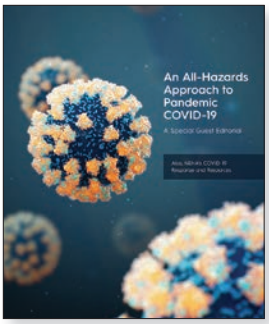
GUEST EDITORIAL



An All-Hazards Approach to Pandemic COVID-19: Clarifying Pathogen Transmission Pathways Toward the Public Health Response

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Editor's Note: **The vision for this guest editorial came about in late February 2020 before the World Health Organization declared coronavirus disease 2019 (COVID-19) a pandemic. While the *Journal* strives to provide its readership with relevant and up-to-date information, the timeliness of the information printed can be hindered by review and production timelines. As such, the *Journal* felt it was vital to provide information about COVID-19 in the May issue by publishing the following article as a guest editorial. It is important to note that as an editorial, this article was not peer reviewed. Furthermore, the information and conclusions presented are those of the authors and do not necessarily represent the views or official position of the National Environmental Health Association (NEHA) or of the authors' affiliations. NEHA and the *Journal* are not liable or responsible for the accuracy of or actions taken on the basis of any information stated herein. The information presented in the article was current as of March 18, 2020. Information regarding COVID-19 case numbers and actions taken by governments will undoubtedly be outdated at the time of publication; however, that does not lessen the value of the information and conclusions provided in this guest editorial.**

Summary

Coronavirus disease 2019 (COVID-19) is caused by SARS-CoV-2 (Centers for Disease Control and Prevention [CDC], 2020a). The World Health Organization (WHO) declared COVID-19 as a pandemic on March 11, 2020, the first caused by a coronavirus (WHO, 2020a). Severe acute respiratory syndrome (SARS) in 2003–2004 was the last unproclaimed pandemic with such terrifying potential. It was a harbinger of forthcoming emerging and reemerging infectious disease, severe enough to initiate the revision of the International Health Regulations (WHO, 2008), including the powerful Public Health Emergency of International Concern that was declared for COVID-19. This virtually unknown pathogen has no associated vaccine and people have no immunity to it.

The world's vulnerable populations could face long-term clinical sequelae that might later develop. For example, evidence of liver damage has been observed through COVID-19 research processes and in over 50% of SARS patients (Gu, Han, & Wang, in press).

In this guest editorial, we clarified known transmission pathways of SARS-CoV-2 and epidemiological commonality from a literature review, and organized descriptors into three categories (zoonotic, person-to-person, and environmental) with discussion of infection dynamics. Our nomenclature system unifies veterinary, environmental public health, and medical terminology by following a One Health concept with a simplified categorization of transmission pathways to enable effective prevention strategies in a straightforward public health message based upon an all-hazards theory that focuses on risk and severity. We analyzed prevention, facilitate behavior modification, and shorten incident mitigation in the absence of full human, animal, and environmental transmission dynamics of COVID-19.

Part 1: The Public Health Response to SARS-CoV-2/ COVID-19

On December 31, 2019, WHO was informed of a cluster of COVID-19 cases in Wuhan, China

(WHO, 2020b). The initial human cases of this disease were linked with the Huanan Seafood Wholesale Market where a novel zoonotic coronavirus transmitted from wild animals to humans (CDC, 2020a; Kaplan, 2020).

Concepts of global health security and national health security in the U.S., as described by the WHO 2005 International Health Regulations and the Office of the Assistant Secretary for Preparedness and Response (ASPR) 2019–2022 National Health Security Strategy, is protected by powerful enforcement tools that enable the control of infectious disease threats (ASPR, 2019a; WHO, 2008). On January 30, 2020, WHO proclaimed that COVID-19 constituted a Public Health Emergency of International Concern (WHO, 2020c). The following day, the U.S. Department of Health and Human Services (HHS) ASPR declared a public health emergency in the country (ASPR, 2020b). The U.S. president also declared a nationwide emergency by implementing the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Federal Emergency Management Agency, 2020).

The WHO's Public Health Emergency of International Concern is designed to recognize and control public health risks from crossing national borders while enabling a coordinated international response (WHO, 2020c). The U.S. public health emergency declaration enables coordination of the Centers for Disease Control and Prevention (CDC), Federal Emergency Management Agency (FEMA), HHS, and other federal partners toward a unified and integrated approach to pandemics, natural disasters, or chemical or radiological threats (CDC, 2018).

