Journal of
Advances in Environmental Health Research

Summer 2022. Volume 10. Number 3

Review Paper

Perceiving Effect of Environmental Factors on Prevalence of SARS-Cov-2 Virus and Using Health Strategies: A Review

Mahmood Alimohammadi[1, 2, 3], **Samaneh Abolli**[1*], **Esfandiar Ghordouei Milan**[1]

1. Department of Environmental Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran.
2. Center for Water Quality Research, Institute for Environmental Research, Tehran University of Medical Sciences, Tehran, Iran.
3. Health Equity Research Center, Tehran University of Medical Sciences, Tehran, Iran.

Use your device to scan and read the article online

Citation Alimohammadi M, Abolli S, Ghordouei Milan E. Perceiving Effect of Environmental Factors on Prevalence of SARS-Cov-2 Virus and Using Health Strategies: A Review. Journal of Advances in Environmental Health Research. 2022; 10(3):187-196. http://dx.doi.org/10.32598/JAEHR.10.3.1266

http://dx.doi.org/10.32598/JAEHR.10.3.1266

Article info:
Received: 03 Jan 2022
Accepted: 23 Feb 2022
Publish: 01 Jul 2022

Keywords:
SARS-CoV-2, COVID-19, Environment, Environmental health, Health

ABSTRACT

Newly emerged SARS-CoV-2 virus has been identified in China since 2019 and is still progressing as a tense threat to the human health worldwide. This virus can cause an acute respiratory infection and lead to death under acute circumstances. To describe the environmental factors affecting the prevalence of the disease as well as make an appropriate health strategy, some databases were reviewed. Coronavirus is mainly transmitted by direct contact through respiratory droplets. It can also be transmitted through secondary routes such as air, close contact and contaminated surfaces. The transmission through food has not been conclusively proven, but there are concerns about the food preparation, storage, infected staffs and improper use of personal protective equipment as the source of infection. Some possible sources of transmission are the contaminated water and sewage, especially in the areas where patients have the symptoms of diarrhea and vomiting. In this study, we described the essential strategies in order to prevent the spread of COVID-19 disease. Based on the most important criteria, this study developed a prevention model and health strategy including updated training information, improvement programs, risk assessment, environmental monitoring, operational measures as well as supportive approaches and programs, which can be used step by step to reach a healthy environment, increase the compliance with protocols and, eventually, decrease the incidence of COVID-19.

*** Corresponding Author:**
Samaneh Abolli, PhD.
Address: *Department of Environmental Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran.*
Phone: *+98 (938) 719 8392*
E-mail: *samanehabolli@gmail.com*

1. Introduction

The coronavirus outbreak began in December 2019 in Wuhan, China that is rapidly spreading throughout the world [1]. This virus had a different behaviour against children and adults [2, 3] that caused a wide range of symptoms among the people. Earlier studies have considered several symptoms such as shortness of breath, cough, fever, body aches, and fatigue in order to diagnose this disease [4, 5].

In severe cases, the syndrome can result in pulmonary pneumonia and death. According to the World Health Organization (WHO), COVID-19 became a pandemic on March 11, 2020. Till August 31, 2021, there were over 216 million confirmed cases with more than 4 million death from the disease [6]. The disease is currently progressing in the world with a different geographical distribution [6, 7]. It is mostly transmitted through direct contact and respiratory droplets scattered in the air after coughing, sneezing, inhaling, and even talking. The transmission through aerosols generated by an infected person is affected by its source [8, 9]. In other words, the droplet size and diffusion/deposition behaviour of aerosols generated by the respiratory mechanism are different from those released after sneezing and coughing. Also, some factors such as sound type can affect the transmission. For example, some words and phrases can make a conical path and accelerate the transmission so that the generated air package is transferred to a further path [10]. In addition to the airflow velocity and turbulent intensity of the air mass exhaled by a patient, the rate and velocity of virus spread can be affected by the aerosol size and environmental conditions such as temperature and humidity [11, 12]. Therefore, given the drop suspension in the air for at least 30 minutes and survival of aerosols after deposition which is depend on the nature of host, the virus can also transmit through contact with the infected equipment [13, 14]. However, to judge about the incidence of this disease and its transmission through the food cycle requires further research. Several studies have criticised the direct transmission of coronavirus through food [15, 16].

Some studies have rejected the food as a main source of contamination. In other hand, some evidence suggest that the virus can survive at the ambient temperature of 4°C [17]. A study examined the extent of coronavirus degeneration. The results showed that SARS-Cov-2 aerosols were detectable after three hours at temperature of 21°C to 23°C and relative humidity of 65% [18]. Also, another study demonstrated that SARS-Cov-2 was an airborne infectious pathogen for 16 hours in under room conditions [19]. The COVID-19 virus can even survive on some surfaces, such as plastic bags for more than three days [4, 20]. Besides, there are still some concerns about the transmission through surfaces at the workplace, cooking area, food processing, and packaging [21-23]. For instance, in bakeries as a key source in the supply chain, particularly in the third world countries, the virus can be easily transmitted through handling cash and bread [14]. As a result, it is necessary to investigate the environmental health status in order to overcome to the outbreak.

