ED-287

GUIDANCE DOCUMENT ON AIRCRAFT CLEANING AND DISINFECTION

DECEMBER / 2020

FOREWORD

1. This document was developed jointly by EUROCAE Working Group 121 “Aircraft Cleaning” and RTCA SC-241 “Cockpit and Cabin Cleaning”, and was approved by the Council of EUROCAE on 23 December 2020.
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PURPOSE AND SCOPE

1.1 INTRODUCTION

This guidance document was developed as a response to the COVID-19 pandemic which has decimated the global aviation industry, and whose harmful effects are still being realized. The aviation industry recognizes that the development and adoption of guidance on the cleaning and disinfecting of aircraft can make positive contributions to the safety and wellbeing of aircraft occupants, and help increase confidence in air travel as a mode of transportation in response to current COVID-19 pandemic and possible future health events.

The target audience of this guidance document is aircraft operators and any third party contractors that provide cleaning, sanitation, and disinfection trained personnel, equipment, products, or services for aircraft interiors. Its purpose is to provide an internationally agreed upon set of principles for the proper cleaning, sanitization and disinfection of commercial aircraft and covers aircraft interiors such as passenger cabin, galleys, lavatories, crew rest areas, cargo compartments and the flight deck.

The guidance summarizes the aviation industry's current best practices, known technologies, and options for equipment for eliminating pathogenic germs (e.g. viruses, bacteria, etc.) in the air and on contact surfaces. This guidance provides valuable information for development of appropriate procedures and applicable training for cleaning personnel, maintenance personnel, and pilot and flight attendant crewmembers.

While this guidance covers aircraft cleaning and disinfection in general, in-flight disinfection practices will involve consideration of additional factors not explicitly addressed in this document.

NOTE: *Please refer to available industry guidance for the additionally information on in-flight cleaning and disinfection: US CDC Preventing Spread of Disease on Commercial Aircraft: Guidance for Cabin Crew Preventing Spread of Disease on Commercial Aircraft: Guidance for Cabin Crew, IATA Suspected Communicable Disease Guidelines for cabin crew.*

It is intended to be updated in the future as new and improved methods of eliminating pathogens are developed.

1.2 ASSUMPTIONS

This guidance document does not and is not intended to describe all of the measures to be used to kill pathogens in the air or on contact surfaces. Rather, it provides a description of additional measures which air carriers and labour can use in this regard as part of a layered approach to mitigate the harmful effects of a pandemic or seasonal viruses, such as influenza. It builds upon recommendations of the World Health Organization and individual State health and safety organizations to combat viruses, such as COVID-19 include physical distancing, wearing a mask, washing hands frequently, and not traveling when feeling ill.

1.3 DEFINITION OF TERMS

Airborne (diseases) means: The spread of an infectious agent caused by the dissemination of droplet nuclei (aerosols) that remain infectious when suspended in air over long distances and time (WHO to footnote);

Aerosol means: A colloidal suspension of particles dispersed in air or another gas;[1]

[1] Simpson J., et al, "*Oxford Dictionary Second Edition*", Oxford University Press, 30 March 1989

Aircraft means: Any machine that can derive support in the atmosphere from the reactions of the air other than the reactions against the earth's surface;[2]

Airport means: A complex of runways and buildings for the take-off, landing, and maintenance of civil registered aircraft with facilities for passengers;**Error! Bookmark not defined.**

Asymptomatic means: An infected person who does not develop symptoms

Bacteria means: Any various groups of unicellular micro-organisms lacking organelles and an organized nucleus some of which can cause disease;**Error! Bookmark not defined.**

Cabin means: A room or compartment in an aircraft for passengers or crew; **Error! Bookmark not defined.**

Cabin Crew means: A crew member who is qualified to perform, in the interest of safety of passengers, duties assigned by the operator or the pilot-in-command of the aircraft, but who shall not act as a flight crew member; **Error! Bookmark not defined.**

Cargo means: The goods or merchandise carried in a ship, aircraft, or vehicle; **Error! Bookmark not defined.**

Clean in this document means: The first step in the disinfectant process, and is defined by the removal of visible dirt or particles through mechanical action;[3]

Coronavirus means: A large family of viruses which may cause illness in animals or humans;[4]

Crew Member means: A person assigned by an operator to duty on an aircraft during a flight duty period;**Error! Bookmark not defined.**

Communicable disease means: An illness due to the transmission of a pathogen from an infected person, animal or inanimate source to a susceptible host, either directly or indirectly.

COVID-19/SARS-CoV-2 means: An infectious disease caused by a novel coronavirus; severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2);

Dangerous Goods means: Articles or substances which are capable of posing a risk to health, safety property or the environment and which are shown in the list of dangerous goods in the Technical Instructions or which are classified according to those instructions;**Error! Bookmark not defined.**

Disinfection means: The procedure whereby health measures are taken to control or kill infectious agents on a human or animal body, in or on affected parts of an aircraft, baggage, cargo, goods or containers, as required by direct exposure to chemical or physical agents;**Error! Bookmark not defined.** Disinfection procedures can be routine o r event-driven;

Disinfectant product means: A commercially produced chemical liquid or spray that destroys germs; **Error! Bookmark not defined.**

Dwell means: Continue for a time in a place, state or condition;[1]

Face Covering/Medical Mask means: Covering the mouth, nose and chin ensuring a barrier that limits the transition of pathogens. It should be worn, consistent with applicable public health guidelines and in accordance with ICAO Cart Take Off guidance. Face coverings refer to non-medical masks made from a variety of fabrics and excludes professional medical masks;

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2 International Civil Aviation Organization, "*Cabin Crew Safety Training Manual (Doc 10002)*", second edition, 2020 (URL: https://portal.icao.int/icao-net/ICAO%20Documents/10002_cons_en.pdf)

3 International Air Transport Association, "Aircraft cleaning and disinfection during and post pandemic", edition 1, 19 June 2020 (URL: https://www.iata.org/contentassets/5d42ffd2b6ee43a8963ee7876584de5a/aircraft-cleaning-guidance-covid.pdf)

4 World Health Organization, "WHO Q&A", [web site] URL: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/question-and-answers-hub/q-a-detail/q-a-coronaviruses [cited December 2020]

NOTE: *Industrial N95 masks are considered to be non-medical masks. Medical masks refer to professional medical masks worn by healthcare workers - also referred to as surgical masks or medical N95 respirators.*

Flight Crew Member means: A licensed crew member charged with duties essential to the operation of an aircraft during a flight duty period;**Error! Bookmark not defined.**

Flight Deck means: The part of an aircraft where the pilot or navigator perform their duties; **Error! Bookmark not defined.**

Galley means: The kitchen of an aircraft;**Error! Bookmark not defined.**

Health Screening means: A system of checking for the presence or absence of a disease;**Error! Bookmark not defined.**

Helicopter means: A type of aircraft without wings, obtaining lift and propulsion from horizontally revolving overhead blades or rotors;1

Ionization means: The process of producing ions as a result of solvation, heat or radiation;**Error! Bookmark not defined.**

Pathogen means: An agent causing disease;**Error! Bookmark not defined.**

Pandemic means: An epidemic occurring worldwide, or over a very large area, crossing international boundaries and usually affecting a large number of people;

Passenger means: A traveller in a public or private conveyance;

Personnel means: Any person performing cleaning and disinfection operations and/or any person involved in cleaning and disinfection process as identified by the company Risk Assessment;

Physical/Social Distancing means: Limiting the spread of COVID-19 or other diseases that is in consideration by keeping a distance from each other and avoid spending time in crowded places or groups;[5] Recommended distance is approximately 2 meters/6 feet or as required by the national health authorities.

Public Health means: Health services such as immunization, preventive medicine that are provided by a government and intended to improve the general health of citizens;**Error! Bookmark not defined.**

Quarantine means: Isolation imposed on persons or animals that have arrived from elsewhere or have been exposed to, and might spread, infectious disease;**Error! B ookmark not defined.**

Sanitize means: Make hygienic or thoroughly free from germs;**Error! Bookmark not d efined.**

Symptomatic means: A change in the physical or mental condition of a person, regarded as evidence of a disorder;**Error! Bookmark not defined.**

Thermal Disinfection means: Thermal disinfection relies on heat (dry or moist) that is applied at or above the recommended temperature to all parts of the it for the recommended time. The time needed to kill or disable organisms depends on the type of micro-organism and the disinfection procedure; [6]

1.4 ACRONYMS

ACI: Airport Council International ;

A4A: Airlines for America;

AHM: IATA Airport Handling Manual;

APU: Auxiliary power unit;

AOSHR: Aviation Occupational Safety and Health Regulations;

ASME: American Society of Mechanical Engineers;

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[5] World Health Organization, “COVID-19: physical distancing”, [web site] URL: https://www.who.int/westernpacific/emergencies/covid-19/information/physical-distancing [cited December 2020]

[6] Royal Melbourne Institute of Technology and Melbourne Technical College, “Cleaning and disinfecting equipment”, [web site] URL: https://www.dlsweb.rmit.edu.au/Toolbox/infection/content/lr_cleaningdisinequip/003_thermal.html [cited December 2020]

CAA: Civil Aviation Authority;
US **CDC**: Centres for Disease Control and Prevention;
US **DHS**: Department of Homeland Security;
US **DOE:** Department of Energy
US **DOL**: Department of Labour;
US **DOT**: Department of Transportation;
EASA: European Union Aviation Safety Agency;
ECDC: European Centre for Disease and Prevention and Control;
EFB: Electronic Flight Bag;
EPA: United States Environmental Protection Agency;
ECS: Aircraft Environmental Control System;
FAA STC: FAA Supplemental Type Certification;
FAA TC: FAA Type Certification;
FAA: Federal Aviation Administration;
GHS: Globally Harmonized System
GPU: Ground Power Unit;
GSE: Ground service equipment;
HEPA: High-efficiency particulate air;
HHS: Department of Health and Human Services;
IATA: International Air Transport Association;
ICAO: International Civil Aviation Organization;
IFE: In-flight Entertainment Unit;
IGOM: IATA Ground Operations Manual
IHR: International Health Regulations;
NIOSH: National Institute for Occupational Safety and Health;
NPBI: Needlepoint Bipolar Ionization;
NRC: National Research Council;
OEM: Original Equipment Manufacturer;
OSH: Occupational Safety and Health;
US OST: Office of the Secretary;
PPE: Personal Protective Equipment;
RNA: Ribonucleic Acid;
SDS: Safety Data Sheets;
SMS: Safety Management Systems;
SRA: Safety Risk Analysis;
STC: Supplemental Type Certificate;
TC: Type Certificate;
TCCA: Transport Canada Civil Aviation;
TOR: Terms of Reference;
UPK: Universal Protection Kit;
US: United States of America;
UV: Ultraviolet Light;
UVGI: Ultraviolet Germicidal Irradiation; and
WHO: World Health Organisation;

1.5 ROLES

The guidance in this document reflects one aspect of a multi-layered approach to support protecting travellers and workers from a communicable disease or other pathogen, and a decrease in the risk of transmission of any disease. A collaborative

approach between aircraft operators, civil aviation authorities, aircraft manufacturers, public health and environmental authorities, aircraft lessors (if applicable), suppliers, employee work groups, and some product manufacturers is required to support an effective response by:

1. evaluating the health hazard or pathogen;
2. developing strategies for combating or reducing the transmissibility of the pathogen such as by cleaning and disinfecting;
3. determining the procedures or products that are effective in killing the pathogen;
4. ensuring that the procedures or products selected do not result in an additional safety hazard to the aircraft components or structure of the aircraft;
5. ensuring that the application or use of the products do not cause any health hazards to those applying the products or other occupants of the aircraft environment that may be exposed to the product;
6. providing education and training to employees and contractors on the pathogen itself, specific occupational exposures to any procedures or products used to reduce or prevent the further spread of pathogens, in the aircraft environment including air and the aircraft surfaces and exposure information on any related hazards.
7. determining (assess/estimate) the implications and impact of the approach to the airline operations (e.g. impact on turnaround times, costs etc.).

