



## Initial impacts of global risk mitigation measures taken during the combatting of the COVID-19 pandemic

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### ABSTRACT

This paper presents an analysis of risk mitigation measures taken by countries around the world facing the current COVID-19 outbreak. In light of the current pandemic the authors collated and clustered (using harmonised terminology) the risk mitigation measures taken around the globe in the combat to contain, and since March 11, 2020, to limit the spread of the SARS-CoV-2 virus known to cause the Coronavirus disease 2019 (COVID-19). This overview gathers lessons learnt, providing an update on the current knowledge for authorities, sectors and first responders on the effectiveness of said measures, and may allow enhanced prevention, preparedness and response for future outbreaks. Various measures such as mobility restrictions, physical distancing, hygienic measures, socio-economic restrictions, communication and international support mechanisms have been clustered and are reviewed in terms of the nature of the actions taken and their qualitative early-perceived impact. At the time of writing, it is still too premature to express the quantitative effectiveness of each risk mitigation cluster, but it seems that the best mitigation results are reported when applying a combination of voluntary and enforceable measures.

### 1. Introduction

The modern world is fast-evolving, interconnected and highly mobile, making risk governance based on the application of harmonised biorisk mitigation measures a significant challenge. After the two zoonotic coronavirus outbreaks (the severe acute respiratory syndrome coronavirus [SARS-CoV] from 2002 to 2003 and the Middle East respiratory syndrome coronavirus in 2012 [MERS-CoV]), another coronavirus has crossed species to infect human populations, for the third time in the 21st century (Perlman, 2020). This virus, provisionally named 2019 novel coronavirus (2019-nCoV), further referred to as SARS-CoV-2, was identified in Wuhan, China, in early January 2020 after cell culture and isolation of the viral particle (Zhu et al., 2020; Lee and Hsueh, 2020). As for SARS-CoV and MERS-CoV, the primary reservoir of the COVID-19 is probably the bat, based on sequence similarity with bat coronaviruses. Presumably, the intermediate animal hosts of 2019-nCoV should be among the wildlife species sold at the

Huanan Seafood Wholesale Market (Ye et al., 2020). Despite public health risk mitigation measures and regulation efforts by many countries, regions and sectors, the current COVID-19 outbreak reminds the world about our vulnerability to natural and man-made chemical, biological, radiological and nuclear (CBRN) hazards and on the importance of mitigation actions.<sup>1</sup>

Emerging biological hazards may include pathogens in new settings due to climate change influencing the spread of vector-borne diseases arising from the melting arctic ice (Smith et al., 2004; Sutherst, 2004; Fox-Skelly, 2017). Other examples are pathogens with zoonotic potential arising from intensive or inappropriate farming (such as avian or swine flu, MERS) or spill-over of pathogens from wildlife due to the continuous expansion of human territory (such as SARS, Ebola) both bringing humans and potential animal vectors in closer contact with each other (Mills, et al., 2010). These new agents may cause significant threats to human health, if they display high infectivity with potentially high morbidity or even lethality.

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<sup>1</sup> <https://eropa.eu/cbrn-risk-mitigation/>.

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On January 30, 2020, a panel of experts of the World Health Organisation (WHO) declared the outbreak of SARS-CoV2, causing the Coronavirus disease 2019 (COVID-19), a Public Health Emergency of International Concern (PHEIC) and on March 11 2020, the ongoing COVID-19 outbreak was upscaled by the WHO to its 6th and highest alert scale as a pandemic (WHO, 2020).

For many years the risk of emerging infectious diseases with pandemic potential was declared a major threat to global health security and addressed by many stakeholders around the world; namely WHO, global health security initiative (GHSI) 2001, nuclear threat initiative (NTI) who have been very active recently in the bio field, the European Parliament, various national or regional Centre's of Disease Control, etc. (McCloskey et al., 2014). The degree to which countries translated these warnings and recommendations on prevention, preparedness and response capacity varies. In many countries, priorities were given to other domains and investments into appropriate and effective personal protective equipment (PPE) stocks in healthcare facilities and other first responder institutions were left behind (Papp et al., 2020). According to these authors, there is also a long lasting and ongoing trend in our societies to undermine scientific facts in the domain of public health and healthcare by non-evidence based opinions or purely economic considerations. One recent example is the discussion about the safety of the vaccine against the 2009 swine flu outbreak when a great deal of mistrust and unfounded theories heavily influenced people's willingness to be vaccinated (Cohen and Enserink 2009; Seale et al., 2011). For example in Scandinavia, great scepticism towards vaccines undermined global vaccination campaigns (e.g. the Mumps, Measles, Rubella vaccine for children)<sup>2</sup>. Due to our increasingly connected world, especially in the last decade, a lot of misinformation spreads through social media and is accessible to all, leading to the politicisation of science (Deming, 2005; Jasanooff, 2005; Davies, 2019) and the organisation of ignorance (Frickel & Vincent, 2007; Knowles, 2014; Wieland, 2017). This adds complexity to the interface between policy, science and practice and underlines the importance of knowledge management and consistent sharing of best practice in the domain of risk mitigation (Daszak et al., 2020).