According to the WHO's report, after the Delta variant, a new variant known as Lambda (lineage C.37) was first identified in Peru in April 2021 which was spread among 29 countries till August 30, 2021 [24, 25]. Given the increase in the pandemic waves, prolonged vaccination of the entire population, need for medicines and hospital beds, and the uncertainty about its eradication, it is therefore necessary to interrupt the transmission chain. Additionally, the researches on older variants (i.e., alpha and beta) have found that the new variants might be different from previous variants in terms of spread and infectious. It affects the efficacy of vaccination as well as function of drugs. Moreover, the burden of COVID-19 is much higher than previous outbreaks such as Severe Acute Respiratory Syndrome (SARS) [26]. So, it is necessary to adopt an appropriate strategy to prevent further spread of this pandemic.

This review covers new and valid studies in terms of period and perceiving the concept of environmental factors affecting the spread of the virus. It also covers the studies in which the most important preventive health strategies of the virus has been addressed.

2. Results and Discussion

Literature review

SARS-CoV-2 belongs to the coronavirus family that can cause an acute respiratory-infectious syndrome in its host. The main route of the disease transmission is through close and direct contact with an infected individual. Indeed, the virus is mainly transmitted through respiratory droplets and aerosols scattered in the air after sneezing, coughing, inhaling, exhaling and talking [27]. Moreover, tools and equipment such as plastic, wood, metal, and glass can be a potential environmental source of virus [22] because the virus can be suspended, deposited, and survived from a few minutes to a few days after being released into the air in which the biological activity can be supported by the host [10].

Many countries suggested and adopted some strategies such as quarantine, restrictions, suspension of some businesses (e.g., restaurants and snack bars) and traffic ban between cities in order to control the coronavirus pandemic. In other hand, in many parts of the world, especially in developing countries, a full-lockdown is impossible. It is due to many intermediary jobs in these areas which are associated with manufacturing industries. So, their closure can result in rapid rise in prices and an economic blow to small production enterprises. Besides, the restaurants closure and lack of ready-to-eat foods can change the lifestyle and increase the demand for raw materials in the markets [28]. Whereas, "food safety" refers to a sufficient, available, and safe supply of nutritious food [29, 30]. As a result, the businesses closure and traffic ban strategies might lead to insufficient food supply followed by famine and food supply crisis [31, 32].

The pollution spread and possible risks can be detected by environmental monitoring in order to prevent the incidence of subsequent outbreaks [33]. To identify the change in the risk of a complex individuals behavior , it is important to pay attention to individual's attitude , degree of sensitivity and personal fear because the success of a policy-based program is depend on the parameters. Thus, it is necessary to have a health strategy with an appropriate cultural background in which the instructor can be a policymaker, physician and news presenter [34, 35]. In this section, the environmental factors affecting the prevalence of COVID-19 and the most important controling strategies for these factors are listed.

Proposed strategies

Training

A person's attitude towards coronavirus disease is affected by the person's knowledge of the prevalence and side effects as personal fear. Training and increasing the knowledge using modern tools and attracting people's attention by a health connoisseur as an environmental health expert can be effective [36, 37]. A study conducted in Philippines and Sri Lanka to examine the quality of guideline processing during the COVID-19 pandemic, showed that the guideline development during a pandemic requires a rugged and time-sensitive model. They highlighted that the protocols must be dropped in a collaborative or co-design process and take account for the value of existing national responses [35].

Providing the latest accurate information

Constant updating of the latest health protocols as well as environmental health status of the community using a trustful organization such as the WHO or local organizations promotes the public health information of individuals, which can increase the health level in a community [34, 38]. The study conducted by Raza et al [36] recommended to provide clear guidelines and social electronic media in local languages. The knowledge about COVID-19 transmission, signs, and safeguards is also an effective approach. It is suggested to include the causes, symptoms, and precautions of viral diseases in the academic syllabus.

Personnel screening

The personnel screening can be done daily using a mercury thermometer or rifle and infrared thermometer that does not require touching .However, real-time RT-PCR testes should be also done to confirm the patient [39]. It is also suggested that the personnel involved in a final stage of the food production cycle, such as those working in a bakery, restaurant or snack bar, are in the priority for vaccination because the vaccine reduces the risk of infection, hospitalization and death. It can also be effective for the new variants of the virus such as lambda [40].

Hospitality, selection, and settlement

Based on the previous evidences, the need for some materials, such as vitamin C and zinc is increased during the pandemic [41]. Additionally, many employers depend on restaurants or package food to provide the meals for their staffs. Management approaches and smart strategies such as electronic menus, credit card payment, or codes, money transfer apps and touch-free payment are suggested to prevent the contact with unnecessary contaminated equipment. This can also reduce the need for disinfecting surfaces that are likely to be contaminated [42, 43].