While much of the burden of the items listed above will fall to the aircraft operator to develop the protocols and procedures for addressing any pandemic event, working with other organizations is imperative for success.

It is unrealistic to assume an aircraft operator will have the expertise related to various health hazards or pathogens. Therefore, evaluating the hazard requires the aircraft operators to utilize the guidance of official organizations such as the World Health Organization (WHO), the European Centre for Disease and Prevention and Control (ECDC), and the US Centres for Disease Control and Prevention (CDC). Communication with other stakeholders such as the International Air Transport Association (IATA), Airlines for America (A4A), or Airports Council International (ACI) Group can provide additional organization sources to help evaluate and develop strategies for mitigating any potential health hazard in air travel.

Much of the document below provides suggested guidance on the issue of developing strategies, determining procedures, and selecting products to limit infection and transmission of the pathogen via either surfaces or airborne. However, like understanding the pathogen, the aircraft operator needs to address the development of strategies and procedures with multiple stakeholders. In order to ensure that either the processes or products do not compromise or effect the functionality of the aircraft structure, system or components, the recommendations of the aircraft manufacturer should be followed. The aircraft environment is different than other work or recreational environments and, therefore, caution should be exercised when determining procedures or selecting products to ensure their suitability for aircraft use.

Creating the initial response to the health hazard also requires collaboration with the employee or contractor stakeholder representatives. Suggesting a practice or process that cannot be accomplished by those stakeholders does not support protecting public health. Likewise, as mentioned in the section on risk-based approaches the processes and products utilized must be continuously analysed and changes to the mitigation measures may be required based on any new risks that may not have been evident in the early processes of developing the procedures or selecting products. This process requires an active evaluation feedback loop.

1.6 FUTURE WORK AND CONSIDERATION

This guidance is considered by WG-121/SC-241 to be a “living” document to be updated in the future as circumstances and needs indicate. It is based on the best practices and technologies available, but these change over time. The COVID-19 pandemic has demonstrated that preparedness for future pandemics, and perpetual attention to cleanliness and disinfection are essential for the airline industry.

CHAPTER 2

CONSIDERATIONS FOR PRODUCTS AND APPLICATIONS

2.1 SAFETY RISK ASSESSMENT

The COVID-19 pandemic, which prompted the development of this document, will likely be different from diseases/pandemics of the future, which may require different products and methods to mitigate their transmission. Any new products or procedures to combat future pathogens or communicable diseases must begin with a Safety Risk Assessment (SRA) to evaluate a proposed response.

Safety Management Systems (SMS) are key to identifying, addressing, and reducing organizational and systemic risks. An established SMS as published by a governing regulatory agency or ICAO should be used. SMS is supported through traditional data collection as well as understanding the impacts of organizational culture and policies regarding safety. The goal of these programs is to identify active failures and inadequate defenses so that hazards can be contained while preventative measures can be reinforced. The SMS adds value to an organization's safety structure by identifying hazards and mitigating risks before they develop into full accidents. The programs are complex and require assessments of human factors and their relation to other workplace components. A successful SMS incorporates a collaborative effort between the organization, their regulator, labor organizations, manufacturers, and other stakeholders to build a robust and diverse team. The team's objective is to leverage data and knowledge to collectively build risk assessments and design systemic improvements and support a positive safety culture.

2.1.1 Tracking and Testing

The Safety Risk Assessment (SRA) process is a critical segment of SMS because it examines the individual factors that contribute to the overall system and reviews both the frequency and severity of undesired outcomes for mitigation. Safety risk assessments typically begin with the overall system analysis, followed by hazard identification. Each hazard should be analyzed by utilizing both qualitative and quantitative data, and assigned a value based on the likelihood and severity of the hazard. From this stage the team should determine the need for risk control development based on the results of their assessment and develop feasible mitigations. This stage should also include a plan to monitor and assess the mitigations for effectiveness, which fits into the Safety Assurance segment of SMS and is an integral part of the closed loop process. This would include inspection intervals to ensure no detrimental effects have occurred from either the original use or repeated use of any chemical or non-chemical process. Tracking and testing should include a venue for employee reporting.

2.1.2 Employee Reporting – Monitoring and Effectiveness

When conducting the SRA phase, a team of subject matter experts composed of stakeholders from all organizations and affected departments should include variables such as organizational culture, current workforce demographic, and human factors. This may affect how personnel interact when safety precautions such as Personal Protective Equipment (PPE) are utilized. Other inadvertent hazards brought on by the introduction of changed cleaning or disinfecting procedures should be considered in the risk assessment and could include, but are not limited to condensed turnaround time, sensitivities to chemicals, and other operational changes. Even if items are deemed as an acceptable risk, data and reports from the front line should be continuously gathered to ensure the risk stays at an acceptably low level. Additionally, the safety risk assessment should consider the local legislation and guidance from the regulator or health organizations for effective ways to mitigate known risks. This process for addressing and controlling risk is an industry standard for all aspects of the operation and supporting documents and guidance have been published by international agencies

such as ICAO. These supporting documents provide detailed information to build a successful SMS and conduct a thorough risk assessment.

2.2 OCCUPATIONAL SAFETY AND HEALTH

2.2.1 General

Occupational Health and Safety (OHS) measures should be implemented to protect personnel, including any inflight personnel, performing disinfection operations, so they understand and follow procedures to ensure the effectiveness of any cleaning or disinfecting products or processes. This would include proper personal protection including proper training and use of Personal Protective Equipment (PPE), understanding the risk of exposure to any specific pathogens as well as other risks associated with disease outbreak, epidemic or pandemic situations. It is also necessary to evaluate any adverse health effects of persons in the area of the disinfection process, or if the process could result in any residual substance that could be harmful to occupants.

As noted in the section above, workplace risks need to be assessed and mitigated in accordance with the company's Safety Management System (SMS) and/or Risk Management as well as all applicable legislations and health authorities' guidelines pertaining to disease outbreak, epidemic or pandemic situations. It is important to update company risk assessments and check systematically if all risks have been addressed and taken all the necessary measures to respond to disease outbreak, epidemic or pandemic situations.

During disease outbreak, epidemic or pandemic situations all personnel, not just those performing disinfection operations, can be exposed to various new risks such as the possibility of infection and illness.

2.2.2 Personnel Protection

Cleaning and disinfection should always be carried out by qualified personnel.

To protect personnel from the exposure to pathogens it might be necessary to implement a multilayered approach as suggested below. The level of protection should be risk assessed and evaluated on a case-by-case basis. The following list represents areas to be taken into consideration:

- Enhanced hygiene routines
- Physical distancing during job and breaks
- Limitation of exposure
- Personal Protection Equipment (PPE)
- Syndrome recognition, testing and health screening

For protection of personnel from risks associated with disinfection methods, e.g. the disinfectant being used, and the device being operated, please see section 3.2 Chemicals and section 3.3 Non-chemicals.

Relevant and effective PPE should be provided to all personnel performing disinfection operations to perform the job safely, to prevent contamination of other areas and other individuals, as well as to minimize occupational health and safety risks.

It is essential that PPE types and procedures for use by the aircraft personnel performing or overseeing disinfection operations are reviewed and amended based on the risk of exposure and the transmission dynamic of pathogens, regulatory requirements related to pandemic, changes in cleaning and disinfection methods, changes of chemicals used as per product manufactures safety data sheet recommendations and other changes from the previous procedures.

2.2.3 Education Related to Disease Outbreak, Epidemic or Pandemic Situations

Guidance should be provided to personnel on the preventive health measures to eliminate risk of exposures to pathogens such as:

- Hygienic behaviours such as physical distancing, hand hygiene, respiratory etiquette
- Proper use and proper disposal of PPE

- Avoidance of contact with people presenting any sickness to reduce or prevent the further spread of pathogens symptoms
- Seeking medical advice early if signs and symptoms develop and not reporting to work if sick
- Process to report concerns (e.g. feedback forms to improve process)
- Specific characteristics of the pathogen including symptoms and impacts,
- Outcomes of disease outbreak, epidemic or pandemic management
- Any regulatory requirements and any specific health guidance
- Any health/quarantine restrictions specific to the pathogen, including required paperwork implemented by a countries' immigration or health authority.

2.2.4 Training for Personnel

Personnel performing cleaning and disinfection operations should be competent to perform cleaning and disinfection tasks. Each person should be provided with initial training before starting the job and with recurrent training within the recurrence period as per regulatory requirements or as defined by the company. The training should be relevant to duties and tasks performed. Personnel providing cleaning and disinfection in the flight deck may be required to receive special training.

Additionally, personnel performing disinfection operations need to understand and apply disinfection processes and tasks that will ensure the effectiveness of the disinfecting products and procedures to reduce or prevent the further spread of pathogens, these may include:

- Disinfection methods, tasks and disinfection products as per aircraft operator instructions. These personnel may also require specialized hands-on training on the product or procedure especially if recommended by the product manufacturer or as noted by the air carrier's SRA.
- Use of the proper PPE to prevent contamination of other areas to minimize occupational health and safety risks to other personnel.
- Regulatory and airlines requirements related to disease outbreak, epidemic or pandemic as applicable.
- Event-driven and non-routine disinfection procedures see section 3.1.3 for additional information.

CHAPTER 3

PRODUCTS AND APPLICATIONS

3.1 GENERAL REQUIREMENTS

A multi-layered approach to mitigating infection may look different today than that of any future mitigation to combat a health hazard that may be transmissible in the aviation sector. Infection control and prevention requires a disruption of the transmission of a pathogen. Understanding the different routes of disease transmission is imperative for an informed, multi-layered approach to mitigate the health hazard. Transmission of pathogens can be by different routes: direct contact, fomite, aerosol (airborne), oral (ingestion), or vector-borne.