The challenge to achieve sharing of best practices for risk mitigation during the current COVID-19 pandemic is high (Koonin, 2020). It requires mechanisms that build upon knowing how to evaluate, plan, implement and maintain risk mitigation measures, along with appropriately deciding who to involve (Renn, 2008; Di Nucci et al., 2017), making decisions about the chain of command, and channelling communication. Communication and information sharing foster democratic learning across governments and sectors, amongst varied stakeholders (decision-makers, scientists, practitioners and citizens), and between different levels of society (international, national, regional and local) (Tompkins et al., 2008). These mechanisms are especially important when they are able to bring together different regions of the world in discussing and preparing for the different phases of a pandemic, quickly understanding lessons learned and applying them in the regions that are going through the earlier steps of the process. An excellent example of an existing mechanism is the European Union's Chemical Biological Radiological and Nuclear risk mitigation Centres of Excellence Initiative (EU CBRN CoE), which was launched in 2010 to strengthen and structure the institutional capacity and country mechanisms outside the European Union with regard to prevention, preparedness and response of chemical, biological, radiological and nuclear risks. This initiative addresses risks of criminal origin (e.g. the Sarin attack on the Japanese subway; Okumura et al., 1998a,b), accidentally created (e.g. Bhopal, Broughton, 2005) or naturally occurring (e.g. swine flu outbreak, COVID-19 pandemic). The EU CBRN CoE is led, financed and implemented by the European Commission, in close coordination with the

European External Action Service (EEAS) and with the support of the United Nations Interregional Crime and Justice Research Institute (UNICRI) and other International Organisations and local experts. The EU CBRN CoE is active in 61 countries in eight regions, each region hosting a Regional Secretariat, and each country with a National Focal Point and a CBRN National Team (see Fig. 1).

Through activities led by the EU CBRN CoE initiative, many countries have elaborated CBRN national action plans, notably against biological threats, creating awareness and mechanisms<sup>3</sup> to structure prevention, preparedness and response during disasters. These plans include the establishment of a chain of command, the identification of national stakeholders, decision-making procedures, enhanced inter-agency communication, stockpiles of PPEs, medicines, drills, communication procedures, etc. Over the last ten years, 25 projects (out of a total of 82 to date) have focused on capacity building in the domains of biosafety and biosecurity including the identification of risk mitigation measures for biological disasters.<sup>4</sup> With the help of the EU CBRN CoE network, the project outcomes are being activated for quick response to the spread of the virus, by quickly compiling the experiences and by keeping in touch through the regional secretariats using virtual meeting tools. Other initiatives could take the same approach, disseminating risk mitigation actions such as the ones compiled in the present paper.

By studying the literature, media and national information channels, in light of the current pandemic, we have collated and clustered the risk mitigation measures taken around the globe first in the effort to contain and since March 11, 2020 to mitigate the risks of COVID-19 by limiting the spread of SARS-CoV-2 (Li et al., 2020). The objective is to make this clustering globally available and to harmonise its terminology so that governments and sectors gain valuable time to put adequate measures in place. Furthermore, the intention of this paper is to highlight the importance of building trust, by improving effective communication processes with cross-country and cross-sectoral information sharing, enhancing the learning process (Edelman Trust Barometer, 2020), and in turn enhancing risk governance mechanisms (Keping, 2018).

## 2. From COVID-19 risk perception to risk mitigation

Three adult patients with severe pneumonia were admitted to a hospital in Wuhan on December 27, 2019, two of whom were linked to the Huanan Seafood Wholesale Market (Zhu et al., 2020). Patients 1 and 3 recovered and were discharged from the hospital on January 16, 2020. Patient 2 died on January 9, 2020. Evidence for the presence of SARS-CoV-2 was found by the identification in bronchoalveolar-lavage fluid in the three patients by whole-genome sequencing, direct PCR, and culture (Zhu et al., 2020). Before the end of December 2019, still few people knew that this new virus existed.