Specialists in environmental health are specifically designated to assist in the assessment of risk among a coordinated partnership between state, local, tribal, and territorial governmental jurisdictions. From global to local public health, and in particular the practice of environmental health, plurality of government in the U.S. represents the intention of the constitutional framework and presents challenges to uniformity of service (Gable, 2012). By March 16, 2020, all 50 U.S. states independently declared public health emergencies.

Global Situation

The Chinese government locked down the original hot spot of COVID-19 (Wuhan City) to contain the outbreak on January 23, 2020 (Du et al., 2020). In the ocean nearby, on February 1, 2020, an international cruise ship traveling with 3,711 passengers and crew found that an already-disembarked passenger tested positive for COVID-19 in Hong Kong (Princess Cruise Lines, 2020). The cruise ship, operated by the world's largest leisure travel company, Carnival Corporation, arrived at Yokohama, Japan, and isolated passengers who tested positive with COVID-19 in Japanese hospitals and quarantined the rest on the ship on February 3, 2020. The Disaster Infection Control Team under the Japanese Society for Infection Prevention and Control intervened to manage/mitigate infection on the ship until all disembarked on March 1, 2020 (Japan Ministry of Health, Labour, and Welfare, 2020a). By March 8, 2020, 696 former passengers and crew tested positive, 357 were discharged, and 7 died (Japan Ministry of Health, Labour, and Welfare, 2020b). Experiencing surging numbers of suspected cases, South Korea conducted drive-thru virus tests that were capable of completion in 10 min (Yonhap, 2020). With an approximate population of 52 million, South Korea counted 7,869 COVID-19 cases with 66 deaths on March 12, 2020 (Yonhap, 2020).

U.S. Situation

Human cases of COVID-19 erupted onboard a series of cruise ships that caused the initiation of an unprecedented U.S. repatriation response, the first of which involved careful coordination between HHS/ASPR, CDC, and the U.S. Department of State. Infected American citizens were extracted from the Diamond Princess, transported in buses to U.S. aircraft in Japan, and flown to U.S. Air Force bases to be medically assessed, quarantined, and processed for their return home (U.S. Department of State, 2020). As the repatriated, infected American citizens were sequestered in quarantine, the first cases of community-acquired COVID-19 were recorded in the U.S. (EveryCRSReport.com, 2020).

When asked if the U.S. had already moved from containment to mitigation phases of outbreak response, CDC director Dr. Robert Redfield stated that we are in "a blended containment/mitigation phase" as human cases increased across the U.S. (C-SPAN, 2020). Meanwhile, states and cities individually declared states of emergency, adopting policies and procedure uncoordinated with other states (Government of the District of Columbia, 2020).

Part 2: Pathogen Transmission Pathways and an All-Hazards Approach

Increasing cases demonstrate that the experts have neither fully assessed the virus risk yet, nor is there consensus on the methods to prevent its spread. WHO guidelines have no clear definition of a pandemic and its pandemic alert seven-phase descriptions are influenza specific (WHO, 2009). Current biosurveillance is inadequate—creating vulnerabilities to future epidemics by novel pathogens—and public health messaging about zoonotic disease reservoirs and modes of transmission is lacking (Eddy, Sase, & Schuster, 2010; Eddy, Stull, & Balster, 2013).

An Equivocal Source of a Pandemic

The origin of SARS-CoV-2 is still being investigated, including "…wild animals sold illegally in the Huanan Seafood Wholesale Market" (Huang, 2020; Tan et al., 2020). Considering the biological evolution of COVID-19, WHO finds that although the novel pathogen, SARS-CoV-2, moved from animal to human reservoirs, the intermediate host animal has not been identified, stating that it could be "a domestic food animal, a wild animal, or a domesticated wild animal which has not yet been identified" (WHO, 2020d). WHO is investigating the capacity for food to directly, and indirectly through cross-contamination, transmit COVID-19 if mishandled (WHO, 2020d). New research supports the concept of food as a pathogen transmission source (Pung et al., 2020).

