Water Environment Federation
the water quality people

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Respiratory Syncytial Virus Information for Water Professionals

Key Take-Home Messages

What we know from clinical surveillance

- Infection with respiratory syncytial virus (RSV) causes mild, cold-like symptoms in most people but can be dangerous for infants and older adults.
- In the U.S., approximately 58,000 to 80,000 children younger than 5 years and 60,000 to 160,000 adults 65 years and older are hospitalized due to RSV infection each year. It is the leading cause of infant hospitalizations in the U.S.
- RSV infection can result in complications such as bronchiolitis, pneumonia, and respiratory failure, especially in people who are very young, older, immunocompromised, or have certain chronic conditions.

How wastewater surveillance plays a role

- Wastewater surveillance shows promise as a tool for complementing clinical RSV data by providing information on community incidence and the timing of RSV season onset and peak, possibly serving as an early indicator.
- Many public health labs are already testing wastewater for RSV viral RNA, and the U.S. National Wastewater Surveillance System added RSV data to its public dashboard in September 2024.

What wastewater workers need to know

- RSV RNA has been detected in excretions from infected people, including feces, and in wastewater.
- No data are available on the infectivity of RSV in wastewater, although infective RSV can persist on surfaces, including stainless steel, for days.
- Wastewater workers, similar to the general public, are at risk of exposure to RSV from infected colleagues, primarily through inhaling or coming into contact with respiratory droplets when the infected person breathes, coughs, sneezes, or talks.
- Obtaining a one-time RSV vaccine (if older than 75 years or between 60 and 74 years old with certain chronic health conditions), understanding the effectiveness of disinfectant products, conducting job safety assessments, practicing good hygiene, and wearing appropriate personal protective equipment are important for protecting wastewater worker health and preventing RSV infection.
- RSV can be inactivated on surfaces with many readily-available disinfectants, including a dilute (1:50) solution of 5.25% sodium hypochlorite (bleach) or commercial disinfectant formulations with alcohol, aldehydes, or hydrogen peroxide.

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Why It's a Concern

Infection with respiratory syncytial virus (RSV) usually causes mild, cold-like symptoms that resolve within 1 to 2 weeks but can be dangerous for infants, young children, and older adults. RSV is the leading cause of infant hospitalizations in the U.S., and results in 58,000 to 80,000 hospitalizations and 100 to 300 deaths among children younger than 5 years each year (Surie et al. 2023; US CDC 2024d). Additionally, RSV causes 60,000 to 160,000 hospitalizations and 6,000 to 10,000 deaths among adults 65 years and older annually in the U.S. (Melgar et al. 2023). For comparison, influenza leads to 12,000 to 51,000 deaths in the U.S. each year (US CDC 2024c)[1]. Like flu, RSV infections usually follow a seasonal pattern, making co-infection with influenza (or COVID-19) a possibility that has the potential to increase the severity of respiratory illness (Bourzac 2023).

About the Virus

Members of the *Paramyxoviridae* family, respiratory syncytial viruses are enveloped with genomes consisting of a single molecule of negative-sense, single-stranded non-segmented RNA (Do et al. 2015). Respiratory syncytial virus particles (or virions) are usually 150 to 300 nm long with an irregular spherical shape (Figure 1a), although they can be present as filaments (Figure 1b) with diameters of 60 to 100 nm and lengths up to 10 μm (Mohapatra and Lockey 2008). Compared with influenza virus, the RSV genome is thought to be relatively stable with respect to evolutionary changes (Ascough et al. 2018). Observed variation in the encoding for a particular protein (specifically, the "G protein" that mediates viral

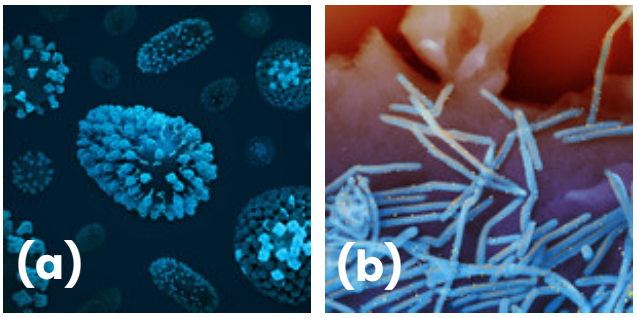

Figure 1. Typical forms of respiratory syncytial virus: (a) irregular spherical and (b) filamentous Source: National Institute of Allergy & Infectious Disease; licensed under Creative Commons; no changes to images were made

[1] For more influenza information, please refer to the Influenza Information for Water Professionals fact sheet.

attachment to the host cell) has led to the classification of RSV into two strains: RSV A and RSV B. RSV B appears to be more common and may cause more severe illness (Shishir et al. 2023).