Social distancing and lockdown

Staying at home and avoiding unnecessary exposure to the virus sources can be an effective strategy to reduce the prevalence of coronavirus [44]. However, working from home is not possible for many businesses (e.g., supply chains). If someone is unconsciously infected with coronavirus (i.e., the infected person who is in the incubation period with no clinical symptoms), the contaminated droplets and secretions can be produced through talking, breathing and sneezing which

can infect other staff and even service recipients. Additionally, COVID-19 aerosols can be suspended in the air and settled on the equipment before being degraded and evaporated. Also, many surfaces such as wood, plastic and metal artifacts can keep this virus alive for several hours [45]. Therefore, a possible spread way of the virus can be through equipment. To prevent this transmission route, the strategies of regular examination of personnel and reduced working hours per shift are essential [46-48]. However, some staffs might be absent in workplace due to coronavirus disease and accordingly the public demand is increased. So, the full-time presence of workforce is essential. Consequently, the previous method might not be very effective, and a business requires more cost-effective method, such as using personal protective equipment (PPE), social distancing, regular disinfection of workplace, ventilation and sunlight improvement [14, 49-51]. Random degradation in the nucleic acid occurs at low temperatures. Also, the change in the syntax of the virus constructional proteins occurs when the temperature is at high level which leads to the virus inactivation [52].

There is a significant relationship between overcrowding of social distancing and increased coronavirus transmission rate [51, 53, 54]. The study conducted by Yan et al. [48] among the American population showed that the reaction to stay-at-home mandates increased the time spending at home. Implementing stay-at-home guidelines needs the individuals voluntary partnership which can lead to a shift in people's behaviour. Therefore, given a distinct place for changing staff's uniforms, to keep a distance of at least 2 m or 6 feet between people [9, 55], , proper disposal of personal PPE and using disposable equipment that are less hazardous to the environment are required to improve the environmental health level [56, 57]. All of these measures will be taken if there is an expert who does the training and monitoring of an appropriate implementation of health protocols at all stages [58, 59].

Risk assessment

To reduce the possibility of coronavirus transmission through water and food cycles, it is necessary to use the framework and standards suggested by WHO, Food and Drug Administration (FDA) and Centers for Disease Control and Prevention (CDC). Hazard analysis and critical control points (HACCP) approach is one of the suitable programs to keep food safety from origin to destination. This program can be effective to decrease in the biological, chemical, physical and even radiological risks associated with a food supply chain. It can be applied in the sector of health facility providers. It can also promote the quality of final products and increase the satisfaction, particularly in emergency conditions such as coronavirus outbreak [14, 31, 60].

Contamination of water sources or improper disposal of wastewater can also be a potential risk factor [61]. To achieve a healthy water supply system, especially at the time of outbreaks, a powerful risk assessment and management tool, such as Water Safety Plan (WSP), can be used. The advantage of using this program is risk identification, decrease in potential hazards, water quality improvement, better perception of risk management and appropriate reaction in emergencies. Therefore, the above approaches might be used to provide healthy water and food during the COVID-19 outbreak [62].

Personal hygiene

Although it is not still clear that COVID-19 disease is foodborne or waterborne, the WHO emphasizes that hands play a key role in transmitting the virus, and there is a high risk of transmission through food and packaging. In addition to covering of mouth and nose when preparing a portion of food, the hands must be washed frequently and correctly using soap for at least 20 seconds or disinfected using 70% alcohol [63].

Personal protective equipment (PPE)

To use disposable masks, face shields, robes, hats, gloves, and shoes can prevent the occurrence and spread of the disease [64, 65]. To evaluate the fitted filtration efficiency (FFE) of various consumer-grade and improvised face masks a study was conducted by Clapp et al [66] in 2020. The development of medical techniques to improve the mask fit can increase the filtering capability and reduce inhalation of airborne particles. The above mentioned study revealed that the FFEs of consumer-grade masks are almost equivalent or even more profitable than the non-N95 respirator medical mask in many cases.

Disinfection

Previous studies have shown that the virus can survive on some surfaces from several hours to several days [18]. Door knobs, drawers, cooking equipment, desks, sales counters, card readers, refrigerators, shelves and food containers are the most commonly used items, which can shorten the transmission route of the virus from an infected person to others. Throwing out additional equipment, secluding the workplace and disinfecting the surfaces are necessary to control the transmission route

[67]. Disinfectant solutions have an active agent that inhibits microbial survival and increases the environmental health. There is a wide range of disinfectant solutions, the instructions of which are provided by various sources. Disinfection and washing using chlorine-based solutions, such as calcium/sodium hypochlorite, ethanol, benzalkonium chloride, formaldehyde and hydrogen peroxide are suggested for areas with no potential risks [22]. Before disinfecting, it is important that the surfaces should be first cleaned and, then, the disinfectant should be sprayed properly [68, 69].

Prevention model and health strategy

Coronavirus pandemic has affected all aspects of human life and society. The diseases is transmitted through the infected person, air, and contaminated surfaces which have been confirmed by previous researches. In addition to spreading of COVID-19 disease through the main route (i.e., direct contact), there are still concerns about the transmission through secondary ways [70, 71].The side routes include airborne, fecal-oral, improper sewage disposal, and water contamination, specifically when the patients have symptoms of diarrhea and vomiting [72-74]. The results of the study conducted by Hu et al. [54] in Washington DC showed that the housing quality, living conditions, race, and occupation were strongly correlated with the deaths due to COVID-19 pandemic. The study showed that the building, social, and environmental variables were the strongest and most significant predictors of the deaths.