Understanding of the pathogen can help air carriers make an informed selection of disinfection products relevant to the pathogen and its transmission path while at the same time taking into consideration the unique environment of the aircraft. Just as important as selecting the correct product, the product or method chosen must not compromise, damage, or adversely affect the functionality of the aircraft structure, systems or components.

APPENDIX A lists the multiple documents used to develop this paper. Many of those documents used the terms “cleaning” and “disinfection” interchangeably. While this document’s focus is related to product selection and procedures relevant to disinfection, it is necessary to clarify the similarities and differences in the two important processes needed to break the pathogen transmission route.

3.1.1 Pathogens

In the past, aviation has needed to respond to health events like Severe Acute Respiratory Syndrome (SARS), Swine Influenza A (H1N1), and Zika virus. The current threat pathogen, SARS-CoV-2, has been identified as either present on surfaces or in aerosol form with both chemical and non-chemical processes being utilized against the SARS-CoV-2 virus. Different agencies in the US and internationally have evaluated the toxicity and health implications of chemicals in other work places. Non-chemical approaches, including solutions currently in use and emerging solutions in development, vary in terms of description (equipment, processes, procedures) and documented efficacy.

Sections 3.2 and 3.3 provide more detailed information on both chemical and non-chemical approaches to combatting pathogens, including evaluating their effectiveness and use in the aircraft.

Specific pathogen characteristics are beyond the scope of this guidance and those data should be made available through agreed sources, such as the US CDC, WHO and other resources. Likewise, a specific disinfectant product or procedure related to the effectiveness against a pathogen, or the specific disinfection frequency is beyond the scope of this guidance. As noted above, an SMS process should be followed for evaluating both chemical and non-chemical processes and disinfection frequencies based on the information gathered from the multiple sources including the respective health organizations, aircraft manufacturers and others as appropriate.

3.1.2 Cleaning

Cleaning is an important first step in the disinfection process. Cleaning as defined by IATA Ground Operation Manual (IGOM) and IATA notes that “Guidance for Aircraft cleaning and disinfection during and post pandemic", is the removal of visible dirt or particles through mechanical action. During a pandemic, general cleaning procedures are still a best practice, but may need to be conducted more frequently or the process adjusted. Cleaning and disinfection can be combined into one process if disinfectants are used during the cleaning. There are a number of considerations for an effective cleaning procedure.

- Cleaning personnel require proper training in correct cleaning procedures to safely clean without damaging the aircraft or harming themselves or others.
- Cleaning product selection should be subject to a safety risk assessment (SRA). Cleaning products and it should also be based on OEM recommendations, SAE standards and approved for the country of use (if applicable).
- Consideration should also be given to the methods appropriate for specific areas of the aircraft including the flight deck, galley, passenger cabin, lavatory, and cargo area. High-touch surfaces, such as door handles, armrests or interphones may require additional cleaning frequency or cleaning products as well as additional training.
- Appropriate personal protective equipment (PPE) for the environment and product used should be provided, and training on the proper use of PPE for cleaning staff should be provided.

3.1.3 Disinfection

The purpose of disinfection is to eliminate, reduce or prevent the further spread of pathogens in the aircraft environment. The disinfection process builds upon the assumption of a previously cleaned surface. This document provides guidance on two methods of disinfection, specifically chemical and non-chemical.

Disinfection schedules, techniques, and products may be different at each aircraft operator considering the operational circumstances and the duration of the disinfecting effects of the substance used. The procedure should be updated when new information becomes available.

Routine disinfection procedures are in place to prevent the spread of diseases and are standard procedures which are routinely performed in addition to the cleaning process.

Aircraft operators should review and update their disinfection matrices based on specific configurations of their aircraft types, continue monitoring the high contact surface areas in aircraft, and establish tasks that are necessary to be completed during a turnaround and layover based on the company's risk assessment. Based on the conducted risk assessment, each aircraft operator should implement policies and procedures for disinfection of aircraft.

Post-event (also known as event-driven) disinfection is performed after a specific event (e.g. after the transport of suspected or confirmed cases of communicable diseases onboard, spill of body fluids in the aircraft). This disinfection is not a frequent or standard practice and the requirements, methods, procedures as well as training for personnel will most likely differ. The World Health Organization (WHO) recommends that post-event disinfection procedures should meet the requirements under 3.2.4 and Annex F of Guide to Hygiene and Sanitation in Aviation, ICAO Annex 9 Chapter 2 (E) requirements. IATA Guidelines for aircraft cleaning and disinfection to manage affected aircraft carrying suspected communicable disease, also outlines general considerations. In case such event happens during the flight, inflight personnel may need to perform inflight disinfection.

It is important to ensure that the disinfection and other measures meet conditions required by applicable regulatory authorities to fulfil the following requirements:

- The disinfectants should be tested by a certified laboratory according to the specifications of the aircraft manufacturers for material compatibility tests, and not be corrosive or detrimental to aircraft components.
- The disinfectant should be applied according to the label instructions (e.g. concentration, method and contact time).
- Any contaminated items should be handled appropriately to mitigate the risk of transmission.

It is necessary to exercise caution in selecting disinfecting products or processes suitable for aircraft use. While being nationally approved for use, all disinfectants used should be aircraft-component compatible in that they must not have any negative effects on the individual parts or the structure of the aircraft. The products or processes should not have any negative effects on human health.

There are two types of disinfections:

- Chemical disinfection (e.g. wiping methods spraying, fogging…)
- Non-chemical disinfection (e.g. HEPA filters, UVC, ionization, ….)

Please see 3.2 for specific guidance for chemical products and 3.3 for non-chemical products.

3.1.3.1 Frequency of application of aircraft cleaning/disinfection substances or processes

The table in APPENDIX B that follows was designed to assess the usefulness, effectiveness and practicality of a multitude of products and systems proposed to the airlines for reducing the spread of a pathogen causing viruses as transmitted by passengers and crew aboard commercial transport aircraft. One of the distinct challenges is assessment of the duration of effectiveness of the products or systems, as it drives the frequency of application. As an example, some liquid disinfection products are highly effective until the product dries and/or evaporates, after which the treated surface is susceptible to re-contamination when touched or otherwise brought in fresh contact with the virus. Similarly, it is known that ultraviolet light can be effective, but generally only where the light directly falls.

During an outbreak of disease (prior to effective vaccine or fully reliable pre-boarding screening), the criteria for selection of a product will be effectiveness of the product at the time of application, health risks associated with the substance or treatment, and what, if any, residual effectiveness remains following application. Re-contamination of treated surfaces can occur at any time, however some products have demonstrated a residual anti-microbial action.

Primary references on anti-viral effectiveness are guidelines and substance list established on the country level (e.g. the US Centers for Disease Control (CDC) guidelines and US Environmental Protection Agency substance lists). Regarding health risks of products, reference must be made to the manufacturers' Safety Data Sheets (SDS), which are documents produced in alignment with the UN's Globally Harmonized System (GHS) of Classification and labelling of chemicals.

Substance or process application could adversely affect or degrade any flight safety-related items or aircraft systems therefore it is imperative to identify any effect and mitigate and address them through maintenance tasks, processes, training and other mitigation actions. Substance or process application could adversely affect airworthiness of aircraft structure and systems. It is imperative to identify any adverse effects and adequately address them through the implementation of maintenance tasks, training and other mitigating actions, such as occasional deep cleaning to remove any residual product. Aircraft operators should employ Safety Management System (SMS) practices to assess the adverse effects on the airplane of their cleaning/disinfection programs

There is no one answer to cleaning/disinfection application intervals as that will completely depend upon the means employed and the expected level of interaction between the occupants and the aircraft cabin. Different cabin areas may require different disinfection frequencies, if exposed to different level of interaction with occupants, and depending on the level of separation or isolation with other cabin areas. For example, for aircraft where the flight crew compartment is not separated from the passenger cabin, the frequency of preventive disinfection of the flight crew compartment should be the same as for the passenger cabin. Aircraft Operators must assess the minimum application effectivity based on OEMs, disinfectant product and equipment, manufacturer's data against more frequent application they may wish to publicize, designed to create good will and passenger confidence. There remains, however, a need to reliably evaluate application processes and products and mechanical systems using direct quality assessment. Measurement of effective application and confirmation of expected duration of effectiveness is not widely available and remains an outstanding challenge. Such means will be required to complete an SMS program.

Consideration for evaluation and frequency of application are listed in APPENDIX B.

The current threat pathogens have been identified as either present on surfaces or in aerosol form. Both chemical and non-chemical processes are being utilized against the

virus causing COVID-19 and other pathogens. While chemical effectiveness has been evaluated, the non-chemical approaches listed herein, while in use, are still under varying degrees of evaluation and development, as some validations have been carried out and further evaluations are in process. Both chemical and non-chemical processes have new solutions expected that will need evaluation. The next two sections provide more detailed information on both chemical and non-chemical approaches to combatting pathogens, including evaluating their effectiveness and use on the aircraft.

The specific pathogen characteristics are beyond the scope of this guidance and those data should be made available through agreed sources, such as the CDC in USA, WHO and other resources as needed, available. As noted above, an SMS process should be followed for evaluating both chemical and non-chemical processes.

3.2 CHEMICALS

3.2.1 Selection and Approval Process

The selection of chemicals to be used to mitigate a pathogen must be found to be safe for the aircraft, crew, passengers and employees, including personnel performing the aircraft disinfection. The specific identification of the chemicals to be used is outside the scope of this document, however the best practice for the use and application is within scope. Section 3.2.2 through 3.2.10 will assist in the process of making the decision if the chemical choice will be safe for all parts and efficacious.

Air carriers should use their Safety Management System in the selection of their chemical disinfectant and application process. An integral part of that selection process is to utilize information from organizations like the US CDC, the WHO, and other public health organizations in a collaborative approach to understanding the chemical's safety, effectiveness against a pathogen, and any health hazards of the chemical.

Certain agencies, like the US CDC or the European CDC (ECDC), have lists of disinfectant substances that can be efficient against certain pathogens. In the US, the Environmental Protection Agency (EPA) has published a list of products that are effective against COVID-19. Information from these organizations should be utilized in the selection process.

Given the nature of some chemicals, it is important to protect the health of the cleaning crew as well as other occupants with specific procedures for use of the chemicals. As example, ensuring that all occupants are off the aircraft before the chemical is used to ensure the other occupants are not incidentally exposed to the chemical.

During disinfection, any personnel not involved in conducting the actual disinfection should not enter the aircraft. If others need to enter the aircraft, they must also be protected to ensure they are not exposed to the disinfection chemicals. Sufficient time must be allowed for chemicals to dissipate prior to personnel, crew, or passengers entering the cabin. Ventilation of the aircraft may be necessary during the disinfection to reduce the build up of harmful aerosols in the aircraft, if recommended by the product manufacturer.

Coordination with the aircraft manufacturer or the component manufacturer is recommended when selecting a chemical and process for use in an aircraft to ensure the chemical does not have a negative effect upon the aircraft systems or structures, such as corrosion of metal components or degradation of any visual panels. Ensuring the safety of the aircraft components is critical to the selection process.