Disease Overview

***Clinical features*:** RSV causes an acute viral illness usually associated with mild symptoms that appear in stages, including runny nose, decreased appetite, coughing, sneezing, wheezing, and sometimes fever (Alfano et al. 2024; US CDC 2024d). RSV symptoms in infants can include irritability, decreased activity, eating or drinking less, and pauses in breathing for more than 10 seconds (also known as apnea) (US CDC 2024d). Most infants infected with RSV show symptoms, although adults can be asymptomatic (Alfano et al. 2024). While RSV symptoms typically improve within 1 to 2 weeks, severe RSV illness can lead to lower respiratory tract infections such as bronchiolitis (inflammation of the small airways in the lung) and pneumonia (infection of the lungs) (Alfano et al. 2024; Daniels 2024; US CDC 2024d). RSV can also exacerbate serious chronic conditions, such as asthma, chronic obstructive pulmonary disease, and congestive heart failure (Daniels 2024; US CDC 2024d).

Transmission: RSV can be transmitted directly through personal contact with an infected person or immediate exposure to droplets excreted by a nearby infected person when they cough, sneeze, or talk. RSV can also be transmitted indirectly through aerosol transmission (coming into contact with droplets shed by infected individuals that can remain suspended in the air for a long time) or fomites (touching contaminated surfaces, such as doorknobs) (Kulkarni et al. 2016; Kaler et al. 2023; US CDC 2024d). Infective RSV can persist on surfaces for hours to days, with persistence on non-porous surfaces like countertops and metals longer than on porous surfaces like cloth and paper (Hall et al. 1980; Meister et al. 2023). People infected with RSV may become contagious 1 to 2 days before showing symptoms, and remain contagious for a total of 3 to 8 days (US CDC 2024d). Some infants and people with weakened immune systems can be contagious even after they stop showing symptoms and for as long as 4 weeks (US CDC 2024d).

Incubation period: The incubation period for RSV ranges from 2 to 8 days (Manti et al. 2017), although is probably typically closer to 4 to 5 days (Lessler et al. 2009).

***Diagnosis*:** Because RSV can be difficult to distinguish from other respiratory diseases based on symptoms alone, diagnostic testing is needed for a definitive diagnosis. The two most common diagnostic tests for RSV include: (1) PCR-based test that detects viral RNA, and (2) antigen testing that detects specific virus proteins (US CDC 2024b). Both PCR and antigen testing are suitable for infants and young children, while only PCR is recommended for older children and adults due to its higher sensitivity. Either upper respiratory (throat, nasal, or nasopharyngeal swab) or lower respiratory (such as bronchoalveolar lavage) specimens can be used for clinical analysis.

Risk groups: While RSV can affect anyone, some groups are at higher risk of complications from RSV, including: infants, especially premature infants; children with chronic lung or heart disease, neuromuscular disorders, or who are otherwise immunocompromised; and adults over 60 years, especially those with chronic lung or heart disease or weakened immune systems (US CDC 2024d).

Mortality: Overall case fatality rates for RSV are not well understood but could be up to 4.7% among older (>60 years) adults hospitalized for RSV infection (Havers et al. 2023). Being infected with RSV increases the risk of death for adults hospitalized due to infection with any respiratory viruses (e.g., influenza, RSV, or SARS-CoV-2) (Surie et al. 2023). In infants, RSV-related mortality rates are higher in preterm (< 29 weeks gestational age), American Indian/Alaska Native, and Medicaid-insured infants than in full-term, white, or privately insured infants (Reichert et al. 2022).

Clinical surveillance: Although not a nationally notifiable disease in the U.S., RSV is monitored through multiple public health surveillance systems. These include: virological surveillance through the National Respiratory and Enteric Virus Surveillance System; surveillance of symptoms as reported in electronic health records through the National Syndromic Surveillance Program; monitoring RSV hospitalization in children and adults through the RSV Hospitalization Surveillance Network (RSV-NET); and monitoring RSV-associated hospitalizations and outpatient visits among Native American persons on the Navajo Nation, White Mountain Apache Tribal Lands, and in Alaska through the RSV Surveillance in Native American Persons (RSV SuNA).