Although there is not enough evidence to prove the transmission of coronavirus disease through food, it might be transmitted through packaging, transportation, storage, sale, and consumption, because the cycle is affected by the interactions between the consumer and the environment [75]. On the other hand, previous studies have shown that overcrowding and non-compliance with social distancing considerably increase the prevalence of COVID-19 disease [43]. However, social distancing and local rules, such as lockdown, traffic ban, and reducing working hours are impossible in some countries, and if applicable, they can have a heavy economic burden [51, 76]. Guo et al. [77] have studied the factors that affect the social distancing among 2130 cases of the Chinese population in 2020. The results showed that 95.6% of participants agreed with social distancing and compared to men the females had more admired it. Some factors such as psychological distress, depressive signs, and social media were effective for the social distancing after controlling for other individual and environmental factors. The study also indicated that mental health quality and social media were significant factors of social distancing, which had accordingly an influence on improvement of prevention strategies to control the COVID-19 outbreak.

Thus, more flexible strategies should be considered in developing countries. Figure 1 shows some necessary factors for accurate decision-making and some health strategies for coronavirus control. To make a suitable decision in order to decrease the prevalence of coronavirus, to rely on health care and take account for environmental factors in addition to treatment methods are highly essential [78].

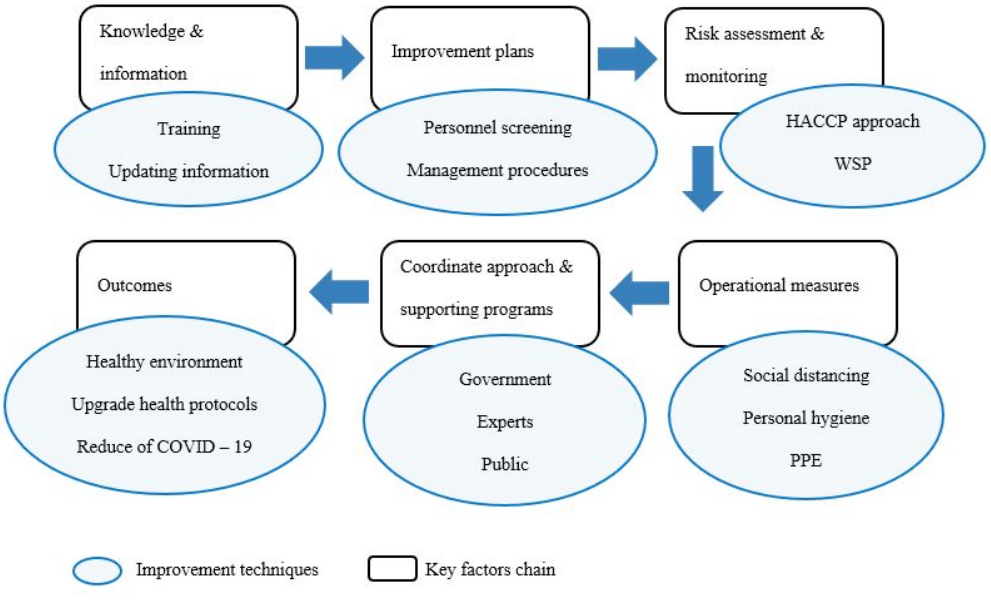

Figure 1. COVID-19 prevention model

To better understanding of the disease spread model as well as improvement in the people's attitudes, teaching the health protocols, including personal hygiene, correct use of personal protective equipment, especially masks and disinfection methods was considered in the first step. However, to inform and give the latest information produced by reliable sources to the community, such as number of the confirmatory tests, mortality, behaviour, and spread rate of disease in each region can be an accurate training method as well. The next strategy is to use improvement plans, such as staff screening and management approaches. In the next step, similar to HACCP a reliable risk assessment approach can be used. This approach is based on seven principles including identify the threatening risks of a system, such as the food supply cycle which leads to an acceptable reduction/control of risk. In addition to safety and reliability, the approach has archived some evidence that can be useful in tracking the contamination sources [79]. A novel risk assessment and management approach can be used to provide safe drinking water. The WSP can evaluate all components of a water supply system from the source to the point of use and ensure the safety of drinking water for consumers by identifying potential risks.

In the next steps, it is better to apply operational measures, coordinate approach and supporting programs. In addition to public cooperation, the participation of the government and systems managers (e.g., food suppliers) are required to implement these steps. To place these loops next to each other increase compliance with health protocols, create a safe environment, and finally reduce the spread of COVID-19 disease.

3. Conclusion

Since the incubation period might last 2-14 days , an infected person with the coronavirus can unknowingly transmit the disease to others. Early diagnosis, lockdown, and treatment can reduce the concerns about the disease. In other words, to control the environmental factors and apply uniform health strategies, such as social distancing, quarantine, health protocols, management approaches, attention to individual and community health, personal protective equipment, proper disposal of waste, risk assessment, identification and operational plans, the public education is essential. Consequently, we can overcome the disease using change in human behaviour, to understand the environmental factors, and apply practical strategies.