For purposes of this document, several distinct areas of concern were noted for their electronics and or furnishings. These are: passenger cabin, galleys, lavatories, crew rest areas, cargo compartments and the flight deck. Due to their unique features, an individual SRA for each section may be necessary.

Both APPENDIX B and APPENDIX C provide spreadsheets that can be used in the evaluation and selection process.

To ensure a continued effective response, after a chemical selection and application process has been selected it is imperative that there be a periodic SMS monitoring process, or feedback loop, to evaluate the chemical, the process, and any possible degradation of aircraft systems or components, or any health risks.

3.2.2 Effects on Aircraft Interiors and Components

The US Environmental Protection Agency (EPA) List N contains hundreds of disinfectant products for use against SARS-CoV-2, additionally other national agencies have created lists of chemicals for use, however, it is imperative to recognize that not all of these products are appropriate for use on commercial airplanes. Commercial aircraft cabins, galleys, flight decks, and cargo compartments are made of parts with many different materials, some based on very specific safety requirements. Special attention should be made to consider the effects of the different chemical solutions for cleaning and disinfecting these areas of the aircraft on the different material parts. Given the many different materials, different chemical disinfectants may be needed for different parts of the aircraft.

Liquid chemical solutions can be of concern if not applied properly. Only trained personnel should be cleaning and disinfecting the airplane. Problems can arise if liquid chemicals are over applied, allowed to pool, seep into crevices, or soak into porous surfaces, such as airplane seat fabric. Some chemical disinfectants are only intended to be used on hard surfaces. Operators should carefully follow the chemical solution manufacturer's recommendations for applications.

Frequent and repeated use of chemical solutions may cause undesired effects on some materials. These include material degradation, corrosion, discoloration, staining, or other visual defects on surfaces. Airlines performing multiple flights a day must be particularly attuned to long term impacts and accelerated deterioration of materials with frequent chemical disinfection.

Chemical disinfectants can also be highly flammable. Careful precaution should be taken to ensure these flammable disinfectants be kept away from heat, sparks, flames, and other sources of ignition and that proper ventilation of the aircraft is accomplished, if recommended by the product manufacturer. Operators should coordinate with the OEM for power on/off during the disinfection process, taking precautions to collar appropriate circuit breakers to avoid any unintentional re-application of power.

Operators should implement an inspection interval to ensure no detrimental effects have occurred from repeated use of chemical disinfectants. Depending on the aircraft part and use, operators should inspect for functionality, durability, material degradation, aesthetics, readability (for placards, etc.), and visibility (no scratches or crazing).

Specifically, for the flight deck, careful attention should be given to determine disinfectant compatibility with all parts and also the quantity of any liquid disinfectant used to disinfect. Given the critical flight controls located in the flight deck, operators need to avoid any over saturation, pooling, or moisture ingression on any surface. Also, ensure the flight deck is properly ventilated during the disinfection process.

3.2.3 Chemical Makeup

In addition to the need to ensure any chemicals selected do not pose a safety hazard to the aircraft, a challenge all operators may face are the regulations around chemical disinfectants. Different countries, governing regulatory agencies, and local governments may each have separate requirements and restrictions for use of specific chemical disinfectants. Operators should understand and follow these requirements and restrictions for every destination. Some chemical disinfectants may not be able to be procured in certain parts of the world due to restrictions, high demand, etc.

Operators should follow the chemical manufacturer's instructions for application of disinfectant product.

3.2.4 Efficacy

The chemical disinfectant products used must be safe for the aircraft, crew, passengers, and employees while at the same time effective. Individual operators should use the Safety Management System (SMS) to determine safety The distinct areas of concern were noted earlier due to their electronics and furnishings. A safe and effective chemical disinfectant must be identified for each area. Each area will need a Safety Risk Assessment (SRA) to protect the aircraft, crew, and employees. In addition to the standard members of the SRA, Subject Matter Experts (SME) should be added to the SRA. SMEs will be the best source for determining which chemicals meet Original

Equipment Manufacturer (OEM) recommendations, approved for the country of use, and most important, are safe and effective. Due to the dynamic nature of the environment and pathogens, the following SMEs should be added to the SRA.

- Original Equipment Manufacturer (OEM) to identify risks and threats (e.g. potential material or equipment damage) to the aircraft. In addition, make recommendations on products that are safe for the equipment.
- Industrial Hygienist to identify disinfectants that are approved and available in specific locales.
- A SME educated in microbiology or epidemiology for review of tests and efficacy.
- A dangerous goods SME related to any proposed shipping of the chemical disinfectants.

It is important to evaluate the disinfection process and safety of that process as part of the SRA feedback loop. The feedback should happen through testing and evaluation at set intervals as established by stakeholders and Subject Matter Experts (SME). The ongoing testing and evaluation of the four areas should be accomplished by the original SRA stakeholders and SMEs as noted above, that is the OEM, an industrial hygienist and a microbiology or epidemiologic SME.

For each of these areas the stakeholder and SMEs will evaluate the current chemical disinfectants used, the application process for those chemicals, and the effectiveness of those chemicals for the environment and current pathogens. The type and frequency of the testing should be determined and accomplished by the operator, regulator, third party, or a combination of those. This ongoing testing and evaluation process will monitor the effectivity of the disinfectant chemicals used in the four areas of the aircraft. The data from this testing and evaluation process will provide feedback for the SRA process.

3.2.5 Application Locations, Methods, Phases of Flight

For purposes of this document, several distinct areas were noted with respect to their unique electronics or furnishings. These are: passenger cabin, galleys, lavatories, crew rest areas, cargo compartments and the flight deck. Given the uniqueness of each area, the air carrier will need to take into consideration the needs of each area in relation to the number of occupants, the use of the area, the ability to disinfect the area, and any electronics or furnishings that could be damaged by the chemical disinfection. Additional information is provided in section 3.2.2 related to possible adverse effects on aircraft interiors and components.

The passenger cabin is the largest area in relation to the disinfection process. This area can also present the biggest challenge in relation to disinfection because of the high-volume of passengers that could potentially infect another passenger or crewmembers during the boarding process, the inflight segment, and the deplaning segment. Passenger movement during the inflight segment can also add to the potential exposure to an infected person/surfaces. A best practice for efficient disinfection involves utilizing different cleaning tools for different areas of the aircraft cabin to limit cross-contamination. Likewise starting from the either the front or the back, top to bottom of the area can reduce cross-contamination.

Other cabin areas include the chemical disinfection of the lavatory, both inside and out as it can be a high-touch area. Other areas that air carriers should take into consideration are disinfecting any crew rest compartments, including any bedding and furnishings. Consideration related to health hazards such as crew allergic reactions to chemicals need to be tracked to ensure an additional health hazard is not induced.

Aircraft galleys can be considered high-touch areas, especially for crewmembers. A unique aspect of galleys is that the area is considered a food preparation area, so a chemical that may be acceptable for cleaning overhead bins may not be acceptable for cleaning a galley countertop surface. Any chemical utilized on that surface may need to be reviewed for appropriateness related to food service. Like other areas care should be taken to ensure any chemical chosen for the area takes into consideration the electronic items such as ovens coffee makers, and, the possibility of chemical spray entering any food service compartments especially if food is contained in the

compartment. Concerns over possible food contamination may limit the chemical disinfection to pre- or post-flight application versus inflight application.

Cargo compartments, although not high touch environments, should be disinfected. Unique characteristics can include a limited size and limited ventilation, therefore proper application of chemical disinfectants should take into consideration those characteristics related to health risks. Use of flammable chemicals in poorly ventilated areas can also be a concern. Cargo compartments can contain unique safety design features such as smoke detectors, electronic door operation equipment and fire extinguisher discharge nozzles, so care should be taken to ensure that these systems are protected during the chemical application and ensure the safety benefits of these items is not compromised. As example, detectors resulting in spurious warnings because of mis-application. Cargo compartments are designed to only be utilized at the gate area during the boarding and deplaning process so any type of chemical used during flight is not applicable.

Flight decks, although separated from the passenger compartment, due to the frequency of crew transitions will require disinfection. This area of the aircraft is also the one that may require a broader list of chemical disinfectants because of the potential to damage the flight critical equipment. Careful evaluation of any chemical, including quantities, chemical types such as liquid (including spray) or wipes, need to be taken into consideration as they can each present a hazard if used incorrectly. The limited area of the flight deck can also present a hazard related to the time when disinfection occurs, specifically an inhalation hazard. Disinfection of the flight deck at the gate may permit adequate ventilation to minimize health risks. However, if disinfection of the flight deck is required during the flight, the disinfection process may need to be revised to take into consideration any inhalation concerns related to the selected chemical. The SRA process should be used to evaluate any additional hazards that may result from any proposed disinfection processes used during flight.

Air carriers should also take into consideration what type of personnel should be permitted to disinfect the flight deck to reduce the probability that aircraft switch settings are not disturbed during the disinfection process, including whether powering on/off aircraft systems is appropriate during the process. After the flight deck is disinfected the operator should verify the aircraft configuration to ensure all switches are in the correct positions, especially prior to turning back on if it was turned off. This is to avoid personal injury and damage to the aircraft.

3.2.6 Effects on Humans

Two considerations should be made when discussing the effects of chemicals on humans: acute and chronic (repeated) exposure. The primary reference documentation for acute chemical exposure to humans is the Safety Data Sheet (SDS), which is sometimes referred to by the now obsolete term Material Safety Data Sheet (MSDS), as specified in the United Nations' SDS standard called Globally Harmonized System of Classification and Labelling of Chemicals (GHS) revision 8 (2019). SDS provide critical information about the chemical's identity and ingredients, health and physical hazards, safe handling and storage procedures, emergency procedures and disposal considerations. Use of these documents is an essential starting point in the selection process especially for consideration of the chemical's effect on humans. When evaluating a chemical for possible use, the air carrier should consider any health hazards to the personnel actively applying the disinfectant, as well as any other persons that may be in the disinfected environment.

In the US, the two portions of the SDS paramount to the discussion on any effects on humans are Section 2, Hazard(s) identification, and Section 4, First Aid measures.

Section 2 Hazard Identification contains information on:

- Acute toxicity
- Skin corrosion/irritation
- Serious eye damage/eye irritation
- Respiratory or skin sensitization
- Germ cell mutagenicity
- Carcinogenicity

- Reproductive toxicity
- Specific target organ toxicity-single exposure
- Specific target organ toxicity-repeated exposures
- Aspiration hazard

Section 4 First Aid contains:

- Description of necessary measures, subdivided according to the different routes of exposure, i.e. inhalation, skin and eye contact and ingestion
- Most important symptoms/effects, acute and delayed
- Indication of immediate medical attention and special treatment needed, if necessary

The information located within the SDS is valuable for both emergency and chronic exposure details. Any employee or passenger should have access to the appropriate SDS of the chemical's used within the airplane. Education and training will be required for the employees and crew on proper protocols and reporting of adverse reactions as defined by section 3.2.9 and 3.2.10.