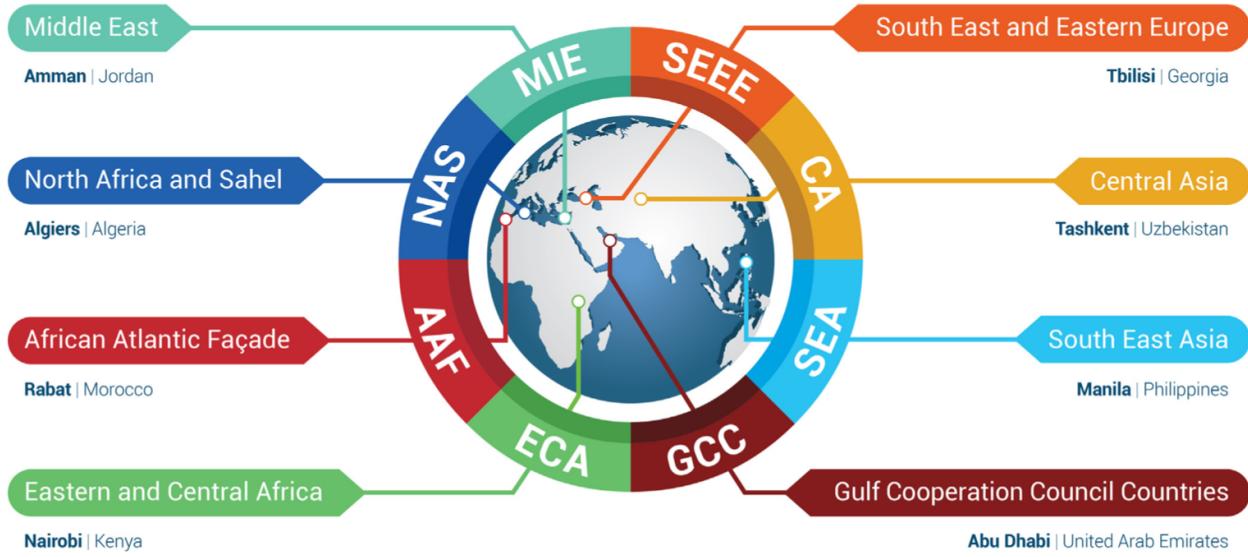
As the infection spread within the city of Wuhan local health workers alarmed local authorities and the outbreak got international attention via media coverage. In early January local risk mitigation measures were implemented including the closure of the Huanan Seafood Wholesale Market. At that time for the rest of the world, especially outside Asia, business continued as usual and any risk perception was considered minimal. On January 12, 2020 China shared the genetic sequence of SARS-CoV-2<sup>5</sup> and on January 13, 2020 the first case was reported outside China: a patient in Thailand reported to have visited the Huanan Seafood Wholesale Market<sup>6</sup>. Due to the absence of a

<sup>3</sup> [https://ec.europa.eu/fpi/sites/fpi/files/documents/icsp-strategy-paper-mip-20140812\\_en.pdf](https://ec.europa.eu/fpi/sites/fpi/files/documents/icsp-strategy-paper-mip-20140812_en.pdf).

<sup>4</sup> [https://ec.europa.eu/cbrn-risk-mitigation/projects\\_en](https://ec.europa.eu/cbrn-risk-mitigation/projects_en).

<sup>5</sup> <https://www.who.int/csr/don/12-january-2020-novel-coronavirus-china/en/>.

<sup>6</sup> <https://www.who.int/csr/don/14-january-2020-novel-coronavirus-thailand-ex-china/en/>.



**Fig. 1.** The countries that join the initiative work together in eight regions, headed up by a secretariat at regional level.



**Fig. 2.** Time line of events and application of COVID-19 risk mitigation measures.

cure or a vaccine, controlling the infection to prevent the spread of COVID-19 was correctly seen as the only intervention that could be used (Lai et al., 2020). Consequent risk mitigation measures were soon after announced in Wuhan (holiday extension, city lockdown, quarantine requirements) (Lin et al., 2020) and in neighbouring cities and regions. Other areas and countries such as Hong Kong, Taiwan, South Korea and Mongolia followed with almost daily announcements of ever more strict risk mitigation measures to limit the spread. These comprised of travel restrictions, isolation of travellers coming from the Wuhan region, closure of schools and universities and the prescription of hygienic measures (see the timeline of the events in Fig. 2). On January 30, 2020 the WHO Emergency Committee convened for a

second time under the IHR2005 rules (World Health Organisation, 2008) and declared the outbreak as fulfilling the criteria for being a Public Health Emergency of International Concern (PHEIC).<sup>7</sup> At this time, related discussions started in European countries but still dramatic measures such as locking down entire cities, regions or countries was not considered (Kervorkian et al., 2020). Concern grew but no real changes occurred, since the perception of the risk was still low and individual and group behaviour was not affected. This status started to