Presence in Wastewater

Shedding: People infected with RSV can shed virus in mucus, sputum, saliva, and feces (von Linstow et al. 2006; Akbari et al. 2017; Lowry et al. 2023). In a systematic review and meta-analysis, Lowry et al. (2023) analyzed data from 20 studies on RSV shedding. They found that, on average, 14% of people with confirmed RSV infection shed viral RNA in feces (based on the data available for 37 samples analyzed with PCR by von Linstow et al. 2006) vs. 96% in mucus (197 samples), 87% in sputum (697 samples), and 78% in saliva (99 samples). Of the 20 studies analyzed by Lowry et al. (2023), 19 utilized PCR to detect RSV RNA, while only 1, focusing on mucus samples, reported positive results using viral culture methods (Heikkinen et al. 2002). Additionally, van de Pol et al. (2010) reported successful RSV cultures from sputum samples. While infective virus could be present in both mucus and sputum, to our knowledge, no positive cultures of RSV from feces have been reported. This raises the quesiton of whether the detection of viral RNA in feces indicates the presence of infective virus. Further, no data are available on RSV RNA concentrations in feces or urine. It remains unclear whether the presence of RSV RNA in feces is due to direct intestinal infection or swallowing virus-containing nasopharyngeal secretions (Akbari et al. 2017).

Detection and quantification: Culture-independent methods are commonly used to detect and quantify RSV RNA in wastewater. These have included droplet digital PCR (Hughes et al. 2022; Boehm, Wolfe, et al. 2023; Zafeiriadou et al. 2024; Zambrana et al. 2024; Zhang et al. 2024) and quantitative PCR (Ando et al. 2023; Boehm, Hughes, et al. 2023; Koureas et al. 2023; Mercier et al. 2023; Toribio-Avedillo et al. 2023; Allen et al. 2024; Giron-Guzman et al. 2024; Rector et al. 2024; Zafeiriadou et al. 2024). As discussed above, the detection of RSV RNA with PCR-based methods does not necessarily mean that infective virus is present and, to our knowledge, no studies have attempted to culture RSV from wastewater.

Wastewater RSV RNA concentrations are being tracked as part of multiple programs, including the North Carolina Wastewater Monitoring Program, the Wisconsin Wastewater Surveillance Program, and others. The U.S. National Wastewater Surveillance System (NWSS) added RSV data to its public dashboard in September 2024. The NWSS dashboard shows the current RSV wastewater viral activity level (WVAL), WVAL trends over time at national and state/territory scales, and WVALs for each site for the current week. Another dataset for RSV RNA concentrations in wastewater is available from WastewaterSCAN (2024). Between January 2022 and June 2024, the program detected RSV in 24,792 out of >48,000 samples, across 192 water resource recovery facilities (WRRFs). Positive PCR detections ranged from $10^{2.8}$ to $10^{6.2}$ gene copies per gram (dry weight) of wastewater solids for RSV. Detections were more common from September through March (79% and 71% of samples were positive for RSV during these months for the 2022-2023 and 2023-2024 seasons, respectively) than from April to August (42% and 17% of samples were positive for RSV during these months in 2022 and 2023, respectively), consistent with RSV seasonality in the U.S. (A. Bidwell, personal communication, July 22, 2024).

In addition to quantification, amplicon-based sequencing of the RSV G gene has been performed in wastewater samples (Allen et al. 2024).

Survival and viability in untreated wastewater: To our knowledge, no studies have considered the persistence of RSV RNA or infective virus in raw wastewater or water matrices. In their systematic review and meta-analysis of the persistence of enveloped viruses in environmental waters and wastewater, Silverman and Boehm (2021) identified one study (Nazir et al. 2010) that considered the fate of an enveloped virus (Newcastle disease virus [NDV]) in the same family as RSV (*Paramyxoviridae*) in lake water at different temperatures. The researchers demonstrated that NDV spiked into lake water remained viable—based on the results of viral cultures[2]—for 51 days at 30°C but longer at lower temperatures (Nazir et al. 2010). It is not known whether RSV would remain similarly viable when spiked into wastewater, or whether RSV shed by infected individuals (non-spiked scenarios) would demonstrate similar persistence.

[2] The initial dose of NDV in lake water in Nazir et al. (2010) was 10^6 $TCID_{50}$, where TCID = "tissue culture infective dose" and $TCID_{50}$ is the number of viruses needed to show "cytopathic effects" (CPE) in 50% of the cells in the culture. In this study, Vero cells were used to determine CPE from NDV.