Ethical Considerations

Compliance with ethical guidelines

This article is a review with no human or animal sample.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

Conceptualization and Supervision: Samaneh Abolli; Methodology: Mahmood Alimphammadi; Literature search; Esfandiar Ghordouei Milan and Samaneh Abolli; Investigation, Writing–original draft, and Writing–review & editing: All author.

Conflict of interest

The authors declare no conflict of interest.

References

[1] Yousefi M, Oskoei V, Jonidi Jafari A, Farzadkia M, Hasham Firooz M, Abdollahinejad B, et al. Municipal solid waste management during COVID-19 pandemic: effects and repercussions. Environ Sci Pollut Res Int. 2021; 28(25):32200-9. [PMID]

[2] Cui X, Zhao Z, Zhang T, Guo W, Guo W, Zheng J, et al. A systematic review and meta-analysis of children with coronavirus disease 2019 (COVID-19). J Med Virol. 2021; 93(2):1057-69. [PMID]

[3] Gottlieb RL, Nirula A, Chen P, Boscia J, Heller B, Morris J, et al. Effect of bamlanivimab as monotherapy or in combination with etesevimab on viral load in patients with mild to moderate COVID-19: A randomized clinical trial. JAMA. 2021; 325(7):632-44. [DOI:10.1001/jama.2021.0202] [PMID] [PMCID]

[4] Alikord M, Molaee-aghaee E. Impact of COVID-19 pandemic crisis and food safety system: A literature review. Afr J Food Agric Nutr Dev. 2021; 21(6):18206-22. [DOI:10.18697/ajfand.101.20795]

[5] Chhikara BS, Rathi B, Singh J, Poonam FN. Corona virus SARS-CoV-2 disease COVID-19: Infection, prevention and clinical advances of the prospective chemical drug therapeutics. Chem Biol Lett. 2020; 7(1):63-72. [Link]

[6] World Health Organization (WHO). Coronavirus (COVID-19) Dashboard [Internet]. 2021. [Link]

[7] Karlinsky A, Kobak D. Tracking excess mortality across countries during the COVID-19 pandemic with the World Mortality Dataset. Elife. 2021; 10:e69336. [PMID]

[8] Ereth MH, Fine J, Stamatatos F, Mathew B, Hess D, Simpser E. Healthcare-associated infection impact with bioaerosol treatment and COVID-19 mitigation measures. J Hosp Infect. 2021; 116:69-77. [PMID]

[9] Guzman MI. An overview of the effect of bioaerosol size in coronavirus disease 2019 transmission. Int J Health Plann Manage. 2021; 36(2):257-66. [PMID]

[10] Delikhoon M, Guzman MI, Nabizadeh R, Norouzian Baghani A. Modes of Transmission of Severe Acute Respiratory Syndrome-Coronavirus-2 (SARS-CoV-2) and factors influencing on the airborne transmission: A review. Int J Environ Res Public Health. 2021; 18(2):395. [PMID]

[11] Bourouiba L. Turbulent gas clouds and respiratory pathogen emissions: Potential implications for reducing transmission of COVID-19. JAMA. 2020; 323(18):1837-8. [PMID]

[12] Balachandar S, Soldati A. Multiphase flow community must have a role in predicting host-to-host airborne contagion. Int J Multiph Flow. 2020; 132:103440. [PMCID]

[13] Zhang W, He H, Zhu L, Liu G, Wu L. Food safety in post-COVID-19 pandemic: Challenges and countermeasures. Biosensors (Basel). 2021; 11(3):71. [PMID]

[14] Dinçoğlu Ah, Rugji J. COVID-19 and food safety management systems. Turk Klin J Med Sci. 2021; 6(3):651-5. [Link]

[15] World Health Organization (WHO). COVID-19 and food safety: Guidance for food businesses. 2020. [Updated 7 April 2020]. Available from: [Link]

[16] Centers for Disease Control and Prevention (CDC). Division of foodborne, waterborne, and environmental diseases (DFWED) [Internet]. 2022. [Updated 14 September 2022]. Available from: [Link]

[17] Liu P, Yang M, Zhao X, Guo Y, Wang L, Zhang J, et al. Cold-chain transportation in the frozen food industry may have caused a recurrence of COVID-19 cases in destination: Successful isolation of SARS-CoV-2 virus from the imported frozen cod package surface. Biosaf Health. 2020; 2(4):199-201. [PMID]

[18] van Doremalen N, Bushmaker T, Morris DH, Holbrook MG, Gamble A, Williamson BN, et al. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. N Engl J Med. 2020; 382(16):1564-7. [PMID]

[19] Fears AC, Klimstra WB, Duprex P, Hartman A, Weaver SC, Plante K, et al. Comparative dynamic aerosol efficiencies of three emergent coronaviruses and the unusual persistence of SARS-CoV-2 in aerosol suspensions. MedRxiv. 2020; [In press]. [DOI:10.1101/2020.04.13.20063784]