While much is known about acute exposure to most disinfecting and cleaning material, little is known about prolonged chronic exposure experiences in humans. Although the GHS SDS does address specific target organ toxicity-repeated exposures, few large-scale studies have been done on repeated human exposures on most products. Likewise, as pointed out by the WHO:

Safety of active ingredients for humans: In spite of best practices in the decontamination of environmental surfaces, human exposure to microbiocidal chemicals cannot be prevented altogether; this is particularly the case in confined spaces such as aircraft cabins. Therefore, formulations with the safest possible ingredients must be selected for such use, including proper ventilation as recommended by the product manufacturer.[2]

Also, the WHO explains:

Freedom from off-gassing and volatile organic chemicals (VOCs): Pungent odors are obviously undesirable, but addition of even strong scents/perfumes to disinfectants is now discouraged because of increasing numbers of individuals with multiple chemical allergies. Formulations that may release corrosive gases (e.g. chlorine) and VOCs must be avoided because of potential exposure of sensitive and vital components of the aircraft. Advice from the equipment manufacturer or aircraft operator's engineering department should be followed. Appropriate ventilation during cleaning is also important[2]

Furthermore, EASA goes on to point out:

3.4 Any residual disinfection substances that may be harmful to humans should be removed from the seat covers or any other surfaces. This is essential especially when using cleaning and disinfection products which can cause skin irritation or harm.[3]

These identified risks can be minimized by providing a feedback loop into the operator's SMS system. Ongoing monitoring and reporting should feed back into the SMS feedback loop. This will provide protection for the employees, crew, and passengers. There should be a designated point of contact for the employees and crew in the event of exposure or adverse effects. These exposures must be tracked for the SMS process.

Lastly and best stated within the WHO International Health Regulations in Article 22, to the regulation authorities in each state, health measures "shall be carried out so as to avoid injury and as far as possible discomfort to persons, or damage to the environment in a way which impacts on public health, or damage to baggage, cargo, containers, conveyances, goods or postal parcels"[1]

Reference:

1. World Health Organization, "International Health Regulation", second edition, Geneva, Switzerland, 2005 (URL: WHO International Health Regulation)
2. World Health Organization, "Guide to Hygiene and Sanitation in Aviation", third edition, Geneva, Switzerland, 2009 (URL:WHO Guide to Hygiene and Sanitation in Aviation)

3. Ionuț Panait C., “Guidance on aircraft cleaning and disinfection”, European Union Aviation Safety Agency, Issue 02, Cologne, Germany, 30 June 2020 (URL: EASA Guidance on aircraft cleaning and disinfection)

3.2.7 Frequency

The chemical disinfection frequency may vary from air carrier to air carrier based in part by their types of operation, their aircraft environments, and their destinations. Disinfection frequency is also dependent on the chemical chosen, the location of the disinfection, and operational circumstances. It is essential that air carriers conduct a safety risk assessment, coordinate with local health authorities and, possibly include the SMEs referenced in 3.2.4 to assess the chemical. It is important to note that any measures or frequencies utilized may need to be adjusted relative to any changes in the pathogen, or in relation to any regional conditions given the global nature of aviation. Frequency may also be determined by the location specifics, as example the passenger cabin, galleys, cargo compartments and the flight deck due to their unique electronics or furnishings in those various areas. Informed selections and correct use of products should support the determined frequency schedule.

3.2.8 Relevant PPE use and limitations

Personal Protective Equipment (PPE) is worn to minimize exposure to workplace hazards. PPE may include, but is not limited to, items such as face coverings, gloves, safety glasses or shoes, respirators, coveralls or body suits. Chemicals in general can create a need for the use of PPE, making it more relevant to ensure protection of personnel assigned the task of apply chemical disinfectants in the aircraft environment. Air carriers or the contract service provider should ensure personnel who will be working with the selected chemicals, should be provided the appropriate PPE based on the chemical hazards. Although not recommended, if others need to enter the aircraft during the actual disinfection process, they must also be provided the appropriate PPE for the specific chemical hazard. Employees who shall be assigned roles for use of chemical must understand:

1. The purpose of each PPE item to be used
2. The use of correct PPE item(s) for each function specified
3. The proper selection, fit, and use, including donning and doffing as necessary, of each PPE item.

NOTE: *It is recommended when appropriate:*

1. *Disposable gloves that are recommended by the manufacturer of the chemical should be worn.*
2. *Disposable gowns should be worn while disinfecting the cabin and lavatories.*
3. *If splashing is possible, eye protection, such as a face shield or goggles and facemask may be required according to the manufacturer’s label.*

4. Other personal protective strategies e.g., bio-safety measures that must be applied during the application phase
5. Useful life of PPE, maintenance & care of PPE (if applicable) and appropriate disposal methods
6. Limitations of PPE
7. Risk, and hazards for not using PPE, or improper use, while working with specific chemicals
8. Process for reporting any breaches or concerns with selected PPE

3.2.9 Training requirements – Chemical Specific

Air carriers should provide training to personnel related to the chemicals selected for use in the aircraft. In addition to the training for all personnel, those employees specifically tasked with performing chemical disinfection, either on the ground or during the flight, should be provided an additional specialized training either by the air carrier or the contract service provider on exposure control procedures in addition to being

provided appropriate PPE. The correct application process, properties, risk exposures and hazards of the selected chemical should be part of the training. Inflight disinfection may need to take into consider additional aspects and provide more details on the specific tasks for inflight personnel. Employees who shall be assigned roles for use of chemical must understand:

1. Authorized chemical products to be used based on each jurisdiction or regulator
2. Recommendation of aircraft manufacturer regarding any new chemical composition introduced
3. Recommendation of chemical product manufacturer's instructions to ensure that the proper application, ventilation and personal protection equipment is used
4. Chemical composition type and use of the chemical products
    - Chemical composition and effects of product used on aircraft
    - Instruction of use e.g.; Mixing ratios
    - Understanding of the Safety Data Sheets (SDS) for the products used
    - PPEs required for products used
5. Application methods and effective contact time in different areas of the aircraft e.g., Flight deck, cabin, cargo holds/compartments

NOTE: *Use of chemicals in the flight deck must be approved by and supervised as per airline requirements. Effects on contact with aircraft electrical wiring should also be known and avoided where possible.*

6. Compatibility with different chemical or with non-chemical methods
7. Hazards and risks associated with the use of the products on personnel health and aircraft
8. Safe storage, hazards of storage, and disposal methods
9. Reporting channels in case of any incidents or accidents with use of the chemical

3.2.10 SRA for Chemicals

The SMS process is a closed feedback loop that needs to be ongoing and reviewed. A minimum standard must be set that is scalable to address the emergent threat of pathogens. Furthermore, evaluation of the process must be completed periodically and increased when a known threat has been identified. Monitoring of the aircraft needs to be established for threats of degradation of systems and potential for safety risks. Employees and crews will require a reporting system to monitor their health and exposure complications.

It is recommended that the SRA committee be included in the monitoring process as the chemical application, process, and choice may need to be changed over time.

3.3 NON-CHEMICAL DISINFECTION METHODS

Generally, the non-chemical disinfection methods, solutions include portable devices and in-line installation devices which will require FAA supplemental type certification. These devices and processes are either in current use, in development, emerging technology, or an application of existing technology. There will likely be other processes and or solutions developed in the future. "Current use" could mean processes approved by aviation safety regulators including effectivity or approved as no hazard and not reviewed or approved by aviation safety regulators for effectivity (i.e. US FAA, EASA and those states that utilize reciprocity with the aviation safety regulators).

One difference from chemical disinfectant solutions is that non-chemical processes may include installed devices requiring a different review and/or certification process. Generally aviation safety regulators like the FAA or EASA approve the part or installation as a safe, or non-hazardous, component of the aircraft. These authorities are not the relevant agency for evaluating the effectivity of the disinfection process in relation to a pathogen.

Examples of non-chemical disinfection methods are:

- HEPA Air Filtration
- Ionization

- Ultraviolet
- Thermal

3.3.1 Selection and Approval Process

- Applicable to all currently identified non-chemical processes in this guidance and listed in section 3.3.2, and other processes as may be agreed as non-chemical processes.
- Intended use, within the interior of an aircraft, of non-chemical processes to eliminate, neutralize surface and, or aerosol COVID-19 virus and other existing, known specified pathogens and scalable for pandemic responses.
- Non-chemical processes are applicable to all aircraft pressurized spaces.
- For each device, process, if an aviation regulator approved device, OR NOT, an evaluation process following an agreed, nominal safety management systems (SMS), shall be employed, identifying the hazards, and analyzing, assessing, and controlling risk.
    - A key characteristic, differentiator is the specific process used in the presence of passengers, ground crew, flight crew or the process used when passenger, ground crew, flight crew are not present, and the SMS process shall include consideration, evaluation accommodation for this differentiation.
- As a part of a suggested nominal SMS, the application of a Safety Risk Analysis (SRA) process should address intended use specificity regarding interaction with pathogens, including minimum performance expectations, scalable for pandemic responses.
    - Recommended minimum SRA participants:
        - Applicable aircraft OEM and, or device OEM (preferably, both OEMs)
        - Aviation regulator, if applicable
        - Industrial hygienist, or equivalent
        - Subject matter experts, as needed
        - Operator (or representative), as applicable
    - Review & recommendations regarding regulator documentation shall be undertaken.
        - If approval documents in existence, provide and/or referenced.
        - Review device OEM supporting documentation, qualifications, testing.
    - Review approval requirements with applicable aviation regulator to determine if regulatory approval required and process.
- Specifically, a nominal SMS process shall address the following issues, providing guidance to meet objectives as determined in the nominal SMS.
    - Effectivity
        - Per the nominal SMS process, non-chemical processes shall demonstrate that through the proper operation and application of the process, the process eliminates, neutralizes the stated, intended targeted pathogens and per recommendation of the SRA.
        - Review and reference testing documentation of independent testing and device OEM testing.
        - Determine process and periodic review feedback loop for continuous effectivity.
    - Application locations / methods / phases of flight
    - Effects on aircraft interiors / components
    - Effects on humans
    - Other Safety considerations

- Frequency
- Training requirements
- Use of non-chemical process, devices shall be same as determined by aviation regulator, and as required.
- Supplemental training, if required in consideration of intended use in pathogen elimination, neutralization, shall be determined through the agreed nominal SMS process and implemented by the device or aircraft OEM.

3.3.2 Devices (Products, including air filtration)

- Non-chemical processes and associated devices identified in current use or in development.
  - Aircraft Environmental Control System (ECS)/ HEPA Filters & Related
  - Ionization
  - Ultraviolet
  - Thermal
  - Other devices as may be identified
- Three of the four identified non-chemical processes, ECS, ionization and UV, are currently in use and as such have reference data to be used in the SMS process. Here is brief discussion on each of the three in-use systems, with references to supporting data.