Pathogen Transmission Pathways

SARS-CoV-2 transmission pathways have not been clearly identified, although body fluids are specifically mentioned and the importance of sanitizing services is emphasized in definitive guidance documents from U.S. agencies (CDC, 2020b; Pung et al., 2020). CDC reports that "like other close-contact environments, ships may facilitate transmission of respiratory viruses from person-to-person through exposure to respiratory droplets or contact with contaminated surfaces" (CDC, 2020b), which

would account for other indirect contact pathogen transmission pathways in the cruise ship outbreaks that directly amplified pandemic COVID-19 (Carlton, 2020; Pung et al., 2020). Mounting evidence shows the association of gastrointestinal/fecal-oral SARS-CoV-2 transmission capacity (Gu et al., in press; Pung et al., 2020; Xiao et al., in press), which would also account for other aspects of cruise ship onboard pathogen transmission and should be added to pandemic mitigation strategies. Similar to some influenza strains, there is evidence that shows the conjunctiva of the eye to be a primary point of infection, thus necessitating the reevaluation for eye protection in the hazard vulnerability assessment process of an unknown pathogen (Besler, Lash, Garg, Tumpey, & Maines, 2018; Chang, Xu, Rebaza, Sharma, & Dela Cruz, 2020; Yan, 2020).

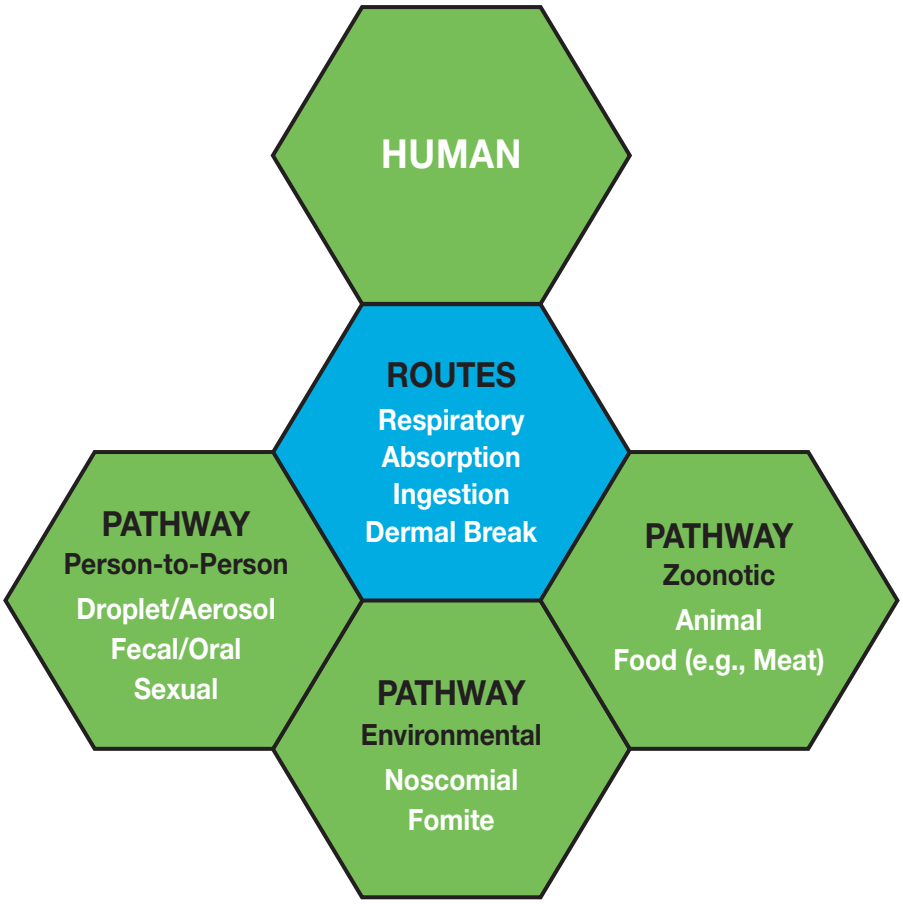
In our previous article on the Ebola virus and in our forthcoming article on the Zika virus, we establish transmission pathway descriptions and associated hazard vulnerability assessments that drive selection of personal protective equipment (PPE) according to assessed and expected worker hazards (Eddy & Sase, 2015a, 2020), which might be highly applicable to pandemic COVID-19. Regarding the Zika virus, we report relevant descriptors that should be clarified to include discussion about fecal-oral pathways and fomites, such as car keys, charge and ID cards, smartphones, purses, and luggage, in plain language that must drive effective public health outreach to correctly educate the public in order to advocate positive community behaviors (Eddy & Sase, 2020).