[20] Iftekhar A, Cui X. Blockchain-based traceability system that ensures food safety measures to protect consumer safety and COVID-19 free supply chains. Foods. 2021; 10(6):1289. [PMID]

[21] Galanakis CM. The food systems in the era of the coronavirus (COVID-19) pandemic crisis. Foods. 2020; 9(4):523. [PMID]

[22] Kampf G, Todt D, Pfaender S, Steinmann E. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. J Hosp Infect. 2020; 104(3):246-51. [PMID]

[23] Mohammadi-Nasrabadi F, Salmani Y, Esfarjani F. A quasi-experimental study on the effect of health and food safety training intervention on restaurant food handlers during the COVID-19 pandemic. Food Sci Nutr. 2021; 9(7):3655-63.[PMID]

[24] World Health Organization (WHO). COVID-19 Weekly Epidemiological Update [Internet]. 2021 [Updated 19 January 2021]. Available from: [Link]

[25] Oróstica KY, Contreras S, Mohr SB, Dehning J, Bauer S, Medina-Ortiz D, et al. Mutational signatures and transmissibility of SARS-CoV-2 Gamma and Lambda variants. arXiv preprint arXiv:2108.10018. [Link]

[26] Kumar S, Singh R, Kumari N, Karmakar S, Behera M, Siddiqui AJ, et al. Current understanding of the influence of environmental factors on SARS-CoV-2 transmission, persistence, and infectivity. Environ Sci Pollut Res Int. 2021; 28(6):6267-88. [PMID]

[27] Stariolo DA. COVID-19 in air suspensions. arXiv preprint arXiv:200405699. 2020. [Link]

[28] Shereen MA, Khan S, Kazmi A, Bashir N, Siddique R. COVID-19 infection: Origin, transmission, and characteristics of human coronaviruses. J Adv Res. 2020; 24:91-8. [PMID]

[29] Globalchange: Climate and Health Assessment. Food safety, nutrition, and distribution. 2021. [Link]

[30] Cable J, Jaykus LA, Hoelzer K, Newton J, Torero M. The impact of COVID-19 on food systems, safety, and security-a symposium report. Ann N Y Acad Sci. 2021; 1484(1):3-8. [DOI:10.1111/nyas.14482]

[31] Alrasheed A, Connerton P, Alshammari G, Connerton I. Cohort study on the food safety knowledge among food services employees in Saudi Arabia state Hospitals. J King Saud Univ-Sci. 2021; 33(6):101500. [DOI:10.1016/j.jksus.2021.101500]

[32] Dumas B, Lee SH, Harris D, Pomeroy M, Yaroch A, Blanck H. Characteristics Associated with self-reported worry among adults about food availability and food safety during the COVID-19 pandemic -- United States, June 2020. Curr Dev Nutr. 2021; 5(S2):552. [DOI:10.1093/cdn/nzab043_004]

[33] La Rosa G, Mancini P, Bonanno Ferraro G, Veneri C, Iaconelli M, Bonadonna L, et al. SARS-CoV-2 has been circulating in northern Italy since December 2019: Evidence from environmental monitoring. Sci Total Environ. 2021; 750:141711. [PMID]

[34] Thomas MS, Feng Y. Consumer risk perception and trusted sources of food safety information during the COVID-19 pandemic. Food Control. 2021; 130:108279. [DOI:10.1016/j.foodcont.2021.108279]

[35] Haldane V, Ratnapalan S, Perera N, Zhang Z, Ge S, Choi M, et al. Codevelopment of COVID-19 infection prevention and control guidelines in lower-middle-income countries: The 'SPRINT' principles. BMJ Glob Health. 2021; 6(8):e006406. [PMID]

[36] Raza A, Ali Q, Hussain T. Role of knowledge, behavior, norms, and e-guidelines in controlling the spread of COVID-19: evidence from Pakistan. Environ Sci Pollut Res Int. 2021; 28(30):40329-45. [PMID]

[37] Simpson J, Gafson I, Mooncey M, Swart J, Fertleman C. Experiences of a new training programme for final-year medical students during the COVID-19 pandemic. Future Healthc J. 2021; 8(1):e23-e26. [PMID]

[38] Lauriola P, Martín-Olmedo P, Leonardi GS, Bouland C, Verheij R, Dückers ML, et al. On the importance of primary and community healthcare in relation to global health and environmental threats: lessons from the COVID-19 crisis. BMJ Glob Health. 2021; 6(3):e004111. [PMID]

[39] Chaimayo C, Kaewnaphan B, Tanlieng N, Athipanyasilp N, Sirijatuphat R, Chayakulkeeree M, et al. Rapid SARS-CoV-2 antigen detection assay in comparison with real-time RT-PCR assay for laboratory diagnosis of COVID-19 in Thailand. Virol J. 2020; 17(1):177. [PMID]

[40] Centers for Disease Control and Prevention (CDC). SARS-CoV-2 variant classifications and definitions [Internet]. 2021. [Updated 7 September 2021]. [Link]