3.3.2.1 Aircraft Environmental Control System (ECS)/ HEPA Filters & Related

The ECS on civil aircraft is part of an aircraft type certification and as such has been approved by the regulator. This is airworthiness and does not necessarily mean the process is “approved” as effective for disinfection, neutralization and, or elimination of pathogens. The regulator approved documentation will or will not address the pathogen issues, such as effectivity, and may include effects on humans, for example. A best practice is to check with the aircraft or system OEM with regard to regulatory approval details, if there are any.

Most turbojet aircraft and some turboprop powered aircraft have some type of environmental control system that uses a mixture of engine bleed air and ambient air for airflow. HEPA filters are utilized on these aircraft and are capable of eliminating pathogens through the filtration process of airflow from the ECS. These ECS are normally approved as part of the aircraft Type Certificate (TC) by FAA, EASA and other aviation regulatory organizations.

High-efficiency particulate air (HEPA), also known as high-efficiency particulate absorbing and high-efficiency particulate arrestance, is an efficiency standard of air filters. Filters meeting the HEPA standard must satisfy certain levels of efficiency. Common standards require that a HEPA air filter must remove—from the air that passes through—at least 99.95% (European Standard) or 99.97% (ASME, US DOE) of particles whose diameter is equal to 0.3 μm; with the filtration efficiency increasing for particle diameters both less than and greater than 0.3 μm.

The effectivity of HEPA filters is dependent on factors such as filter rating, airflow volume, airflow patterns, and how often the filters are changed.

Here is a listing of links to online information and reference documents regarding ECS and HEPA filtration that may be considered as a part of the SMS process for ECS:

- Federal Aviation Administration Regulations, 14 C.F.R. § 25.831(a); European Union Aviation Safety Agency, Certification Specifications, CS-25.831(a)2.
- ASHRAE 62.2-20163 (American Society of Heating, Refrigeration and Air Conditioning Engineers)

  American Society for Healthcare Engineering – Hospital HEPA usage in “protective environment" rooms https://www.ashe.org/compliance/ec_02_05_01/01/airfiltration/
- The Airliner Cabin Environment and the Health of Passengers and Crew

- National Research Council (US) Committee on Air Quality in Passenger Cabins of Commercial Aircraft. Washington (DC): National Academies Press (US); 2002

3.3.2.2 Ionization

Ionization in-line aircraft installation requires STC certification. Ionization also can be installed on ground air supply equipment.

In general ionization can produce ozone, the concentration and amount dependent on a number of variables. As such, ozone presence testing should be a part of the SMS process.

One ionization purification system process is currently available for use on aircraft. The device is approved by the US FAA and EASA for installation and operation on aircraft through the Supplemental Type Certificate (STC) process. The STC approvals are NOT efficacy approvals against pathogens. Ionization devices are installed on a wide range of aircraft including many commercial air transport and business jet aircraft.

Following is general information regarding ionization.

- Ionization eliminates pathogens, throughout the aircraft, by electronically creating positive (H+) and negative (OH-) ions from hydrogen and oxygen atoms in the water vapor present in the air. Pathogens infect a host by binding to sites on the cell membrane. Viruses expelled from a person through mucus or saliva are airborne aerosol form. Ionization works by leveraging an electronic charge to create a high concentration of positive and negative ions. These ions travel through the air continuously binding to particles, which sets in motion a process of particle combination. As these particles become larger, they are eliminated from the air.
- Additionally, positive and negative ions have microbicidal effects on all pathogens, rendering the COVID-19 virus non-infectious, while neutralizing and removing other viruses, allergens, contaminates and even mold spores. The ions produce a natural reaction on the cell membrane of all pathogens so that they cannot reproduce and die.

Here is a listing of reference documents that should be considered as a part of the SMS process involving ionization (NPBI) processes accessible at Aviation Clean Air online, www.aviationcleanair.com .

Tests for the Component's Ability to Neutralize Bacteria

- SARS-CoV-2 Neutralization by Needlepoint Bipolar Ionization by Innovative Bioanalysis
- Efficacy of a Bipolar Ionization System - (C. difficile) by EMSL Analytical, Inc.
- Efficacy of a Bipolar Ionization System - (ECOLI) by EMSL Analytical, Inc_
- Efficacy of a Bipolar Ionization System - (MRSA) by EMSL Analytical, Inc_
- Efficacy of a Bipolar Ionization System - (TB) by EMSL Analytical, Inc_
- Efficacy of a Bipolar Ionization System - (Reduction of L. Pneumophila) by EMSL Analytical, Inc_
- Ozone Emissions Testing by Underwriter's Laboratories (UL)

3.3.2.3 Ultraviolet

Ultraviolet (UV) treatment is an example of a process that is in current use by at least two major airlines, maybe more. A best practice guidance would be to refer to the aircraft and system OEM for detailed information and secure regulatory approval details, if available.

Ultraviolet light is the portion of the electromagnetic spectrum between 100 and 400 nm. It is divided into the vacuum-UV region below 200 nm, the UV-C region between 200 and 280 nm, and the UV-B and UV-A regions at higher wavelengths. The vacuum-UV region is so called because at these wavelengths oxygen from the air begins to absorb some of the light, limiting transmission and generating ozone. The UV-C region is most commonly used for germicidal treatment, since the peak wavelength for germicidal action is at 264 nm. Some germicidal activity remains in the UV-B and UV-A regions, and even with visible light, but much higher doses are required.

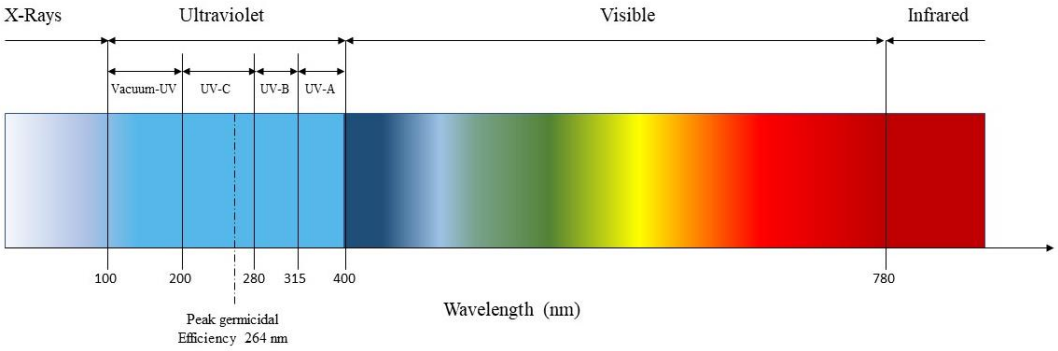

FIGURE 3-1: THE SPECTRUM OF LIGHT

3.3.2.3.1 Selection & approval process

Use of ultraviolet light for germicidal treatment, while widespread in hospitals and other settings, has only recently been considered for aircraft. Germicidal treatment of air using UV is well known for use in buildings[7], and has now begun to be used in commercial aircraft. Treatment of surfaces using ultraviolet light is rapidly gaining acceptance and is useful in treating surfaces that are touched by passengers or crew in the cabin, lavatories, galley or flight deck. When UV treatment is completed while the aircraft is on the ground and no passengers are present, certification by airworthiness authorities may not be needed. Local and regional laws and regulations should be reviewed. These rules will include provisions to ensure electrical safety and the safety of personnel using the equipment.

3.3.2.3.2 Products

Ultraviolet germicidal products for aircraft use include both hand-held wands or lamps, and larger systems on wheels. Handheld systems are lightweight and can be used in tight spaces where the larger systems will not fit. Typically, the lamps are lower in intensity, so they must be held closer to the surfaces to be disinfected and/or used to irradiate the surfaces for a longer period of time. The angle between the surface to be treated and the lamp focus direction is also important. Operator training and diligence is very important with hand-held units, since holding the lamps too far from the surfaces or using them too quickly will result in inadequate treatment. As a result, the SMS approval for handheld devices to be used should specify the distance and exposure time for surfaces. UV systems mounted on wheels are larger and heavier than the hand-held units. Frequently equipped with a rechargeable battery, they can move down the aisle of an aircraft cabin, disinfecting all surfaces exposed to the UV light. Because of the higher light intensity, they can be used more rapidly than a hand-held system, and because of the fixed geometry, they expose surfaces in a reproducible way. The UV dose will be determined by the light intensity (a function of the distance between the lamp and the surface) and the speed with which the device is moved through the cabin. The UV system can be operated by a single individual, appropriately protected to avoid UV light exposure, or robotic systems which avoid the risk of human exposure. The SMS should specify the rate to be used, and further directions to ensure that all necessary touchpoints will receive an adequate dose.

UV devices can also vary in the wavelength of the light used. The most common is 254 nm light, which has commonly been used in hospital and other applications. These devices generally use mercury vapor lamps similar to fluorescent lamps. Pulsed xenon lamps provide a broader spectrum of UV light, including the UV-C region. UV-LED lights can also be used and are significantly smaller, with wavelengths from 280 nm to 400 nm. “Far-UV” lamps with a wavelength of 222 nm have recently been proposed and use krypton chloride excimer lamps. The efficacy of these different wavelengths will be

[7] ASHRAE, “*Ultraviolet Air and Surface Treatment*” 2019 ASHRAE Handbook, Chapter 62.

discussed below. Some lamps emit multiple wavelengths of light. If emission occurs below 200 nm, there is potential for ozone to be generated.

3.3.2.3.3 Efficacy

Properly applied, Ultraviolet Germicidal Irradiation (UVGI) has been found to reduce pathogens - including tested bacteria and viruses - on multiple surfaces and in multiple environments.[8] [9] [10] UV treatment can be performed on surfaces, in which case the applied intensity and treatment time are easily measured, or on a volume of air. In the latter case, the intensity will change with the distance from the lamps, and the residence time of the microorganisms in the irradiated zone will depend on the air velocity. Reference 12 (Malayeri et al) has a very complete compilation of the required dose to disinfect various microorganisms.

The reduction in live organisms on a surface or in the air is a function of the dose or fluence of ultraviolet light, and the micro-organism specific and wavelength specific rate constant. Dose (fluence) is defined as the intensity of UV light at the surface multiplied by the irradiation time. Typical units for intensity are mW/cm^2 and typical units for dose (fluence) are mJ/cm^2. The relationship between dose and fractional reduction is expressed [11] in EQUATION **3-1**, where K is the rate constant, H_0 is the dose and D is the fractional reduction. Increasing the intensity or increasing the exposure time increases the % reduction.

$$\boldsymbol{H_0 = \frac{-\ln(1 - D)}{K}}$$

EQUATION 3-1: RELATIONSHIP BETWEEN DOSE AND FRACTIONAL REDUCTION

The referenced materials indicate that, properly applied, UVGI may reduce viruses with organic structures (single strand RNA) such as SARS-CoV and MERS-CoV at levels as high as 90.0% - 99.999% when irradiated at specified doses.[12] UVGI has been used to inactivate viruses in hospitals and other critical public and military environments for years.[13] When disinfection is event-driven or concerns group 4 pathogens, UV treatment should be replaced or supplemented by chemical cleaning by companies certified for this task e.g. ebola, human, animal liquids on board, death on board, etc.