<sup>7</sup> [https://www.who.int/news-room/detail/30-01-2020-statement-on-the-second-meeting-of-the-international-health-regulations-\(2005\)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-\(2019-ncov\)](https://www.who.int/news-room/detail/30-01-2020-statement-on-the-second-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-(2019-ncov)).

change when two regions in Italy (Veneto and Lombardy) faced a rapid growth in the number of infected people, forcing the Italian Authorities to lockdown the most affected villages first, then the entire Northern part of the country and finally the entire country. Other countries followed, albeit with a one to two week delay. At the time of writing, the Italian health care system is still fighting the crisis and remains on the brink of collapse experiencing innumerable numbers of hospitalised patients, a scarcity of intensive care beds, medical staff (over 60 doctors in Italy have died<sup>8</sup>), PPEs, ventilators and medicines. Although in different degrees, other countries are also experiencing similar challenges, including Spain and the United States.<sup>9</sup>

Looking at what seems to be the critical points in reaching an 'out-of-control' situation in Italy, we note that while many Italian first responders did their utmost to contain the virus, many citizens in Italy did not comply with restrictions at first, and it took some time and multiple efforts of the authorities to communicate to the population why compliance with the restrictions was important. It is believed that one of the critical moments of spread was the Champions League football match played in the San Siro stadium in Milan on February 19, 2020 where about 40,000 football fans from Bergamo – which became the hotspot in the Northern region of Italy in the following weeks - attended and afterwards filled up the bars and restaurants around the stadium<sup>10</sup>. Most strikingly, while the Northern Regions already had many restrictions being most importantly self-quarantine, social/physical distancing, hygienic measures and a lock down of the Northern region, the weekend of March 7–8 is believed to have caused the collapse of the respective regional health system in the weeks thereafter, by coinciding with the celebration of the International Women's Day. Following Italy, other European countries were experiencing rapidly increasing numbers of COVID-19 patients in the time after the spring break. It is believed that many people became infected in Alpine ski resorts during the spring break spreading the virus upon their return. Consequently, as another mitigation measure European ski resorts were shut down.<sup>11</sup>

Many countries followed Italy implementing risk mitigation measures starting from advisory, to recommendable and finally enforceable measures. Interestingly though, and similarly to the experience in Italy, the process of risk perception and the translation to compliance and trust in taking risk mitigation measures also took time in other countries (Edelman Trust Barometer, 2020), at the likely cost of additional spread and contamination. As health is a national responsibility in the EU (not regulated by the European Union), many countries have applied different levels of risk mitigation measures and followed different communication strategies. These ranged from the acceptance of a propagation in view of promoting group immunity (mainly in the United Kingdom, the Netherlands and Sweden<sup>12,13</sup>) to strategies to fully protecting all individuals, mainly to prevent overwhelming the healthcare systems but also in the interest of awaiting the results from ongoing medical trials on treatments and studies about individual and group immunity (Kwok et al., 2020). In an attempt to understand these fundamental differences, the authors believe that this is related to the differences of the societal structure as seen in Northern regions in Europe and many parts of the US (Northern structure) versus the Southern European, Arab, Asian and Latin world (Southern structure). The Northern structure is based on elderly people living in retirement homes (similar to parts of the US) and elderly living alone. The

Southern structure is based on large(r) families living under the same roof and across multiple generations. Because inside retirement homes disease can rapidly spread due to the higher risk group, leading to segmented, high mortality numbers,<sup>14</sup> retirement homes were locked down and the assumption may have been made that the elderly living alone may stand a better chance of not contracting the disease at all.

### 3. Clusters of COVID-19 risk mitigation measures

Risk mitigation is an interdisciplinary decision-making process based on information from risk and exposure assessment (Bruinen de Bruin et al., 2007). It entails consideration of political, socioeconomic, epidemiological, (mental) health and engineering data to compile regulatory options and select the appropriate regulatory, societal, sector or company response to COVID-19. At the time of writing many countries have taken risk mitigation measures and are trying to prepare for the future by looking at countries that are ahead in the course of the pandemic and learning from their experiences (Wu and McGoogan, 2020).

To better understand the underlying differences and to harmonise terminology, the risk mitigation measures were clustered into various categories. The categorisation along with the timeline of events are illustrated in Fig. 2.

