drain into the console electronics.
8. Enter passenger compartment area. Starting from one end and working in a clockwise (or counterclockwise) circle, liberally apply disinfection solution to all surfaces, including floors and ceilings. Do not directly spray HVAC outlet vents or HVAC return air intake.
9. Liberally apply disinfection solution to rag and manually wipe the HVAC outlet and return air vents.
10. After the manufacturer's required dwell time, using clean dry rags, wipe down and dry all passenger compartment touch surfaces (stations/handrails, seats, windows, intercoms, walls, doors, etc.). *Do not* wipe the ceiling, floor or heater grilles.
11. Move to the next vehicle and repeat steps 4 through 10 until all vehicles are complete.

Appendix B: Equipment and processes used by participating transit agencies

Agency	Disinfectants and Cleaning Materials	Purpose	Notes
Pierce Transit	• Virex II 256	• Used to disinfect vehicles.	
King County Metro	• Virex II 256 • EvaClean PURTABS with an electrostatic sprayer	• Used to disinfect coaches, light rail trains, streetcars, and nonrevenue vehicles. • Used to disinfect facilities.	Fond of PURTABS because it cleans more surface area with less fluid (due to the electrostatic spraying method vs. backpack sprayers).
Lane Transit District	• DS1 from Cintas • Safetec p.a.w.s. antimicrobial hand wipe towelettes	• Used to disinfect buses. • For operators to use.	
LA Metro	• Maintex Turbo Kill • Kik International Pure Bright bleach • Spartan NABC • Chemco Triple-2 Germicidal Cleaner • WAXIE 710 Multipurpose Disinfectant Cleaner • Maintex Claire Disinfectant Spray Q	• Used to disinfect facilities and vehicles throughout system.	
Omnitrans	• Vital Oxide • WAXIE 710 Multipurpose Disinfectant Cleaner • Germ Swipe	• Used to disinfect buses and relief cars. • Used for facilities in high touch areas and bathrooms. • Used to clean stops, station areas, benches, etc.	Supplied disinfectant wipes and hand sanitizers to coach operators and instruct them to wipe down the seat, steering wheel and high-touch areas on their buses before and after each shift they drive
Chatham Area Transit	• Vital Oxide • Lysol disinfectant products • Bleach (mop water)	• Used to disinfect vehicles. • Used to disinfect high-touch surfaces. • Used to disinfect floors and bathrooms.	Provided disinfectant wipes and hand sanitizer to employees.
Santa Clara Valley Transportation Authority	• Bleach dilution, ⅓ cup per gallon of water • Clorox Disinfecting Wipes	• Used to disinfect vehicles, stations and facilities. • Used in small spaces.	

Agency	Disinfectants and Cleaning Materials	Purpose	Notes
BART	• PURTABS with electrostatic sprayers • Alcohol solution (70 percent-plus alcohol) • Lysol spray • Neutra-Tec-64 • Bleach solution • TEC-CIDE 128 • Alcohol wipes (70 percent-plus alcohol) • Alcohol hand sanitizer dispensers • Comet cleanser • Surtecide • Ruhof Liquizime	• For end-of-line revenue vehicle disinfection, soon to use for stations, buildings, etc. • Disinfect nonrevenue vehicles, office surfaces, etc. • Revenue vehicle spot-cleaning (mainline response), stations, buildings. • All-purpose disinfectant used at stations, police, maintenance, etc. • Restrooms and mainline suicide response. • All-purpose disinfection. • To use between operators. • Public use within paid areas of stations and employee work locations. • All-purpose disinfectant. • All-purpose disinfectant. • Enzyme cleaner.	
Sacramento Regional Transit District	• Chlorine dioxide solution fog • Chlorine dioxide solution spray • Alcohol-based hand sanitizer • Alcohol-based sanitizer wipes • Clorox Fuzion	• Daily sanitizing of buses and LRVs and used to clean office and public areas. • Daily sanitizing of stations/stops. • Personal hand sanitation when soap and water are not available. • Sanitizing operators' area at change points. • Spot-disinfection of biohazards.	
Hillsborough County	• Vital Oxide	• Used to disinfect vehicles.	
Capital Metro Transportation Authority	• Vital Oxide wipes • Oxivir wipes • Zep Spirit II	• All products used to disinfect vehicles.	
Lee County Transit	• Benefect Botanical Disinfectant (spray and wipes) • Washlinc Virucide 3000 (spray and wipes) • Vital Oxide (fogging application)	• All products used to disinfect fleet.	
Central Midlands Regional Transit Authority	• Benefect Botanical Disinfectant	• Used to disinfect facilities and buses.	