In this editorial, we characterized pathogen transmission pathways of COVID-19 and epidemiological commonality from a literature review—reservoirs (e.g., food and pets), hosts (e.g., recipient and amplifier), and points of environmental contamination (e.g., fecal-oral and fomite), among many other terms—to describe pathogen transmission pathways. We organized known descriptors into three categories (zoonotic, person-to-person, and environmental contamination) with discussion of infection dynamics below.

Our nomenclature system unifies veterinary, environmental public health, and medical terminology with a simplified categorization of transmission pathways to enable effective prevention strategies that follow One Health ideologies (Eddy et al., 2013; Nolen, 2007). In the absence of consensus regarding human, animal, and environmental transmission dynamics, Figure 1 clarifies our perspective of pathogen transmission pathways, generally and as applicable to pandemic COVID-19, as a possible model to be used for PPE selection at residential and institutional levels.

FIGURE **1**

Pandemic Coronavirus Disease 2019 (COVID-19) Potential Pathogen Transmission Pathway Model



Human

Variably identified descriptors, such as close contact, has led to vague and politically sensitive public health outreach messaging (Eddy & Sase, 2020). In several studies performed during the 2003 SARS global epidemic, SARS was identified in 100% of patient stool samples (WHO, 2003). As researchers struggle to identify and differentiate potentially mutated COVID-19 viral strains, well-documented initial onset of disease in Wuhan, China, included diarrhea and other gastrointestinal symptoms (Li et al., 2020; Phan et al., 2020; Tang et al., 2020; Zhang et al., 2020). COVID-19 has been detected in feces and urine, through sexual contact, and from fomite and contaminated surfaces, which are all factors to consider in nosocomial source transmission (National Health Commission of China, 2020; Pung et al., 2020).

Snohomish County Health Department in the State of Washington, sharing a border with nearby King County, reported its first human COVID-19 case on January 21, 2020 (Q13 News Staff, 2020). In a press release published on February 29, 2020, the county reported a positive case in a high school student but provided no advancement of preventive pathogen transmission strategies, stating that "this case suggests that local transmission of COVID-19 is occurring" (Snohomish Health District, 2020). The State of Washington governor proclaimed a state of emergency on February 29, 2020, (State of Washington, 2020). On March 18, 2020, the city of Kirkland, located in King County, reported 562 COVID-19 cases and 56 deaths in Seattle and King County, including 35 of those cases (10 of which were fatalities) linked directly to the Life Care Center of Kirkland nursing home (City of Kirkland, 2020; Walker, 2020). Observing the presence of COVID-19 within institutions such as hospitals and nursing homes, nosocomial infection prevention strategies must be in a heightened state of readiness.

The first two human COVID-19 cases in San Francisco reported on February 5, 2020, were not related and did not share common contacts with known COVID-19 positive cases or with people who had recently traveled to nations experiencing epidemics. The infectious disease pathway is described as community transmission (Holmes, 2020).

Regarding cruise ships as amplifiers of disease, applicable and relevant guidelines from CDC state the following, "Like other close-contact environments, ships may facilitate transmission of respiratory viruses from person-to-person through exposure to respiratory droplets or contact with contaminated surfaces" (CDC, 2020b). According to CDC (2017a), "Quarantine separates and restricts the movement of people who were exposed to a contagious disease to see if they become sick."

Quarantine has become a major part of the multinational mitigation effort to control pandemic COVID-19. Millions have been quarantined on multiple continents. This process of separation has been applied to cities and regions of the world in this pandemic. It is unclear if it has worked and it is clear that human rights are severely impacted by the quarantine process. First introduced by the Venetians in the 14th century, ships were made to wait 40 days at anchor (hence *quaranta*, which is forty in Italian) before being allowed to dock. It was codified in the U.S. originally in 1878 and has been modified a number of times since (CDC, 2012). During the mass immigration to the U.S. in the 19th and early 20th centuries, it was used extensively to attempt to limit the arrival of people with contagious diseases from entry into the country. Although Ellis Island is famous as the entry point for so many in the U.S., Hoffman and Swinburne Islands in New York Harbor were dreaded by those arriving from overseas as they became quarantine sites for those suspected of contagious diseases (ellisisland.se, 2006).