[41] AlTarrah D, AlShami E, AlHamad N, AlBesher F, Devarajan S. The impact of Coronavirus COVID-19 Pandemic on food purchasing, eating behavior, and perception of food safety in Kuwait. Sustainability. 2021; 13(16):8987. [DOI:10.3390/su13168987]

[42] Sampath Kumar NS, Chintagunta AD, Jeevan Kumar SP, Roy S, Kumar M. Immunotherapeutics for COVID-19 and post vaccination surveillance. 3 Biotech. 2020; 10(12):527. [PMID]

[43] Saponara S, Elhanashi A, Gagliardi A. Implementing a real-time, AI-based, people detection and social distancing measuring system for COVID-19. J Real Time Image Process. 2021; 18(6):1937-47. [PMID]

[44] Gollwitzer A, McLoughlin K, Martel C, Marshall J, Höhs JM, Bargh JA. Linking self-reported social distancing to real-world behavior during the COVID-19 pandemic. Soc Psychol Personal Sci. 2022; 13(2):656-68.[DOI:10.31234/osf.io/kvnwp]

[45] Hwang SE, Chang JH, Oh B, Heo J. Possible aerosol transmission of COVID-19 associated with an outbreak in an apartment in Seoul, South Korea, 2020. Int J Infect Dis. 2021; 104:73-6. [PMID]

[46] Centers for Disease Control and Prevention (CDC). Interim guidance for businesses and employers to plan and respond to 2019 coronavirus disease 2019 (COVID-19), February 2020 [Internet]. 2021 [Updated February 26, 2020]. [Link]

[47] Centers for Disease Control and Prevention (CDC). What to do if you are sick [Internet]. 2022 [Updated 22 March 2022]. Available from: [Link]

[48] Yan Y, Malik AA, Bayham J, Fenichel EP, Couzens C, Omer SB. Measuring voluntary and policy-induced social distancing behavior during the COVID-19 pandemic. Proc Natl Acad Sci U S A. 2021; 118(16):e2008814118. [PMID]

[49] Dietz L, Horve PF, Coil DA, Fretz M, Eisen JA, Van Den et al. 2019 novel Coronavirus (COVID-19) pandemic: Built environment considerations to reduce transmission. mSystems. 2020; 5(2):e00245-20. [PMID]

[50] Eslami H, Jalili M. The role of environmental factors to transmission of SARS-CoV-2 (COVID-19). AMB Express. 2020; 10(1):92. [DOI:10.1186/s13568-020-01028-0] [PMID] [PMCID]

[51] Nakada LYK, Urban RC. COVID-19 pandemic: environmental and social factors influencing the spread of SARS-CoV-2 in São Paulo, Brazil. Environ Sci Pollut Res Int. 2021; 28(30):40322-8. [PMID]

[52] Aboubakr HA, Sharafeldin TA, Goyal SM. Stability of SARS-CoV-2 and other coronaviruses in the environment and on common touch surfaces and the influence of climatic conditions: A review. Transbound Emerg Dis. 2021; 68(2):296-312. [PMID]

[53] Ahmadi M, Sharifi A, Dorosti S, Jafarzadeh Ghoushchi S, Ghanbari N. Investigation of effective climatology parameters on COVID-19 outbreak in Iran. Sci Total Environ. 2020; 729:138705. [PMID]

[54] Hu M, Roberts JD, Azevedo GP, Milner D. The role of built and social environmental factors in COVID-19 transmission: A look at America's capital city. Sustain Cities Soc. 2021; 65:102580. [DOI:10.1016/j.scs.2020.102580]

[55] Chong KL, Ng CS, Hori N, Yang R, Verzicco R, Lohse D. Extended lifetime of respiratory droplets in a turbulent vapor puff and its implications on airborne disease transmission. Phys Rev Lett. 2021; 126(3):034502. [PMID]

[56] De-la-Torre GE, Rakib MRJ, Pizarro-Ortega CI, Dioses-Salinas DC. Occurrence of Personal Protective Equipment (PPE) associated with the COVID-19 pandemic along the coast of Lima, Peru. Sci Total Environ. 2021; 774:145774. [PMID]

[57] Haddad MB, De-la-Torre GE, Abelouah MR, Hajji S, Alla AA. Personal Protective Equipment (PPE) pollution associated with the COVID-19 pandemic along the coastline of Agadir, Morocco. Sci Total Environ. 2021; 798:149282. [PMID]

[58] Chowdhury T, Nandi S. Food safety, hygiene, and awareness during combating of COVID-19. In: Dehghani MH, Karri RR, Roy S, editors. Environmental and Health Management of Novel Coronavirus Disease (COVID-19). Amsterdam: Elsevier; 2021. pp. 305-24. [DOI:10.1016/B978-0-323-85780-2.00002-0] [PMCID]

[59] Duda-Chodak A, Lukasiewicz M, Zięć G, Florkiewicz A, Filipiak-Florkiewicz A. COVID-19 pandemic and food: Present knowledge, risks, consumers fears and safety. Trends Food Sci Technol. 2020; 105:145-60. [DOI:10.1016/j.tifs.2020.08.020] [PMID]