Fate in treatment processes: Most of the research on the fate of viruses in wastewater treatment has focused on non-enveloped enteric viruses[3] (Katayama et al. 2008; Kitajima et al. 2014; Schmitz et al. 2016). Enveloped viruses, such as RSV (and influenza and SARS-CoV-2), are thought to be more susceptible to inactivation than their non-enveloped counterparts although they do demonstrate some level of persistence when spiked into water matrices (Wigginton and Ellenberg 2015). While Zhang et al. (2024) demonstrated that RSV nucleic acid spiked[4] into primary sludge can persist for days, requiring 35 days (at 37°C) to 43 days (at 22°C) for a 90% reduction in spiked RNA concentrations, they did not consider infective virus. To our knowledge, no studies have considered the impacts of wastewater disinfection processes on the viability of RSV. However, it seems reasonable to assume that chlorination would be effective against RSV based on in vitro studies considering inactivation of RSV by sodium hypochlorite and other disinfectants (Krilov and Harkness 1993). Additional research is needed to more fully understand the fate of RSV, especially infective virus, in wastewater treatment processes.

Suitability for Wastewater Surveillance

As shown in **Table 1**, RSV concentrations in wastewater have been shown to correlate with clinical data at the city/community scale. Potential public health uses of wastewater RSV data may include: identifying distinct circulating lineages within and between RSV seasons; informing timely deployment of pharmaceutical and non-pharmaceutical interventions; identifying the onset, peak, and offset of RSV season; supplementing data available from other surveillance systems; and guiding the use of long-term monoclonal antibodies for RSV prevention (Boehm, Wolfe, et al. 2023; DeJonge et al. 2023; Mercier et al. 2023; Thampi et al. 2023; Allen et al. 2024; Rector et al. 2024).

Due to its public health significance and amenability to wastewater-based detection, RSV is one of the pathogens for which wastewater WVAL data are displayed on the NWSS dashboard. Utilities should coordinate with their public health partners to learn whether RSV is included in wastewater testing within their community, or if/when it might be added.

[3] Enteric viruses are defined by their habitat, namely, the gastrointestinal tract of mammals. They include viruses in the *Enterovirus* genus (such as coxsackieviruses, echoviruses, enteroviruses, polioviruses, and rhinoviruses), but also adenoviruses, astroviruses, noroviruses, rotaviruses, and others (Flint et al. 2015).

[4] The spiked RSV concentration used was 5.13 x 10^6 copies per gram (dry weight) of primary solids, compared with a background/endogenous concentration of 5.53 x 10^3 copies per gram dry weight (Zhang et al. 2024)

Table 1. Examples of Correlations Observed Between Wastewater and Clinical RSV Data

- *All examples are at the community scale*
- *This is not an exhaustive list and excludes studies for which a correlation was not explicitly calculated*
- *Correlations may be moderate or strong; any correlation characterized as "weak" was excluded*

Sampling Site(s)	Sample Type & Frequency	Population Captured	Wastewater Data Used for Correlation	Clinical Data Used for Correlation	Reference
20 WRRFs	Weekly 24-hour composite of primary influent	11,500 to 228,000 per WRRF*, with WRRFs collectively representing 57% of the country's population	Population-normalized RSV RNA concentrations averaged across all 20 WRRFs and fitted with a B-spline regression model	Number of new RSV cases per week for the entire country	Allen et al. (2024)
3 WRRFs in a single city	Weekly or monthly grab of raw influent	196,000 to 392,000 per WRRF, with WRRFs collectively representing 40% of the city's population	PMMoV-normalized RSV A & RSV B RNA concentrations in raw influent	Number of new RSV cases per week for the entire city	Ando et al. (2023)
1 WRRF	24-hour composite primary sludge 3 times per week	1,500,000, representing ~4% of the state's population	RSV A & RSV B RNA concentrations per gram of solids	State-aggregated weekly clinical sample positivity rates from sentinel laboratories	Boehm, Hughes, et al. (2023)
8 WRRFs	Daily grab primary sludge	66,622 to 1,480,000 per WRRF	PMMoV-normalized RSV RNA concentrations per gram of solids	State-aggregated weekly clinical sample positivity rates from sentinel laboratories	Boehm, Wolfe, et al. (2023)
4 WRRFs serving 3 cities	Raw influent at least once weekly; sample type not specified	189,000 to 1,085,941 per city	RSV RNA concentrations in raw influent; weekly geometric means used if more than 1 sample tested per week	Number of ED visits in city served by respective WRRF(s) each week	DeJonge et al. (2023)
1 WRRF	Weekly grab of raw influent	322,000	RSV RNA concentrations normalized by PMMoV, coliphages, total nitrogen and other means	Daily number of reported bronchiolitis cases caused by RSV	Giron-Guzman et al. (2024)
2 WRRFs	Primary sludge (grab or composited, daily to weekly)	220,000 to 1,500,000	Weekly averaged RSV RNA concentrations (both unnormalized and normalized to PMMoV)	State-aggregated weekly clinical sample positivity rates from sentinel laboratories	Hughes et al. (2022)
1 WRRF	24-hour composite of raw influent	150,000	RSV RNA loads (copies per person)	Weekly visits to sentinel primary healthcare sites for ILI	Koureas et al. (2023)

