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The 2019-nCoV epidemic control strategies and future challenges of building healthy smart cities

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The 2019 Novel Wuhan Coronavirus (2019-nCoV) epidemic (namely COVID 19) was first reported and confirmed on 31 December 2019, in Wuhan, Hubei Province, China, which is one of China's largest cities and a major domestic transport hub (located in the central part of China, as shown in Figure 1).[1] The epidemic is attracting worldwide concern due to its rapid spread and transmission rate between humans. On 30 January 2020, the International Health Regulations, Emergency Committee of the World Health Organization (WHO) declared the outbreak – a 'public health emergency of international concern'.[2] On 8 February 2020 (24:00 GMT + 8), there were 37,198 confirmed infections in China (including 811 deaths with a death ratio of 2.1%; and 6188 patients were confirmed in serious condition and 28,942 suspected cases).[3] The COVID 19 infections were also reported in 26 other countries on 7 February 2020, including Canada, the USA, Australia, India, Sri-Lanka, Cambodia, Thailand, Vietnam, Malaysia, Singapore, Taiwan, the Republic of Korea, Sri Lanka, Japan, Philippines, Nepal, United Arab Emirates, Russia, Italy, Germany, Sweden, Finland, Belgium, Spain, France and the UK.[4]

The coronavirus outbreak reminds us of the many feared and uncertainties that were reported at the peak of the severe acute respiratory syndrome (SARS) crisis in 2003 and some guidance for transmission prevention have been published.[5–8] An estimate of the virus' negative economic impact shows a decline of one percentage point in the growth rate of the Chinese Gross Domestic Product (GDP) in the first quarter of 2020.[9]

The rapid spread of the infection and the high level of morbidity associated with the COVID 19 epidemic is calling for a rapid and strict implementation of the appropriate control measure. The risk from the outbreak depends on whether and how well the virus are spread between people.[10] The outbreaks of the severe virus infection in past decades are all very closely related to the transmission between person to person in indoor environment, such as the 2003 SARS epidemic, the 2009 H1N1 influenza pandemic and the 2014 Middle East respiratory syndrome (MERS) epidemic.[11]

Transmission of COVID 19

Much is unknown about the transmissibility, severity and other features associated with COVID 19 and investigations are ongoing.[12] Current knowledge of the transmission pathways of the new coronavirus is largely based on current epidemiological observations and what is known about similar coronaviruses. The contact transmission and droplet transmission are currently considered as the two likely main transmission pathways of COVID 19 from person to person.[12] The spread is thought to occur largely via infectious respiratory droplets expelled from infected individuals. Droplets containing infectious pathogens can settle at mouths or noses of persons nearby or be inhaled directly to the lungs, leading to the infection of the person with the disease. Another possible way is through direct contact by hands with the polluted surfaces or objects having virus on them. The virus may further enter the eyes, mouth or nose by hand touching. These two ways belong to short-range routes of pathogen transmission, which require close contact among people (about 1.5 m).[13] Figure 2 shows the short-range transportation of exhaled flow between two individuals