Reviewing the risk mitigation measures implemented by numerous countries the measures were clustered according to the following categories:

1. **Mobility Restrictions.** These aim to limit the movement of people in order to contain or to slow down the spread of the virus. It reduces the number of people who can be infected by both symptomatic and non-symptomatic uncontained cases (Gostic et al., 2020; Hellewell et al., 2020). Restrictions comprise active zoning, closing/limiting public transportation, air traffic restrictions or even temporary closure, limiting use of private cars, bicycles, and outdoor activities such as walking (some countries only allowed walking outside with a dog) and running, particularly in groups of more than two people;
2. **Socio-economic restrictions.** These target social and economic activities where people gather for educational, recreational, sportive, or work-related purposes. Restrictions comprise the closure or limiting of schools/nurseries/child-care and homes for the elderly, closure of museums, swimming pools, bars and restaurants, indoor and outdoor sport facilities and hotels. Suspension of retail trade, save for essential goods (including food, medicines and their supply chains) with banking, financial and insurance services also belonging to this cluster. Additional examples are the promotion/obligation of teleworking, limiting/cancellation of production in factories;
3. **Physical Distancing.** These measures have also been referred to as social distancing. In fact, physical distancing is regarded as a more appropriate term to avoid social isolation especially of fragile groups such as the elderly, given that with a proper distance (currently defined between 1.5 and 2 m) it is still possible to be social; it also embraces virtual social connections. Other examples entail the prohibition of groups larger than 2–3 persons, closing public outdoor spaces (parks, benches, beaches, etc.) and imposing regulations in terms of entrances and number of people present per square meter, required distance between humans/occupants in indoor spaces comprising offices, meeting places and commercial spaces;
4. **Hygiene Measures;** These aim to limit the risk of spreading the virus and direct or indirect contamination of others. Recommendations comprise washing hands for at least 20 s, sneezing in elbow, avoiding touching surfaces, contactless payments (avoid exchanging money), wearing PPEs such as masks, eye and hand protections, household waste disposal instructions preventing contact with

<sup>8</sup> <https://www.independent.co.uk/news/world/europe/coronavirus-italy-doctor-death-toll-gp-a9438896.html>.

<sup>9</sup> <https://www.theguardian.com/us-news/2020/apr/03/de-blasio-new-york-coronavirus>.

<sup>10</sup> <https://www.theguardian.com/world/2020/mar/24/bergamo-mayor-says-football-match-escalated-coronavirus-infections-italian-provinceMany>.

<sup>11</sup> <https://news.sky.com/story/coronavirus-european-ski-resorts-close-early-to-stop-covid-19-spread-11957732>.

<sup>12</sup> <https://www.bbc.com/news/world-europe-52135814>.

<sup>13</sup> <https://www.bbc.com/news/world-europe-52076293>.

<sup>14</sup> <https://nos.nl/artikel/2329504-kerkdienst-in-verpleeghuis-lijkt-coronahaard-nooit gedacht-aan-heftige-gevolgen.html>.

- contaminated infectious materials by waste collectors and waste processing operators, worker protection (Semple and Cherrie, 2020) in the places where physical distancing is not feasible (e.g. placement of protective glass in supermarkets between cashier and customer), precautionary and sickness driven quarantine (family vs. individual), targeted symptomatic screening upon arrival or entrance such as obliged temperature check or (large scale) testing;
5. *Communication*; This cluster is, in the authors view, the most essential part of risk mitigation measures since it drives the public understanding, trust, acceptance and compliance with the measures. Especially in societies where large-scale disasters were absent for decades, as is the case in many countries since WWII, where mistrust in authorities prevail and/or where individual freedom became the norm, above caring for the group, the communication of risk mitigation measures during a major crisis situation adds significant challenges. In March 2020 a WHO 'WhatsApp' group was set up, providing information and risk mitigation instructions related to categories 1–4. Countries also launched national communication measures structured in news and information websites/platforms jointly combatting fake news, aiming to encourage awareness, understanding and compliance towards restrictions;
6. *International support mechanisms*; As the world is fighting the same threat, and many countries are limited in their capacity and resources, the importance of acting internationally is acknowledged, as exemplified by the following actions: countries, sectors and companies increased global production and international exchange of PPE's, raw materials for pharmaceuticals, pharmaceutical formulations, basic medical drugs, and ventilators. Existing risk mitigation networks were quickly activated, and new transnational platforms are being set up for knowledge exchange on clinical trials, treatments, lessons learned and publications<sup>15</sup>.

#### 4. Early signs of effectiveness

At the time of writing, increasing information is being generated about the experiences in mitigating COVID-19. Although it is difficult to precisely understand the effectiveness of each category of risk mitigation measure the currently available literature has been studied.