To prevent worker exposure to a pathogen, both international and national occupational health authorities require a provision of PPE and training on how to carefully operate and don and doff the equipment (CDC, 2017b, 2020c, 2020d; Occupational Safety and Health Administration, 2020). There are numerous reports of healthcare workers infected while being at the frontline of COVID-19 containment and mitigation (Chang et al., 2020; Klompas, 2020; Wee & Wang, 2020). Dr. Li Wienliang (33 years old) died on February 7, 2020, in Wuhan, China, while engaged in the treatment of COVID-19 patients (Green, 2020).

In some cases, healthcare workers continued to perform their services after developing COVID-19-like symptoms (Kim, 2020). This trend suggests that an already strained healthcare workforce (e.g., due to shortage issues) is not able to take sick leave. Nevertheless, if healthcare workers continue to provide service, they could be at higher risk of infecting vulnerable populations such as older adults with existing conditions. Moreover, nearly 20% of home-care workers lack health insurance (PHI, 2018), which makes it difficult for them to seek medical care.

Furthermore, this situation might significantly increase required epidemiological work, such as contact tracing (e.g., at outpatient clinics) as it has been done at a number of healthcare facilities. Additionally, according to the U.S. Bureau of Labor Statistics (2017), 46% of workers in service occupations and 47% of workers in construction, extraction, farming, fishing, and forestry occupations have no sick leave benefit entitlements. Therefore, some people will not be financially able to stay home when sick. A particularly large percentage of that population might be involved in the service supply chains, involved directly in food service, lodging, sanitation processes, and various aspects of the transportation and entertainment industries.

Environment

While coronavirus survival in general is known to be limited by conventional cooking temperatures (heat labile), survival on frozen foods might extend for years (WHO, 2020d). New research showing that SARS-CoV-2 can survive on hard surfaces for up to 9 days must be taken into consideration in the adequacy of PPE and prevention/avoidance guidelines (Kampf, Todt, Pfaendar, & Steinmann, 2020). Potential fomites, or contaminated environmental surfaces, can be identified and controlled, such as currency, printed media, etc.

Both nosocomial disease (hospital-acquired infection) and notorious outbreaks of norovirus and other unidentified pathogens on cruise ships are well-documented (CDC, 2020e; Eddy & Sase, 2015a). The closest comparators to COVID-19 are SARS and Middle East Respiratory Syndrome (MERS): 58% and 70% of cases were nosocomially transmitted, respectively (Munster, Koopmans, van Doremalen, van Riel, & de Wit, 2020). Asymptomatic transmission might severely complicate quarantine and pathogen transmission strategies (Nishiura, Linton, & Akhmetzhanov, 2020; Pung, 2020).

Animal

As in the case of Ebola and Zika, the bat has been determined to be the primary reservoir of SARS-CoV-2. Exotic animals sold at the Huanan Seafood Wholesale Market in China were identified as the probable source (Tan et al., 2020; Tang et al., 2020; WHO, 2020e).

Recognizing that animals, specifically pets, are part of the community pathogen transmission calculus, CDC guidelines have been established for people infected with COVID-19. Symptomatic patients should "avoid direct contact with pets, including petting, snuggling, being kissed or licked, and sharing food. Service animals should be permitted to remain with their handlers" (CDC, 2020f). The Global Research Collab-

oration for Infectious Disease Preparedness determined that future COVID-19 research must key upon "the natural history of the virus, its transmission and diagnosis, and animal and environmental research on the origin of the virus, including management measures at the human–animal interface" (WHO, 2020f).

Hazard Severity and Risk Assessment

The thrust of this editorial centers from an all-hazards perspective: the source of the biological hazard must be well understood to initiate the most effective prevention, containment, and mitigation strategies, especially regarding public health outreach messaging and associated recommended PPE. From an all-hazards perspective, the greatest separation between SARS-CoV-2 and H1N1is knowledge and vaccination capacity (CDC, n.d.), while acknowledging much knowledge regarding H1N1 but little regarding SARS-CoV-2. Aside from the obvious unavailability of a vaccine for SARS-CoV-2, it is possible that multiple strains can present with different sets of epidemiological factors (Tan et al., 2020; Tang et al., 2020).