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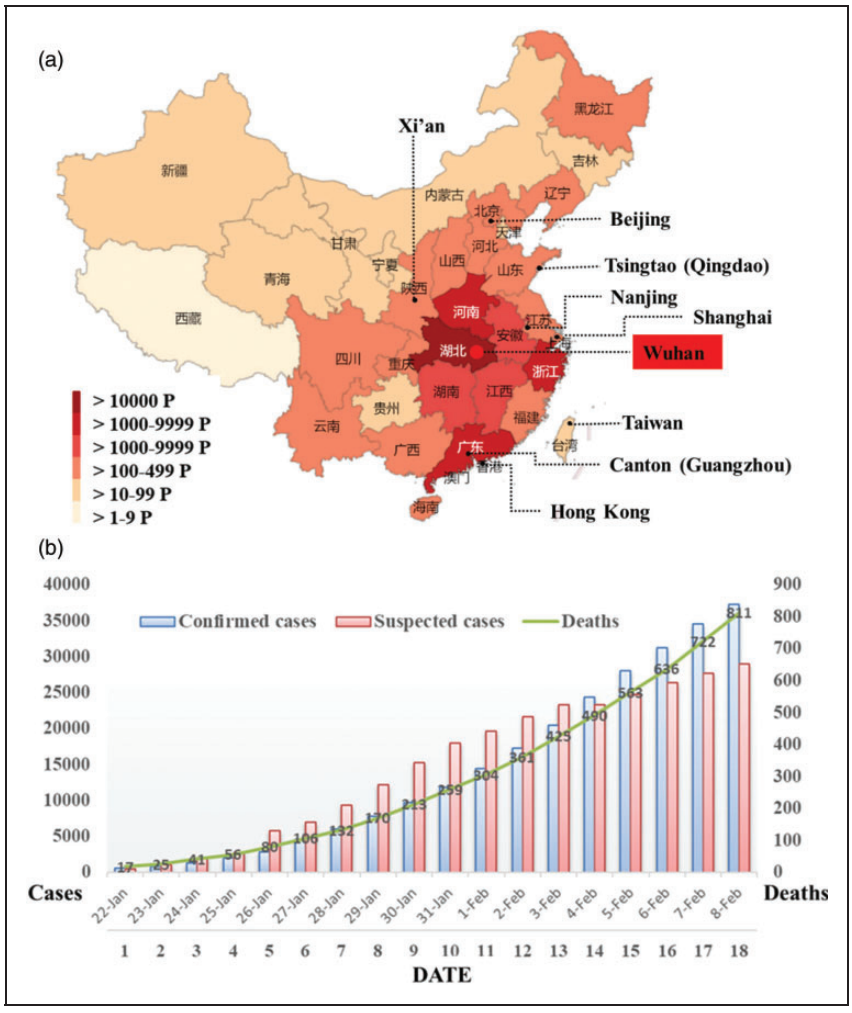

Figure 1. The outbreak map of the COVID 19. (a) the number of cases for confirmed and suspected cases.[3]; (b) The COVID 19 epidemic trends in China (up to 8 February 2020)[15].

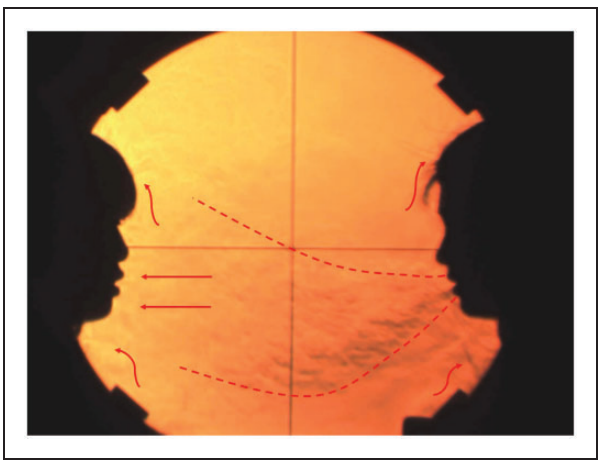

Figure 2. Exhaled flow dispersion between occupants in close proximity.[14]

and the reachable region of the exhalation from an infector could become the infection prone zone.[14] Figure 3 shows the possible pathways of transmission of COVID 19. The virus could also be attached to clothing and be transmitted via contact and again this will need to be proven.[16]

There should also be special consideration on the possibility of faecal transmission since recently the COVID 19 virus were tested positive in the infector's faeces. The aerosols generated from the infectious faeces may also cause infection.[17] The transmission of virus in sewage containing faecal matters transported in drainpipe in multi-storey high-rise buildings is a possibility.[18]

The indirect long-range route of transmission (droplet nuclei transmission or aerosol transmission) is a possibility and could occur but this is currently

unconfirmed and needs to be proven.[19] However, there are still concerns about the long-range transmission because the new coronavirus was recently found to survive within few hours in an appropriate environment. The transmission of airborne pathogenic agents and dispersion route between neighbouring apartments in the re-entrance space of a high-rise residential building in Hong Kong was reported in 2010.[20] The wind-driven inter-unit dispersion of pathogens around multi-storey buildings has also been reported.[21] Also, Ito[22] reported multi-scale transmission of pathogens in indoor spaces. The indoor and outdoor transportation and risk of influenza aerosol exposure was evaluated by Liu and You.[23] The virus could possibly cling onto small particles and be transported in the air to a long distance.