*Mobility Restrictions.* Early analysis of the Wuhan COVID-19 outbreak suggest that the effects of travel limitations are important for national and international agencies dealing with public health response planning. Chinazzi et al. (2020) showed that by January 23, 2020 the epidemic had already spread to other cities within China and therefore the travel quarantine around Wuhan had only modestly delayed the epidemic spread to other areas of China. The Wuhan travel ban was initially effective at reducing international case exportations but not to limit the already ongoing spread outside China. Most importantly, this study showed that additional travel limitations up to 90% of the traffic has a modest effect unless paired with public health interventions and behavioural changes that achieve a considerable reduction in the disease transmissibility in the communities, as also confirmed during the SARS outbreak in Singapore (Drake et al., 2006). These findings underline the importance of quick response based on proper early detection and epidemiological risk analysis, in combination with the application of additional risk mitigation measures. In addition, disease experts estimate that each COVID-19 patient/cARRIER infects between two to three others.<sup>16</sup> Each risk mitigation measure contributes to a

decrease in new infections (Anderson et al., 2020). In order for these restrictions to be effective it is believed that testing, registering number of hospitalisations and deaths in the weeks after the restrictions are key to tracking the effectiveness of the measures. At present, the effectiveness of each measure cannot be quantitatively assessed. However, the authors of this paper believe in the application of the precautionary principle meaning that application of a combination of mitigation measures – even those without current clear scientific evidence such as school closures (Anderson et al., 2020) – is the best practice to gain most time in decreasing the rate of new infections (Hellewell et al., 2020).

*Socio-economic restrictions:* The implementation of socio-economic restrictions occurred gradually within most countries and even up to date there are major differences between countries in terms of the closing down of public places. The most plausible reason is that these restrictions are expected to impose a major impact on the functioning of the current economy and way of life (Nicholson et al., 2019). A recent analysis of smartphone location data by the U.S. search engine giant Google showed that visits to shops, parks or railway stations fell steeply in most European countries between February 16 and March 29 2020 as governments sought to slow the explosive spread of the COVID-19 disease.<sup>17</sup> Reuters reported that in Italy and Spain, retail and recreational trips were down by 94%. Physical presence in workplaces also decreased by over 60% in respective countries. Both Italy and Spain, along with France imposed near lockdown of their states, and, by the time of writing, the restrictions they have imposed are, with a time lag, starting to 'flatten the curve' of new infections at least in some countries (Financial Times, April 4, 2020). These latest findings add to the suggestion that the combination of different categories of risk mitigation measures contribute most successfully to the fastest decrease of new infections, given the geographic scale and severity of COVID-19.

*Physical Distancing.* Individual behaviour is crucial in controlling the spread of COVID-19. In early March 2020 Anderson et al. (2020) described that in Western democracies personal action, rather than government action, might be the most important issue comprising of early self-isolation (within one day from symptom onset), seeking medical advice remotely unless symptoms are severe, and physical distancing. The same authors described the importance of the application of a combination of mitigation measures such as physical distancing in combination with the ban of mass gatherings, good diagnostic facilities and remotely accessed health advice, together with specialised treatment for people with severe COVID-19 infections. A combination of these measures was suggested to lead to a 60% reduction in transmission. At the time of writing, many Western democracies also experienced the effects of the lack of awareness of a significant portion of the population leading to non-compliance with the recommended or obligatory restrictions. As a result, in the course of days, governments increasingly implemented a combination of communication strategies (outdoor signs, use of social media, drones informing the public) in combination with enforcement strategies giving increasing fines to groups that were violating the ever more stringent restriction measures. Germany established on March 22, 2020 a fine of up to 25,000 euro for gathering in groups of more than 3 persons.<sup>18</sup> The Netherlands reported on March 27, 2020 the arrest of an individual coughing in the face of a police officer while claiming to be infected with COVID-19.<sup>19</sup>

Niud and Xu (2020) reported that transmission by people with mild

(footnote continued)

they-have-one-big-thing-in-common.

<sup>17</sup> <https://www.reuters.com/article/us-health-coronavirus-google-europe/europe-s-north-south-lockdown-divide-revealed-by-google-data-idUSKBN21L1US>; <https://www.google.com/covid19/mobility/>.

<sup>18</sup> <https://www.nu.nl/coronavirus/6039503/duitsland-verbiedt-samenscholing-van-meer-dan-twee-personen.htm>.

<sup>19</sup> <https://www.at5.nl/artikelen/200958/man-hoest-agent-in-gesicht-na-arrestatie-ik-heb-corona>.

or no symptoms can undermine the effectiveness of the isolation strategy because of reduced likelihood of isolating all cases and tracing all contacts. The identification and testing of potential cases needs therefore to be as extensive as is permitted by healthcare and diagnostic testing capacity—including the identification, testing, and isolation of suspected cases with no or mild disease (e.g., influenza-like illness). In the fight against COVID-19, early control measures such as isolation and contact tracing could gain more power, thanks to modern technology. The authors believe that detection combined with contact tracing should continue to be an important measure to control the outbreak.