Sampling Site(s)	Sample Type & Frequency	Population Captured	Wastewater Data Used for Correlation	Clinical Data Used for Correlation	Reference
2 WRRFs	24-hour composite primary sludge 5 to 7 times/week	512,000 and 910,000	RSV RNA concentrations in primary sludge; not clear whether they are normalized to PMMoV or not	Daily pediatric laboratory-confirmed RSV hospitalization admissions for 2 local hospitals; weekly regional RSV confirmed cases (adult + pediatric, inpatient + outpatient)	Mercier et al. (2023)
2 WRRFs	Weekly influent	~1,100,000 and ~2,200,000	RSV (A & B combined) RNA concentrations	Number of cases of bronchiolitis reported in hospitals primary	Toribio-Avedillo et al. (2023)
176 WRRFs	Grab or composite raw influent or primary sludge	3,000 to 4,000,000	Weekly median PMMoV-normalized RSV RNA concentrations (including both RSV A and RSV B)	3-week moving average of national positivity rate of clinical tests reported to NREVSS; weekly hospitalization rates from RSV-Net across 12 states	Zulli et al. (2024)

Abbreviations: *ED = emergency department; ICU = intensive care unit; ILI = influenza-like illness; NREVSS = National Respiratory and Enteric Virus Surveillance System; PMMoV = pepper mild mottle virus; RSV = respiratory syncytial virus; RSV-Net = Respiratory Syncytial Virus Hospitalization Surveillance Network; WRRF = water resource recovery facility*

Note: *Expressed as population equivalents.*

Preventing RSV Infection When Working with Wastewater

Routes of exposure: Wastewater workers are at risk of exposure to RSV from infected colleagues, primarily through coming into contact with respiratory droplets when they are in close proximity to an infected person who coughs, sneezes, or talks. Adults infected with RSV are usually contagious while they show symptoms (for 3 to 8 days; US CDC 2024d), although they may start shedding the virus 1 to 2 days before showing symptoms, making it challenging to identify contagious individuals. Another potential route of exposure to RSV in the wastewater workplace may be touching surfaces contaminated with wastewater, followed by touching the face, especially the eyes and nose (Kaler et al. 2023; US CDC 2024d). However, the degree of persistence of infective RSV in wastewater is unknown. It is important to keep in mind that most surfaces near wastewater collection and treatment equipment are likely to be contaminated with wastewater, and the presence of abrasions, open wounds, and punctures may increase the risk of transmission of any pathogen—even if infective RSV is not necessarily present.

Infection prevention measures: The worker safety recommendations of the WEF Blue-Ribbon Panel (WEF 2020) remain relevant for wastewater workers for RSV and other infective agents in wastewater. These recommendations are consistent with the CDC's guidance for reducing health risks to workers handling human waste or sewage (US CDC 2023). Being vaccinated against RSV (if certain criteria are met; see below), understanding appropriate disinfectant products, conducting job safety assessments, practicing good hygiene, and using personal protective equipment (PPE) all play a role in preventing infection from RSV and other pathogens from wastewater.