In addition to UV-C (254 nm), other wavelengths have been used. The relative germicidal efficiency vs. wavelength is well known[14], and reaches a peak at 264 nm. Scientific studies indicate that 405 nm, which corresponds to UV-A light, may be effective in reducing certain bacteria but are not conclusive with regard to its ability to inactivate certain viruses. The referenced studies found no effectiveness against viruses in some cases, and potential effectiveness against viruses only when

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8 Malayeri, A., et al., "*Fluence (UV Dose) Required to Achieve Incremental Log Inactivation of Bacteria, Protozoa, Viruses and Algae*", September 2016

9 Chun-Chieh T., et al., "*Inactivation of Viruses on Surfaces by Ultraviolet Germicidal Irradiation*", Journal of Occupational and Environmental Hygiene, 2007

10 Lore, M. et al., "*Effectiveness of Three Decontamination Treatments against Influenza Virus Applied to Filtering Facepiece Respirators Ann. Occup. Hyg*.", Vol. 56, No. 1, pp. 92–101., 22 August 2011

11 Cabaj A., et al., "*Ultraviolet Air Disinfection*" ,CIE Technical Report 155, Commission Internationale de l'Eclairage, Vienna, Austria, 2003

12 Bedell, K. et al., "*Efficacy of an Automated Multiple Emitter Whole-Room Ultraviolet-C Disinfection System Against Coronaviruses MHV and MERS-CoV*." Infection Control & Hospital Epidemiology, vol. 37, no. 5., May 2016

13 Sagripanti, J, et. al., "*Sensitivity to ultraviolet radiation of Lassa, vaccinia, and Ebola viruses dried on surfaces"*, Arch Virol, 156:489–494, 2011

14 ASHRAE, "*Ultraviolet air and surface treatment*", Chapter 62 p. 62.3, Figure 3, Atlanta, GA, 2019.

suspended in specific organic media in other cases. The authors conclude that further work should be carried out to establish the effects of 405nm light.[15] [16]

'Far-UVC' describes the use of light with 200-222nm wavelength. There has been recent testing which has suggested that Far-UVC has anti-microbial properties.[17] [18] [19]The benefit of using this wavelength has been proposed by these authors to be that it can be used in an occupied space without harm to personnel. Safe limits for human exposure are discussed in section 3.3.2.3.6.

3.3.2.3.4 Application Locations/Methods/Phases of Flight

UV treatment can be completed while the aircraft is on the ground and does not contain passengers. In the future, UV treatment technologies for use during flight may be developed. Since UV leaves no residual disinfecting residue, it is only effective to disinfect surfaces at the time of exposure. It may be performed in between flights as part of a normal cleaning cycle, or more intense cleaning may be performed when more time is available or when there is concern that an infected person may have been present in the aircraft. A UV dose, as described above, should be selected with the assistance of the SMS, and should meet or exceed the dosage on surfaces including seats, seat belts, arm rests, trays, in-flight entertainment screens and other displays, overhead bins and passenger service units. The SMS in this case should include representation from the original equipment manufacturer, the UV equipment provider, and a hygiene expert cognizant of local and regional standards. With hand-held units, this requires that the operator hold the lamps an appropriate distance from the surface for an appropriate length of time, according to the manufacturer's directives. For larger units on wheels, the manufacturer's recommendations for the rate of travel with the device should be reviewed. One product manufacturer has suggested 30 rows/minute pace down the aisle of a commercial aircraft for a rapid cleaning, and a 10 rows/minute pace for in depth treatment. In contrast to chemical disinfection, there is no need for UV treatment to ventilate the disinfected location prior to entry of personnel.

3.3.2.3.5 Effects on Aircraft Interiors/Components

In order for UV-C light to affect the properties of a material, two things must happen: (1) absorption of the light, and (2) chemical reaction[20]. Many materials that are transparent to visible light are opaque to UV light, limiting penetration of the light deep into the material. Other materials, like leather or other fabric materials commonly used for aircraft seating, are opaque because they scatter the light or because of materials blended into the polymers from which they are made. For these materials, the effect of UV-C light will be only on the exposed surface. Once light absorption has occurred, surfaces exposed to air can oxidize, with possible impact on their strength or other properties. In the absence of oxygen from the air, other chemical reactions can occur which may result in color changes to the material.

All UV-C effects on materials are dose-dependent. Dose can be generally measured by the light intensity and time, so the same effect can be observed with low intensity

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15 Halstead, F.D., et al., "*The potential of visible blue light (405 nm) as a novel decontamination strategy for carbapenemase-producing enterobacteriaceae CPE)"*, Antimicrob Resist Infect Control, 17 January 2019

16 Kingsley, D. et al., "*Evaluation of 405-nm monochromatic light for inactivation of Tulane virus on blueberry surfaces*", Journal of applied Microbiology, 21 January 2018

17 Buonanno, M. et al., "*Germicidal Efficacy and Mammalian Skin Safety of 222-nm UV Light"*, Radiation Research, February 2017

18 Buonanno, M. et al., "*207-nm UV Light—A Promising Tool for Safe Low-Cost Reduction of Surgical Site Infections. II: InVivo Safety Studies",* Research Article, 8 June 2016

19 Buonanno, M. et al., "207-nm UV Light - A Promising Tool for Safe Low-Cost Reduction of Surgical Site Infections. I: In Vitro Studies", Research Article, 15 October 2013

20 R.E. Kauffman "*Study the Degradation of Typical HVAC Materials, Filters and Components Irradiated by UVC Energy*", ASHRAE Research Project Report RP-1509, April 2011.

over a long period of time or high intensity for a short time. Since the intensity of the light on a surface will depend on the distance between the surface and the light source, and the angle between the plane of the surface and the incident light, it will be different for different devices or treatment techniques. The cumulative dose experienced by materials in the cabin can be estimated by multiplying the single treatment dose by the number of treatments per day, and the number of treatment days.

Cumulative dose = Treatment dose * Treatments/day * Treatment days

Aircraft materials in the cabin can include wool, polyester, leather or synthetic leather seat coverings, carpets, seat belts, tray tables, in-flight entertainment LCD screens, and other displays, transparent window coverings, decorative foil laminates and window shades. Flight deck materials include a similarly wide range of materials. Materials compatibility information is specific to each material and UV wavelength, and must cover the range of cumulative dose corresponding to realistic use. Materials property information that is useful to airlines includes the effect of UV light on flame retardancy, the effect on strength of the materials, and the effect on appearance. A recent white paper[21] provided results of UV-C irradiation studies with aircraft materials. For many materials, there was no significant effect of UV irradiation on either flame retardancy or strength compared with control samples with no UV exposure. TABLE 3-2 shows the highest UV-C cumulative dose for each material from this white paper with respect to flame retardancy or strength. Similarly, TABLE 3-3 documents studies in which progressively higher UV-C doses were applied to materials, with a focus on appearance, and shows the dose at which perceptible changes were observed.

TABLE 3-1: DOSE AT 254 NM REQUIRED TO CAUSE SIGNIFICANT CHANGE IN FLAME RETARDANCY OR STRENGTH RELATIVE TO SAMPLES WITH NO UV-C EXPOSURE

Material	Flame Retardancy	Strength
	Dose Resulting in Significant Changes	Dose Resulting in Significant Changes
Sateen Leather, Moon Gray LL-3442b	>269 J/cm2	>191 J/cm^2
Nylon Carpet Humility First AB-7400/7664b	>269 J/cm^2	>191 J/cm^2
Columbia Synthetic Leather Glacier DEF-CD287b	>269 J/cm^2	>191 J/cm^2
Luxaire Synthetic Leather Nickel CD47-AR175FRb	>269 J/cm^2	>191 J/cm^2
Heavy Duty Wool-Polyester Blend DEF-7284/0045	>269 J/cm^2	>191 J/cm^2
Heavy Duty Wool-Polyester Blend DEF-7898/48b	>269 J/cm^2	>191 J/cm^2
Polyester Seat Belt Webbing	>269 J/cm^2	>382 J/cm^2
Simona Boltaron 9815N	>382 J/cm^2	-
ProLens Aircraft Grade Polycarbonate	>382 J/cm^2	>382 J/cm^2

[21] Honeywell International, "*Effect of UV-C on Aircraft Interior Materials*", Version 1, Tempe, AZ., August 5, 2020 URL: https://aerospace.honeywell.com/en/learn/products/cabin/uv-cabin-system;

NOTE:

1. *Values in table represent highest doses tested.*
2. *Douglass Interior Products*

Using the equation provided, we would calculate that, if a single treatment dose was 5 mJ/cm^2, then an entry of > 269 J/cm^2 for flame retardancy would mean that after 51,800 treatments, no significant effect on flame retardancy would be expected.

TABLE 3-2: LOWEST DOSE AT 254 NM THAT RESULTED IN PERCEPTIBLE CHANGE IN APPEARANCE FOR AIRCRAFT MATERIALS

Material	Colour Progressive Study	
	Lowest Dose with Perceptible Change	**Description**
Sateen Leather, Moon Gray LL-3442	51 J/cm^2	
Nylon Carpet Humility First AB-7400/7664	34 J/cm^2	
Columbia Synthetic Leather Glacier DEF-CD287	17 J/cm^2	
Luxaire Synthetic Leather Nickel CD47-AR175FR	51 J/cm^2	
Heavy Duty Wool-Polyester Blend DEF-7284/0045	No visible effect	
Heavy Duty Wool-Polyester Blend DEF-7898/48	No visible effect	
Polyester Seat Belt Webbing	No visible effect	
Kydex Polyacrylate Sekisui 7200ST	No visible effect	
Boltaron 9815N	34 J/cm^2	Slight Darkening
Small Airline Tray Table	34 J/cm^2	Slight Yellowing
Large Airline Tray Table	No visible effect	
Window Shade	34 J/cm^2	Slight Yellowing
ProLens Aircraft Grade Polycarbonate	51 J/cm^2	Slight Yellowing
Schneller Decorative Foil Laminate S3863	34 J/cm^2	Slight Yellowing
Schneller Decorative Foil Laminate S016329	34 J/cm^2	Slight Yellowing
Schneller Decorative Foil Laminate S05051-011-H5	17 J/cm^2	Slight Yellowing

Using the equation a dose of 51 J/cm^2 would correspond to 10,200 treatments if a single treatment was chosen to be 5 mJ/cm^2.