**Hygiene Measures.** Wild animals were slaughtered in the Wuhan market, increasing the risk of human exposure to blood and to other animal fluids with high risk of being exposed to wild animal viruses. 'Wet' markets such as these are poorly viewed by many countries in the world who are now combatting the consequences of the outbreak. However, it should be borne in mind that similar 'wet' markets exist in several other places around the world such as in Africa, Asia and South America, with cultural habits and behaviour being hard to change. The authors believe the solution lies with the avoidance of mixing wild and domestic animals in indoor and outdoor spaces, and prohibition of on-the-spot slaughtering of animals in markets due to very weak hygienic measures. For many years already, Western countries have enforced the systematic use of slaughterhouses with very strict hygienic measures and authority control. In a recent announcement, Chinese authorities (temporarily) prohibited these wild life markets as of March 2020<sup>20</sup> adding to the long list of risk mitigation measures currently being taken.

WHO, CDC, ECDC and other international/European organisations have been drawing attention to the importance of hand hygiene for many years. The WHO began drawing up guidelines in 2004 and have produced specific guidelines for 'Hand Hygiene in Health Care' in 2009<sup>21</sup> and in general.<sup>22</sup> Apart from the six languages on the WHO site, most countries have this information available in their official language(s).

The message regarding use, or not, of face masks has been very unclear, also internationally. This lack of clarity has been compounded by the lack of suitable masks, such as those meeting the technical specifications of FFP2 and FFP3, covered by Regulation (EU) 2016/425 on Personal Protective Equipment. Moreover, surgical masks, which seem effective in clinical settings at reducing the risk of infection for professionals, do not provide adequate protection during Aerosol Generating Procedures (AGPs). Therefore, masks need to be used in combination with other PPE measures<sup>23</sup> (Smith et al., 2016; Long et al., 2020). For the ECDC the use of face masks is of highest priority in healthcare workers but also in symptomatic confirmed/suspected cases of COVID-19 and those caring for them. Instead, WHO and others health authorities do not recommend the use of face mask for the general public.<sup>24</sup> Whether the recommendation by Western countries (US, UK, and the majority of EU) that the public should not wear face masks, is or not motivated by the need to preserve limited supplies for professional use in health-care settings is unclear. In parts of Asia (China, Japan, South Korea, Singapore) and recently in some EU countries (Czech Republic and Austria), all citizens have been encouraged to wear face masks in public, regardless of whether they have

symptoms. Austria and Italy have joined a small but growing number of European countries making the wearing of face masks outside the home compulsory amid shifting debate over the medical gear's protective utility.<sup>25</sup> Authorities started distributing millions of free face masks at the entrances to all supermarkets from April 01, 2020 in Austria. Shoppers will only be permitted inside supermarkets and other open stores, such as pharmacies, if they are wearing masks. The Lombardy region of Italy made the outdoor wearing of masks or scarfs in combination with gloves obligatory as of April 04, 2020 (Ordinanza N.521<sup>26</sup>). According to research on the SARS epidemic, face masks (surgical and FFP2/N95) were an effective intervention for reducing the contraction and spread of the virus (Jefferson et al., 2011). As evidence suggests that nearly half of SARS-CoV-2 transmissions occur before the infected person becomes symptomatic, a consistent and proper use of face masks by the general population could offer a partial additional benefit to the other essential mitigation measures such as hand hygiene and isolation of infected people. Moreover, universal use of face masks could prevent discrimination of individuals who wear masks when unwell because everybody is wearing a mask (Feng et al., 2020; Leung et al., 2020). Hence, there is some rationale for mask-wearing in the general population, even if there is evidence disputing this. However, during a pandemic from a new respiratory virus such as SARS-CoV-2, in the absence of specific and well-tested pharmaceutical interventions, masks might well play a role in reducing transmission, in particular when physical distancing is not possible. This is probably why in the U.S., the CDC is reportedly contemplating a change in guidance.

A recent EC communication (Commission Recommendation EU 2020 403 13 March 2020<sup>27</sup>) clarifies many questions including for e.g. those of critical service providers (who will not be able to avail of government supplies destined for health workers), under what conditions they may provide their employees with non-CE labelled masks, assuming they can import their own supply. Also at European level, one of the risk mitigation measures taken was the creation of a strategic rescEU stockpile of medical equipment such as ventilators and protective masks to help EU countries in the context of the COVID-19 pandemic.<sup>28</sup> Part of the stockpile will include items such as: (i) intensive care medical equipment such as ventilators, (ii) personal protective equipment such as reusable masks, (iii) vaccines and therapeutics and (iv) laboratory supplies. It remains to be seen how quickly the European Member States will be able to avail of this stockpile.