Personal prevention

There is currently no vaccine to prevent COVID 19 infection and complete prevention is difficult, but this airborne disease is treatable and there are ways to reduce exposure to this virus. The US Centers for Disease Control and Prevention (CDC)[24] recommends good sanitary habits to reduce the infection risk, such as regular hand-washing with detergent, wear hospital mask in public, people need to cover their mouth with an elbow or tissue when sneeze and cough, touched objects and surfaces should be cleaned and disinfected and there should be frequent and appropriate ventilation with sufficient outside air, etc.

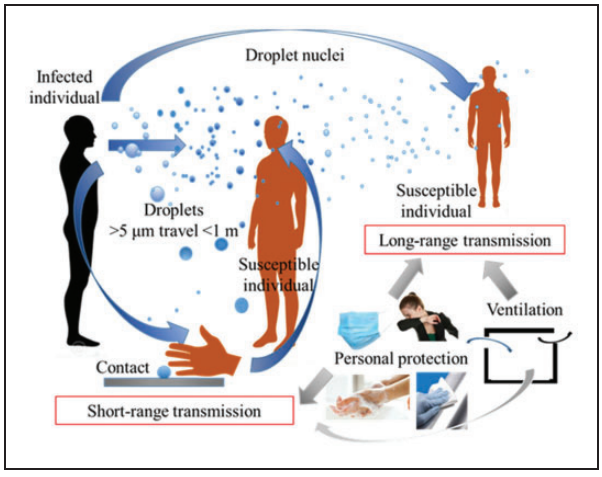

Figure 3. Possible transmission pathways of COVID 19 and personal prevention.

Engineering prevention of airborne transmission in buildings

Although there is currently no evidence supporting aerosol transmission of COVID 19, there are still concerns about this transmission mode. Several other airborne diseases, like influenza, SARS and smallpox were concluded as aerosol transmissible.[25] Engineering practices applied to reduce the infection risk of these airborne diseases should be also applied for this new coronavirus, particularly ventilation control in a hospital should be a major consideration.[26–28] Figure 4 shows the airborne infection routes and the various engineering control method that could affect the long-range dispersion pathway in buildings.[29]

For public buildings, two basic principles should be considered to minimize the cross infection between different rooms and occupants: (1) fresh air should be applied to the maximum amount of the designed ventilation system and if possible use full fresh air system; and (2) recirculated air should be filtered with a high efficiency filter before use. Current ventilation design is mainly intended to maintain good thermal comfort and indoor air quality for occupants. Advanced ventilation strategies should be further developed, aiming at reduce cross infection risk and combining the consideration of thermal comfort and energy saving.[30,31] Except for air dilution method, other disinfection and cleaning methods including mechanical air filters,

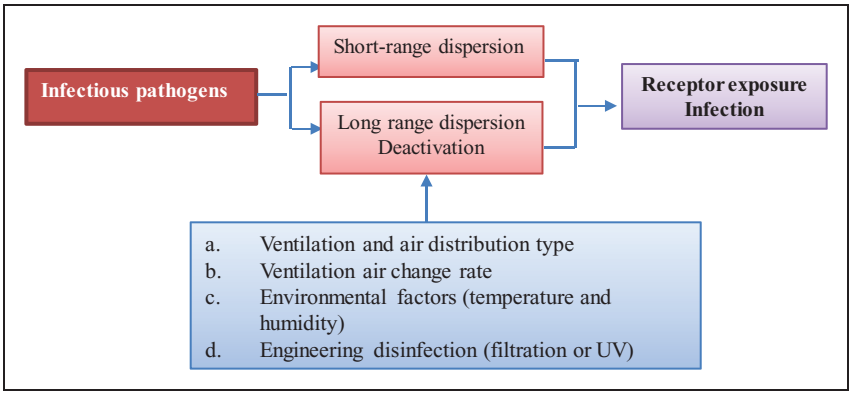

Figure 4. Airborne infection pathways and engineering controls.

ultra-violet (UV) germicidal irradiation, high-efficiency particulate air (HEPA) filters and ion generators should be used to keep the air as free of pollutants and pathogens as possible.[32,33]

Proposed research topics based on the built environment perspectives

Respiratory droplets with different sizes may have different impacts during the transmission process of respiratory infectious diseases.[30] The investigation of their dominant transmission route/routes, the dispersion and infection characteristics of different sizes of droplets are of great importance to further understand and aid the provision of efficient control to reduce transmission of the disease.[33] The evaporation, dispersion and deposition process of respiratory droplets should be evaluated after being expelled, experimentally or numerically.[34] The multi-effects of ventilation, ambient environmental control (e.g. temperature and humidity) on the transmission of droplets should be fully investigated. Droplets containing infectious pathogens are difficult to be directly monitored with existing techniques. However, the indoor ventilation system can continuously adjust the air distribution according to the distribution of indoor personnel, so as to minimize the exposure and infection risk. The construction of an intelligent monitoring system is a great challenge,[35–37] that could use the exposure of personnel infectious aerosols as a control parameter.