Agency	Disinfectants and Cleaning Materials	Purpose	Notes
Port Authority of Allegheny County	• Bleach solution • Apter Disinfecting Cleaner • BactroKill Plus • SOP Green Klean chlorinated disinfecting tablets • Clorox Healthcare Bleach Germicidal Cleaner • Clorox Healthcare Hydrogen Peroxide Cleaner Disinfectant Wipes • Clorox Disinfecting Wipes • Vital Oxide • Purell Hand Sanitizer • p.a.w.s. individual hand sanitizing wipes • p.a.w.s. canister wipes • Odex Hand sanitizer	• All products used to disinfect facilities and vehicles.	
Metra	• Clorox Disinfecting Spray • Clorox Disinfecting Wipes • Lysol Disinfectant Spray • Lysol Deodorizing Disinfectant Cleaner • Lemon-D • PURTABS	• All products used to clean and disinfect stations, facilities and vehicles/coaches.	
Maryland Transit Administration (bus)	• Hand sanitizer (70 percent alcohol) • Vital Oxide • DBK • Oracle 1	• Distributed to coach operators and dispensers installed in facilities. • Used for cleaning buses (2-to-1 mix). • Used for cleaning buses. • Used for all-purpose sanitizing.	
Maryland Transit Administration (rail)	• Bac Stop 3A • Vital Oxide • Airx Spray-N-Go • Smart Touch Sanitizing • Oxivir wipes • Shockwave • Lysol Multi-Surface • Clorox	• All products used to disinfect rail facilities.	
Milwaukee County Transit System	• Virex • Spray bottles (10 percent bleach solution)	• Used to disinfect buses. • For bus operators to use to disinfect work areas.	
Golden Empire Transit District	• Betco 237 Multi-Range Sanibet	• Used to disinfect facilities and buses.	
Keolis Transit America	• RMC CP-64	• Used to disinfect facilities and vehicles.	

Agency	Disinfectants and Cleaning Materials	Purpose	Notes
Maryland Transit Administration	ACV Sanitizing contractor: • Shockwave, • Lysol Multi-Surface • Clorox MTA: • Bac Stop 3A • Vital Oxide • Airx Spray-N-Go • Smart Touch • Oxivir wipes	• Disinfecting for COVID-19	
Utah Transit Authority	• Quaternary ammonia • BleachSoap and water • EvaClean PURTABS applied with electrostatic sprayer	• Used to disinfect buses and rail vehicles.	Masks, face coverings provided for customers on all transit vehicles. Hand sanitizer dispensers provided on all transit vehicles. Lexan safety barrier for drivers on buses.
IndyGo	• Ultra-Tech Sterile Bright UV Light System • TB-Cide Quat disinfectant • Zep Lemonex III disinfectant • Emist EPIX360 electrostatic sprayer device	• Used in offices, locker rooms, buses and HVAC units. • Used on surfaces. • Used on grabbing surfaces	Masks, face coverings and gloves provided for all employees. Created a safety barrier for drivers made from Lexan. Hand sanitizer provided for operators and staff.
Sound Transit	• Virex II 256 • Avanflex	• Used on light rail vehicles. • Selected by contractor to disinfect heavy rail vehicles.	Supply disinfectant wipes and hand sanitizers to operators and instruct them to wipe down the seat, steering wheel and high touch areas on cabs after shifts.
Department of Transportation and Public Works (Miami-Dade Transit)	• 3M Quat Disinfectant Cleaner • Bioesque Botanical Disinfectant Solution • Dispatch disinfectant • Endurance • Husky 814 Quat Tuberculocidal disinfectant • Spartan hydrogen peroxide • Professional Lysol Heavy Duty Bathroom Cleaner • Selectrocide disinfectant • Spartan Xcelente • Virustat disinfectant • WEPAK bathroom disinfectant	• Used to disinfect buses and Metrorail stations, including railings, seats and restrooms.	

Agency	Disinfectants and Cleaning Materials	Purpose	Notes
North County Transit District	• Zep Spirit II • Re-Juv-Nal and Oxivir tb wipes • Triton Solution	• All products used to disinfect facilities and vehicles	Masks, Hand Sanitizer provided for customers if needed. Hand Sanitizers installed on all trains. Masks, Hand Sanitizer provided for all employees and contract staff. Installed temperature screeners at all facilties.

Appendix C: Advanced cleaning and disinfection processes used by participating agencies

Agency	Process used	Notes
BART	• UV-C surface lighting • Improved filtration (MERV-14) • Automated disinfecting robot • Antimicrobial coating • Decon 7 system • Biocidal surface	Filtration • Filters have been fully piloted on revenue vehicle; being implemented fleet-wide
Coast Mountain Bus Company	• Antimicrobial surfaces • Photocatalytic oxidation	Antimicrobial surfaces • Focus on copper materials in transit • Completed 1 month study with promising results • Starting yearlong study • All testing & experimental design completed in collaboration with local health authority • Material testing being conducted by UBC Material Engineering Photocatalytic oxidation • Air sampling report completed by occupational hygienist • Currently completing 1 month ATP surface sampling comparison against control bus

TriMet	• Hydrogen peroxide room fogging • UVC surface disinfection • Photocatalytic oxidation	Hydrogen Peroxide Room Fogging • Tested and implemented on bus fleet for daily disinfecting; now ~ monthly. Very High (6log) effectiveness rate. High initial cost, high operating costs, and time consuming. Significant training and procedure development is required to come up with an effective use. Noted evidence of potential long-term damage to some bus systems and components due to low pH (~3). • Tested and implemented into cleaning/disinfecting trains, buses, and facilities. Moderate initial purchase price, sprayers can be used with any pesticide/chemical. Simple operation/training process. Operating costs are low. UVC Surface Disinfection • Tested, but not implemented into operations. Process was shown to be effective against broad spectrum of pathogens. High initial purchase cost, glass bulbs have limited durability, limited by line of sight application of UVC light. Significant training and procedure development is required to come up with an effective use. Photocatalytic Oxidation • Agency performed a small test with inconclusive results. Vendors provided limited safety testing data and unregulated efficacy claims.