[60] Liu F, Rhim H, Park K, Xu J, Lo CK. HACCP certification in food industry: Trade-offs in product safety and firm performance. Int J Prod Econ. 2021; 231:107838. [DOI:10.1016/j.ijpe.2020.107838]

[61] Wang X, Wu F, Zhao X, Zhang X, Wang J, Niu L, et al. Enlightenment from the COVID-19 Pandemic: The roles of environmental factors in future public health emergency response. Engineering (Beijing). 2022; 8:108-15. [PMID]

[62] Tsitsifli S, Tsoukalas DS. Water Safety Plans and HACCP implementation in water utilities around the world: Benefits, drawbacks and critical success factors. Environ Sci Pollut Res Int. 2021; 28(15):18837-49. [PMID]

[63] World Health Organization (WHO). WHO save lives: Clean your hands in the context of COVID-19 [Internet]. 2020 [Updated 5 May 2020]. Available from: [Link]

[64] Bulfone TC, Malekinejad M, Rutherford GW, Razani N. Outdoor transmission of SARS-CoV-2 and other respiratory viruses: A systematic review. J Infect Dis. 2021; 223(4):550-61. [PMID]

[65] Simmons SE, Carrion R, Alfson KJ, Staples HM, Jinadatha C, Jarvis WR, et al. Deactivation of SARS-CoV-2 with pulsed-xenon ultraviolet light: Implications for environmental COVID-19 control. Infect Control Hosp Epidemiol. 2021; 42(2):127-30. [DOI:10.1017/ice.2020.399] [PMID] [PMCID]

[66] Clapp PW, Sickbert-Bennett EE, Samet JM, Berntsen J, Zeman KL, Anderson DJ, et al. Evaluation of cloth masks and modified procedure masks as personal protective equipment for the public during the COVID-19 pandemic. JAMA Intern Med. 2021; 181(4):463-9. [PMID]

[67] Center for Disease Control and Prevention (CDC). Cleaning and Disinfecting Your Facility [Internet]. 2021. [Updated 15 November 2021]. Available from: [Link]

[68] Ceylan Z, Meral R, Cetinkaya T. Relevance of SARS-CoV-2 in food safety and food hygiene: Potential preventive measures, suggestions and nanotechnological approaches. Virusdisease. 2020; 31(2):154-60. [PMID]

[69] World Health Organization (WHO). Cleaning and disinfection of environmental surfaces in the context of COVID-19 [Internet]. 2020. [Updated 16 May 2020]. Available from: [Link]

[70] Bhattacharjee S. Statistical investigation of relationship between spread of coronavirus disease (COVID-19) and environmental factors based on study of four mostly affected places of China and five mostly affected places of Italy. arXiv. 2020; [Preprint]. [Link]

[71] Qu G, Li X, Hu L, Jiang G. An imperative need for research on the role of environmental factors in transmission of novel Coronavirus (COVID-19). Environ Sci Technol. 2020; 54(7):3730-2. [PMID]

[72] Sajadi MM, Habibzadeh P, Vintzileos A, Shokouhi S, Miralles-Wilhelm F, Amoroso A. Temperature, humidity and latitude analysis to predict potential spread and seasonality for COVID-19. Preprint. 2020; 3550308. Published 2020. [DOI:10.2139/ssrn.3550308] [PMID] [PMCID]

[73] Lim YK, Kweon OJ, Kim HR, Kim TH, Lee MK. The impact of environmental variables on the spread of COVID-19 in the Republic of Korea. Sci Rep. 2021; 11(1):1-5. [Link]

[74] Bashir MF, Shahzad K, Komal B, Bashir MA, Bashir M, Tan D, et al. Environmental quality, climate indicators, and COVID-19 pandemic: Insights from top 10 most affected states of the USA. Environ Sci Pollut Res. 2021; 28(25):32856-65. [Link]

[75] Sim S, Wiwanitkit V. Food contamination, food safety and COVID-19 outbreak. J Health Res. 2021; 35(5):463-6. [DOI:10.1108/JHR-01-2021-0014]

[76] Tian L, Li X, Qi F, Tang QY, Tang V, Liu J, et al. Harnessing peak transmission around symptom onset for nonpharmaceutical intervention and containment of the COVID-19 pandemic. Nat Commun. 2021; 12(1):1147. [PMID]

[77] Guo Y, Qin W, Wang Z, Yang F. Factors influencing social distancing to prevent the community spread of COVID-19 among Chinese adults. Prev Med. 2021; 143:106385. [PMID]

[78] Lai THT, Tang EWH, Chau SKY, Fung KSC, Li KKW. Stepping up infection control measures in ophthalmology during the novel coronavirus outbreak: An experience from Hong Kong. Graefes Arch Clin Exp Ophthalmol. 2020; 258(5):1049-55. [PMID]

[79] Zhang QY, Liu LS, Liu ZJ. Application of safety and reliability analysis in wastewater reclamation system. Process Saf Environ Prot. 2021; 146:338-49. [DOI:10.1016/j.psep.2020.09.010]

This Page Intentionally Left Blank