3.3.2.3.6 Effects on humans

Exposure to an excessive dose of UV light can be harmful, especially to exposed skin or eyes. The limits for safe exposure have been established. Threshold limit values for UV exposure depend on wavelength and are expressed as cumulative dose over an 8-hour period. For the wavelengths in potential use for aircraft germicidal treatment, the limits are shown below from the ACGIH handbook[22] and from the International Commission on Non-Ionizing Radiation Protection[23]. EU Directive 2006/25/EC also provides threshold limit values which are the same as those shown for ACGIH.[24]

TABLE 3-3: THRESHOLD LIMIT VALUES FOR 8 HOUR EXPOSURE INTERVAL

Wavelength (nm)	ACGIH TLV (mJ/cm^2)	ICNIRP (mJ/cm^2)
400	1×10^5	Not stated
254	6	6
220	25	25

The person operating UV equipment should ensure that other personnel are not in close proximity. The operator can be protected by a UV-opaque shield if possible and should wear clothing that cover the arms and legs. Shoes should completely enclose the foot. If no shield is used, gloves may be worn and a faceshield should be used. If a protective shield is damaged, compromised or is not correctly positioned to protect the operator, the equipment should not be used. Similarly, if autonomous or robotic equipment is used, personnel exposure to UV may be avoided.

3.3.2.3.7 Other Safety considerations

UV systems are electrically powered and frequently use batteries. The operator should read and be familiar with the manufacturer's manual and safety warnings, and training should include safe operation. Like any electrical appliance, the system and any battery charger should be kept away from water, heat sources, flammable liquids or areas with flammable gases, vapors, or explosive/airborne dust. If the equipment has been dropped, damaged, left outdoors or dropped in water, it should be disconnected from electrical power, and not used until the equipment has been checked.

UV equipment may use bulbs, LEDs or other UV sources. UVC bulbs are very similar to common fluorescent bulbs and contain a very small amount of mercury. Care should be taken to avoid breaking them, and the equipment should be correctly designed to reduce the risk of lamp breakage. If a lamp does break, the clean-up procedure is similar to that for fluorescent lamps.

3.3.2.3.8 Training requirements

UV equipment should be operated only by trained personnel. Manufacturers will provide a manual for the safe operation of the equipment, and personnel should be trained in and familiar with the contents of this manual. The manual will also provide equipment-specific safety warnings and guidance, and this should also be included in training. Supervisors should oversee UV equipment operators to ensure that the equipment is being operated safely and effectively.

Ultraviolet light sources do not normally generate ozone, but a few UV lamps, generally less expensive ones for home use, do. It is important to check the specifications for any UV light source to check that it does not generate ozone, and that it is compliant with any local or regional regulations or standards. Do not use replacement lamps for any

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22 American Conference of Governmental and Industrial Hygienists, "*ACGIH TLVs and BEIs Book 2019*", Cincinnati, OH, 2019.

23 International Commission on Non-ionizing Radiation Protection, "*Guidelines to Exposure to Ultraviolet Radiation of Wavelengths between 180 nm and 400 nm (Incoherent Optical Radiation)*", Health Physics, pp. 171-186, August 2004

24 The European Parliament and the Council of the European Union, "*DIRECTIVE 2006/25/EC of the European Parliament and the Council, Official Journal of the European Union*", L 114/38 - L 114/38/59, 5 April 2006

UV source from a source other than the original vendor without making sure that these lamps also comply with these regulations.

3.3.2.4 Thermal

Thermal Heating or Thermal Disinfection is an example of an emerging technology to combat SARS-CoV-2. Viruses and bacteria can be inactivated (die off) when exposed to heat for a certain period of time. The specific thermal inactivation temperature with associated relative humidity, and length of heat exposure required to be effective for each virus and bacteria is different. Studies are ongoing to show the functional capability and efficacy for thermal heating against SARS-CoV-2. Efficacy of thermal disinfection is related to a combination of other environmental factors.

Specifically, it appears humidity plays a major role in the relationship between temperature, time, and kill rate for SARS-CoV-2. Currently, studies are showing at certain relative humidity ranges that SARS-CoV-2 thermal inactivation can be achieved from around 50 degrees C at 30 minutes exposure to around 70 degrees C at 10 minutes exposure.[25] Airplane manufacturers and the U.S. military are studying thermal heating as a potential disinfection solution for the flight deck, cabin, and cargo compartment. More testing is needed before conclusions can be made about the efficacy and viability of thermal heating for an aircraft. Testing also needs to address safety of equipment and parts after repeated heating cycles, functional inspection after testing, and proper safety guidelines.

While the testing may prove heat and humidity can eliminate biological contamination, for aircraft operations, the operational heat limits still need to be addressed to ensure safety. As the process evolves or the suspect pathogen changes, operators wishing to utilize the thermal heating should coordinate with knowledgeable entities such as safety regulators, aircraft and equipment OEMs to research the viability of the option, including conducting a SMS and SRA process.

[25] Chin A., et al. "*Stability of SARS-CoV-2 in different environmental conditions",* Volume 1, Issue 1, 1 May 2020
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APPENDIX A

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APPENDIX B

FREQUENCY OF APPLICATION OF AIRCRAFT CLEANING/DESINFECTION SUBSTANCES OR PROCESSES

Considerations for evaluation and frequency of application	Chemical/Cleaners/ Disinfectants	Alterations/Devices/ Procedures
General Considerations		
Effectiveness against current COVID-19phttps://www.epa.gov/pesticide-registration/list-n-disinfectants-coronavirus-covid-19	☑	☑
Aircraft downtime	☑	☑
Duration of efficacy when applied according to manufacturer instructions	☑	☑
Health		
Health risks (from printed labels, re application, “liquid dwell time” and risks) https://www.msdsonline.com/sds-search/	☑	☑
Reactivity of residual product or process on surfaces when passengers or crew board	☑	
Pilot performance impacts of residuals	☑	☑
Airborne residual product when passengers or crew board)	☑	If something added to air; e.g. ions or peroxide
Employee Safety during application/operation	☑	☑
PPE Requirements? (from Manufacturer Safety Data Sheet report)	☑	☑
Specialized Training	☑	☑
Interaction with other safety features/systems on the aircraft (e.g. HEPA filters)	☑	☑
Application Notes (manpower)		
Application Process/procedure "degree of difficulty"	☑	
Cloth wipe (Small area/Adjacent area avoidance/"thickness")	☑	
Electrostatic disbursement (Wide area, if appropriate)	☑	☑
Protection of specific surfaces?	☑	☑
Liquid dwell time required (how long before dry)	☑	
Is special equipment required?	☑	☑
Time between application/operation and safe occupancy - SDS and manufacturer recommendations for dry-to-touch and odor dispersion)	☑	Maybe **e.g. H2O2**
How frequently is application required? Manufacturer recommendation –	☑	☑
Portability of apparatus		☑
QA: Assurance of consistent application at effective concentration	☑	☑

Considerations for evaluation and frequency of application	Chemical/Cleaners/ Disinfectants	Alterations/Devices/ Procedures
Bioluminescence/swap culture/testing for viable pathogens?	☑	☑
Systems and Cosmetic Flight Deck and Passenger Cabin		
General: electrical connectors throughout aircraft, especially flight deck	☑	
Surface effects		
Flammability, crazing, abrasion, leather/Naugahyde, corrosion	☑	☑
Windows/transparent surfaces, esp. coatings	☑	☑
Corrosion	☑	
Embrittlement of plastics	☑	☑
Flight Deck		☑
Controls	☑	
Switches	☑	
Fabrics/leathers	☑	☑
Screens	☑	
Moving Parts	☑	
Cabin		
Passenger Service Units	☑	
Inflight Entertainment Screens	☑	
Fabrics/leathers	☑	☑
Moving Parts	☑	
Systems Effects		
General integration with existing aircraft systems		☑
Interaction with Fire/Smoke detection systems	☑	☑
Air circulation System		
Fans	☑	
Filters	☑	☑
Infiltration to Cargo compartment	☑	
Components/Avionics	☑	
Inspection / QA re system effects	☑	☑
Maintenance		
STC criteria for alteration, weight, MEL relief		☑
Redundancy, degraded conditions.		☑
Residue build up	☑	
Process to remove residue	☑	
QA: Assurance devices operating as designed		☑
Supplies / apparatus required to apply	☑	☑
Equipment cleaning/refurb	☑	☑
Waste management / environmental review (ref SDS)	☑	☑

Considerations for evaluation and frequency of application	Chemical/Cleaners/ Disinfectants	Alterations/Devices/ Procedures
Local product and supply availability	☑	☑
Transport and storage of product	☑	
COMAT	☑	
HAZMAT	☑	

APPENDIX C

DISINFECTANT COMPATIBILITY OF AIRCRAFT TOUCH SURFACE MATERIALS

Disinfectant Compatibility of Aircraft Cabin Touch Surface Materials

LEGEND	NR = Not recommended; known incompatibilities

GENERAL NOTES:
- Chemical categories agnostic of application method (wipe, spray, electrostatic spray, fogging); ranking is based on material susceptibility
- "Incompatibility" is defined as any visual discoloration, crazing, corrosion, softening, and other defects that impact material integrity

DISCLAIMER

- Absence of "NR" ranking does not imply a recommendation or confirmed material compatibility to the disinfectant for all possible materials & disinfectants in those categories.
- Likewise, presence of "NR" ranking does not mean that every material and disinfectant of interest in the indicated categories will result in damage upon exposure, only that a known, high risk exists with at least one combination.
- Completion of an SMS SRA is advised to evaluate with respect to the materials & disinfectants of interest, location in the cabin, and susceptibility of adjacent dissimilar materials.
- The SMS SRA is a more thorough evaluation (which includes equipment/material OEM guidance) that will change compatibility risks of specific material & disinfectant products, and should take precedence over the general compatibility chart below in selecting appropriate disinfectants for use.

	DISINFECTANT CATEGORIES					
EXPOSED SURFACE MATERIAL	**Quaternary Ammonium Compounds**	**Isopropyl Alcohol**	**Ethanol**	**Metallic-Particle-Based Films & Coatings**	**Chlorine Dioxide & Bleach**	**Peroxides**
TEXTILES & UPHOLSTERY (Ex: Seating, Class Divider Curtains, etc.)						
Synthetic		NR	NR		NR	NR
Natural		NR	NR		NR	NR
METALS (Ex: Latches & Handles, Seating Components, Faucets, Labels, etc.)						
Metallic				NR	NR	NR
Painted or Powdercoated				NR	NR	NR
PLASTICS (Ex: Tray Tables, Sink Surrounds & Countertops, Arm Caps, Windows, etc.)						
Transparent to Translucent or Mirror-Finish		NR	NR		NR	NR
Opaque Plastics	NR	NR	NR		NR	NR
COMPOSITE FINISHES (Ex: Stow Bins, Lavs, Closets, Galleys, Class Dividers, etc.)						
Decorative Laminates						
Paints					NR	NR
ELECTRONICS/DISPLAYS (DO NOT spray on surface)	NR		NR	NR	NR	NR

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