Vaccination

- The CDC recommends that adults 75 years of age and older receive a one-time RSV vaccine (US CDC 2024a). Adults aged 60 to 74 who are at increased risk due to cardiovascular disease, lung disease, advanced chronic kidney disease, diabetes with end-organ damage, severe obesity, or other disorders should also receive a single dose of RSV vaccine (US CDC 2024a, 2024d). Obtaining the RSV vaccine in late summer or early fall may maximize the benefit from the immunization. At this point, RSV is *not* an annual vaccine, unlike influenza.
- RSV vaccines first became available in 2023 (Cohn and Hall 2023) and, as of 2024, 3 RSV vaccines are licensed by the U.S. Food and Drug Administration and available in the U.S.: GSK's AREXVY (a recombinant RSV F protein antigen based on the RSV-A subtype), Moderna's mRESVIA (modified mRNA encoding the RSV F glycoprotein monovalent, based on the RSV-A subtype), and Pfizer's ABRYSVO (a recombinant RSV F protein antigen based on both the RSV-A and RSV-B subtypes) (US CDC 2024d).
- While obtaining the RSV vaccine may not eliminate the possibility of becoming infected with RSV, it will likely decrease the duration and severity of disease. One study demonstrated that an acute respiratory illness due to RSV was less likely, shorter, and less severe in adults ≥60 years old who received an RSV vaccine as compared with those who did not (Curran et al. 2024).

- Adverse reactions to all vaccines are tracked in the U.S. using the Vaccine Adverse Event Reporting System (VAERS). For 2023 (August through December), a total of 2,354 adverse events were reported for all types of RSV vaccines in persons ≥60 years old in VAERS. During the same time period, more than 16 million RSV vaccine doses were given in the U.S. to adults ≥ 60 years old, corresponding to an adverse reaction rate of <0.01%. The most common adverse reactions reported in VAERS include pain or redness at the injection site, fatigue, headache, fever, nausea, joint stiffness, and muscle aches.
- Vaccines can be obtained for free or low cost from a healthcare provider, retail clinic (such as a pharmacy or superstore), public health department, community clinic, or employer. A healthcare provider should be consulted to determine vaccine eligibility, most suitable vaccine type, precautions, best timing, and vaccine availability.

Disinfectant products

- Hand sanitizers with either 30% ethanol or 30% 2-propoanol effectively inactivate RSV. RSV is more susceptible to inactivation by both formulations than influenza A, SARS-CoV-2, and other viruses (Meister et al. 2023).
- Commercial disinfectant formulations[5] with alcohol, aldehydes, or hydrogen peroxide as the active ingredient effectively inactive infective RSV within the exposure time (from 30 seconds to 5 minutes) and at the concentration (from 0.5 to 100%) recommended by the manufacturer (Meister et al. 2023).
- Krilov and Harkness (1993) demonstrated that a 1:10 dilution of 5.25% sodium hypochlorite (i.e., bleach) inactivated RSV at starting concentrations of up to 10^7 plaque forming units per mL, while a 1:100 dilution of bleach inactivated RSV at lower starting concentrations. A dilute bleach solution (1:50 dilution of 5.25% sodium hypochlorite [0.1%], or about 75 mL [1/3 cup] of household bleach in a total of 1 gallon of water) with a contact time of 1 minute is recommended by the CDC for disinfection of surfaces.
- Quaternary ammonia compounds (QACs) may also be effective against RSV. (Leclercq and Nardello-Rataj 2020) demonstrated 4-log removal of RSV after 15 minutes of contact time using a solution containing 0.0045% (by weight) didecyldimethylammonium chloride, a commonly-used QAC.

Job safety assessments (JSAs)

- JSAs should follow the protocols outlined in WEF 2020. Please email nwbe@wef.org for JSA templates if needed.
- To inform their JSAs, utilities should coordinate with local public health agencies and healthcare institutions to understand the risk of RSV and other pathogens in their wastewater.

[5] The specific formulations used are included in the Supplementary Information for the manuscript:

Hygiene

- After handling wastewater or touching surfaces potentially contaminated with wastewater, hands should be washed with soap and water or cleaned with an alcohol-based hand sanitizer (ABHS). Contreras et al. (1999) found that liquid dishwasher detergents designed for use when handwashing dishes (e.g., Ajax and Dawn) were more effective in inactivating RSV than antibacterial soaps commonly used in hospital settings (e.g., Bac-Down and Cida-Stat). Hands should be washed with soap and water when visibly soiled.
- Wearing gloves is not a substitute for hand hygiene (Weber et al. 2023).
- While working with wastewater and near surfaces potentially contaminated with wastewater, avoid touching the face, mouth, eyes, nose, or open sores or cuts, and do not smoke or chew tobacco or gum. In addition, sores and cuts should be covered with water-resistant band aids.