Some other control strategies should be investigated to avoid direct-contact infection, such as the cleaning of virus pollution on indoor surfaces of buildings, selection of air purification system for efficient removal or disinfection of new coronavirus in the building ventilation system.

Summary of control solutions during the outbreak

Since the outbreak of COVID 19, there is a need to race against time to win the battle against the epidemic virus infection. The fight against the coronavirus infection should be an emergency affair, which can only be overcome by active cooperation of different trades and professions, such as medical industry, transportation, logistics, government administration, product production technology manufacturers, etc. Several urgent tasks have to be carried out during the outbreak control process.

(1) *Virus source control*: In the face of typical pneumonia, the most effective strategy is to keep every suspected infected patient in a relatively closed space (hospital or home) so that the virus can be prevented from spreading. Those confirmed patients should be immediately treated at the hospital.
(2) *Virus spread control*: Restrictive measures must be taken against the population or the population that may cause the spread to prevent the continued spread of major epidemic.
(3) *Virus tracing*: Meanwhile, the original source of the virus should be traced to understand the origin of the virus, and take effective measures to completely eliminate the source of the virus.

For the whole infected or potentially infected city, continuous detection of air and water should be undertaken to effectively intercept or identify the bacteria and viruses in the air. Masks should be worn by every citizen especially in public places. New mobile hospitals should be efficiently constructed which can accommodate suspected cases in a centralized way, to further relieve the pressure of treating masses of infected patients in large hospitals. For instance, in this outbreak, the construction of Huoshenshan hospital in Wuhan only took 10 days (started from 23 January 2020 to 2 February 2020) to accommodate and to provide treatment of people infected with the highly contagious novel coronavirus.[38] During the whole process, the epidemic status needs to be publicized in a timely and transparent manner.[39] This would also relieve the pressure of the public residents, avoiding undue cross infection of people and unnecessary mental health problems.

AI (artificial intelligence) technology could have a vital role during this outbreak in almost every aspect, such as traffic management, infection detection, logistics supply chain etc., which is a very important characteristic for a modern data-based smart city.[40] If the situation of every citizen is catalogued, everyone can be tracked accurately and every outgoing population can be located, then the control of population flow can be managed in a more orderly way. Related AI technologies could be applied to roll out smart devices to support diagnosis and treatment, and could be used in telecommuting, online education and intelligent production to ensure minimal disruption to people's lives. Some hospitals are using smart devices to assist diagnosis while train stations could install AI-empowered thermal imagers to measure passengers' temperature.[41] During the whole control process, efficiency and speed is extremely important and cross-disciplinary research should be conducted.

Suggestions for building future healthy smart cities

(1) *Establishing a national popularization mechanism for health science*: Health science popularization

has been incorporated into the healthy China strategy.[42] This would be the most effective way to enable citizens to understand and accept health science popularization, which could be written into the teaching materials of primary, middle and high schools, even into the syllabus of teaching and examination. For other members of the public, we should increase the strength and depth of the science popularization, and to encourage the growth in the understanding and practises of the knowledge of the health science popularization into people's daily life.

(2) *Improving the emergency security mechanism*: The overall top-level design of the health emergency system should be carried out, making clear planning and documenting standards of strategic health materials in various regions, so as to prepare for the epidemic situation or the urgent need in time of outbreak crisis or disaster.

(3) *Establishing multi-industry coordination mechanism*: A collaborative linkage logistic mechanism should be established between multi industries and various sectors of the society, such as government administration, health care, transportation, construction environmental protection, social management, etc. when the epidemic occurs, all sectors of the society should be coordinated to enable rapid response, with both division of labour and cooperation, so as to improve the response efficiency to public emergencies.

Authors contribution

All authors contributed equally in the preparation of this manuscript.

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