Our forthcoming articles state that the Zika virus brought microcephaly in human babies, human sexual transmission, and adult onset of neurological symptoms into the severity calculus, and that previously held understandings of West Nile virus-impacted human age spectrum was broader than previously believed (Eddy & Sase, 2020). When assessing the severity of a novel hazard, such as pandemic COVID-19, unknown characteristics such as long-term consequences, vulnerabilities, uncertainties, and hazard characteristics must be anticipated in the risk assessment process (Eddy & Sase, 2015a, 2015b).

The Occupational Safety and Health Administration's Occupational Safety and Health Standards (2013) provide strictly enforced guidelines that require employers to fully evaluate the PPE need of employees based specifically upon the analysis of hazards anticipated in the workplace, including various vulnerabilities that should be reasonably anticipated (Eddy & Sase, 2015a). The 2014 U.S. Ebola crisis in Dallas, Texas, provided ample lessons learned regarding the insertion of a not well anticipated pathogen into the U.S. healthcare system. Adequacy of PPE was argued at federal, state and local agency levels. The National Nurses United (2020a) reports that dozens of healthcare workers have been exposed to pathogens due to employers' lack of protections. It surveyed 6,500 nurses nationwide and found that only 30% of the nurses' employers have sufficient PPE stock if a rapid surge in patients with possible COVID-19 infections occurs (National Nurses United, 2020b).

It is also recommended that preparatory protection be utilized by symptomatic patients to avoid infection of their pets (CDC, 2020f), revealing the necessity to include zoonotic disease discussion in public health outreach communications as a core aspect of the One Health concept.

In the U.S., the public health message to prevent COVID-19 parallels the prevention strategy for influenza, although forming characterization of COVID-19 reveals pathogen transmission pathways that could challenge conventional strategies, such as stay home when sick, coughing into the elbow, and other social distancing strategies.

Conclusion

All phases of disaster planning and public health emergency response, including the opportunity for prevention, containment, and mitigation, from an all-hazards and public health combined perspective require the best available characterization of the pathogen (hazard) transmission pathways. Additionally, significant social economic factors, such as sick leave availability in the industry that can directly and indirectly impact the chain of pathogen transmission in the community, must be taken into consideration when reassessing public health countermeasures.

Like SARS-CoV-1, Ebola, Zika, and avian influenza global public health emergencies, pandemic COVID-19 began in animals and we must not underestimate their impact upon our own infection control practices. Animals and humans can cause human infection directly and indirectly while asymptomatic. Although asymptomatic pathogen transmission pathways must be better understood through further study (Pung et al., 2020), it might prove to provide invaluable evidence for future public health community outreach. Contact with urine, feces, and vomit can cause infection as aerosolized transmission is possible. A new international prevention message that recognizes an expanding universe of avoidable infection pathways and guides people toward ways to prevent disease in their communities is essential to reducing future outbreaks of zoonotic pathogens.

Continuing to empower vulnerable populations and the general public with the knowledge to prevent and control infectious disease is crucial. It will avert unnecessary quarantine enforcement, which is a primary public health defense especially in the absence of an effective vaccine or authorized treatment. Future study should attempt to consolidate the broad language presently utilized to describe pathogen transmission pathways and motivate public health, medical, and veterinary professionals toward a rational discussion of pathways as promoted by the environmental health profession and the concept of One Health (CDC, 2020g).

In this editorial, we provide information that might enable community health initiatives to bolster individual readiness, independent of agency. As the international and national response mission shifts from pathogen containment to mitigation phases of response toward recovery, we posit that containment/mitigation processes can be shortened by effective prevention strategies developed and leveraged across the preparedness and response continuum.

We should enable all people, including those who are immunocompromised such as people living with HIV and/or cancer, to be able to make the best choices about infection prevention in their homes and communities. In the midst of a novel infectious disease pandemic, such as pandemic COVID-19, people need information regarding health determinants, which are outside individual control. Public agencies managing environmental and community health must provide up-to-date information and science-based guidance to the public in a timely manner.

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Did You Know?

NEHA has created a COVID-19 resources page for environmental health professions at www.neha.org/covid-19. The current resources page provides links to pandemic situation reports; information about the disease; guidance for work, schools, and homes; food safety; and related *Journal of Environmental Health* articles. The page will be updated as more information and resources become available.