Personal protective equipment (PPE)

- PPE should be selected to prevent contact with wastewater, either directly (through splashes, contact transfer, or whole-body contact) or indirectly (through touching contaminated surfaces).
- Appropriate PPE may include gloves, boots, coveralls (such as Tyvek suits), face shields, and safety glasses/goggles. Guidance is available for task-specific PPE recommendations (LeChevallier et al. 2020).
- Care should also be taken to prevent cuts or punctures when handling wastewater through the use of durable gloves. Gloves should be changed when torn or heavily contaminated.
- Proper procedures for donning (putting on) and doffing (removing) PPE to minimize pathogen exposure should be followed. **Box 1** provides an example of donning and doffing gloves, boots, disposable coveralls, and a face shield or safety glasses/goggles, while **Box 2** provides steps on how to remove gloves when not wearing a disposable coverall.
- Reusable PPE, such as boots, face shields and goggles, should be cleaned after each use. Visibly soiled PPE can be cleaned with soap and water, followed by a dilute bleach solution (1:50 dilution of 5.25% sodium hypochlorite [0.1%], or about 75 mL [1/3 cup] of household bleach in a total of 1 gallon of water) or a disinfectant with alcohol, aldehyde, or hydrogen peroxide as the active ingredient. For PPE that is not visibly soiled, or not amenable to washing with soap and water, a disinfectant with alcohol, aldehydes, or hydrogen peroxide as the active ingredient can be used. PPE should also be inspected to ensure good condition before each use.

Box 1: Donning and Doffing Personal Protective Equipment

Including gloves, boots, disposable coveralls, and a face shield or safety glasses/goggles

Donning

- Wash hands with soap and water, followed by use of alcohol-based hand sanitizer (ABHS)
- Remove shoes and tuck trouser legs into socks
- Step into legs of coverall, pull on boots, and place coverall legs over boots
- Pull coverall over arms and shoulders
- Put on face shield or glasses/goggles and pull up hood
- Zip up garment
- Put on gloves

Doffing

- Unzip coverall to waist and roll back hood without touching the inside of the garment
- Pull first arm out of garment sleeve by pulling with the other arm at your back (see this video for a demonstration), pulling your glove off as you completely remove your first arm from the sleeve (see Box 2 for glove removal without a coverall)
- Use your ungloved hand to push the garment off your second arm, only touching the inside of the garment with the ungloved hand, and pull your second arm out of garment, removing your second glove in the process
- Roll garment down body, touching only the inside or the garment with your now ungloved hands, and kick off your boots
- Dispose of the garment, again, only touching it on the inside with your ungloved hands
- Wash hands with soap and water, followed by use of ABHS
- Remove face shield or glasses/goggles from the back by lifting the head band (face shield) or earpieces (glasses/goggles), and discard or clean

Box 2: Removing Gloves When Not Wearing a Disposable Coverall

- Remove one glove at a time
- Use one gloved hand to grasp the palm area of the other gloved hand and peel off the glove
- Hold removed glove in gloved hand
- Slide fingers of ungloved hand under remaining glove at wrist and peel off second glove over first glove
- Discard gloves
- Wash hands with soap and water, followed by the use of ABHS

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Author and Reviewers

This document was written by Anna Mehrotra, Ph.D., P.E., Director of the Wastewater Surveillance Program at the Water Environment Federation (WEF), with review from:

- Bruce Adams, Superintendent of Wastewater, City of Cortland Wastewater Treatment
- Megan Bias, MPH, Epidemiologist, U.S. Centers for Disease Control and Prevention
- Megan Gerdes, MPH, Epidemiologist, Applied Science, Research & Technology
- Daniel Gerrity, Ph.D., Principal Research Microbiologist, Southern Nevada Water Authority
- Michael Jahne, Ph.D., Environmental Engineer, U.S. Environmental Protection Agency
- Erin Morin, MHS, Specialist, Environmental Health, Association of Public Health Laboratories
- Naoko Munakata, P.E., Ph.D., Supervising Engineer, Los Angeles County Sanitation Districts
- Heather Reese, Ph.D., MPH, Wastewater Epidemiology Unit Lead, U.S. Centers for Disease Control and Prevention
- Jennifer Sabater, M.S., Manager, Wastewater Surveillance Program, Water Environment Federation
- Carley Truyens, P.E., MPH, Senior Manager, Wastewater Surveillance Program, Water Environment Federation

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