**Communication;** During the outbreak crisis it is key to have trustworthy and well-coordinated communication channels to create community trust and compliance. Hong Kong, Singapore, Japan and South Korea are among those that stabilised the cumulative number of cases within two to three weeks after the 100th case (FT Analysis of John Hopkins University, CSSE, March 14, 2020). These countries quickly applied a combination of risk mitigation measures such as school closures, strict quarantine and isolation measures and contact tracing. Moreover, data studied at the time of March 16, 2020 suggests that a strong community response to the risk mitigation measures communicated by the authorities is key to stabilising the cumulative increase of the spread of COVID-19. This demonstrates the importance of citizen awareness, social trust in authorities and well-coordinated risk mitigation communication.

**International support mechanism;** Avoiding an uncontrollable world pandemic requires the implementation of a global mechanism, built and empowered to act at an unprecedented speed (Niud and Xu, 2020). As

<sup>20</sup> <https://edition.cnn.com/2020/03/05/asia/china-coronavirus-wildlife-consumption-ban-intl-hnk/index.html>.

<sup>21</sup> [https://apps.who.int/iris/bitstream/handle/10665/44102/9789241597906\\_eng.pdf;jsessionid=41E5DD6BBC1CE944DB5F1EEF9FF7C23?sequence=1](https://apps.who.int/iris/bitstream/handle/10665/44102/9789241597906_eng.pdf;jsessionid=41E5DD6BBC1CE944DB5F1EEF9FF7C23?sequence=1).

<sup>22</sup> [https://www.who.int/gpsc/clean\\_hands\\_protection/en/](https://www.who.int/gpsc/clean_hands_protection/en/).

<sup>23</sup> <https://www.cebm.net/wp-content/uploads/2020/03/COVID-CAT-PPE-MASKS-9-REVISED-002.pdf>.

<sup>24</sup> <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/when-and-how-to-use-masks>.

<sup>25</sup> <https://www.ft.com/content/f68f3063-5024-4654-9389-bcc7ee1efd8e>.

<sup>26</sup> <https://www.regione.lombardia.it/wps/portal/istituzionale/HP/DettaglioRedazionale/servizi-e-informazioni/cittadini/salute-e-prevenzione/Prevenzione-e-benessere/red-coronavirusnuoviaggiornamenti>.

<sup>27</sup> <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32020H0403>.

<sup>28</sup> [https://ec.europa.eu/commission/presscorner/detail/en/ip\\_20\\_476](https://ec.europa.eu/commission/presscorner/detail/en/ip_20_476).

Hellewell et al. (2020) described, the time window of early response is potentially extremely short, signifying that, once the number of initial cases increases to a few tenths (40 cases seems to be a critical number), the probability of failure to control is high, i.e. at 80% even if 80% of contacts are traced and isolated. In this context, global coordination is mandatory and help should be quickly directed to the focal points of viral spread. Some effective measures include the pharmaceutical industry, factories, retailers (of medicines, PPE, etc.) are collaborating better and re-directing their production lines to COVID-19 related products. For example, high-level fashion brands such as Armani, Gucci, and others are producing masks and protective garments for healthcare workers, and alcoholic beverage brands are directing their production to disinfectant gel. In addition, solidarity is removing some commercial confidentiality barriers, forming novel supply chains, or easing trade restrictions under certain circumstances, while increasing them on others. For example, the EU introduced a temporary (6 weeks) export ban on certain medical/protective equipment to destinations outside the EU (Commission Implementing Regulation 2020/402, 14 March 2020<sup>29</sup>).

## 5. Conclusions and recommendations

The general lack of understanding of this new virus led to confusion and mixed advice from professionals and authorities. The global community (political, medical and international organisations) were taken by complete surprise in its rapid spread from China and establishment of community spread in Italy, Iran, Spain and at present in the US. At the time of writing the world is overwhelmed with COVID-19 patients and countries are applying risk mitigation measures at an unprecedented level with almost daily updates. In Europe, in the current major hotspots in Italy and Spain, and recently in the US, in New York, hospitals are being overwhelmed and responders are combatting the pandemic by all possible means. Since the rules and policies adopted by many countries differ as well as societal and population structure, and healthcare systems, the mitigation measures will likely lead to various results. It will be interesting to see the exact impact of the different strategies but unfortunately it is still too early, and it is not yet possible to give quantitative advice. The intention of this paper is to highlight the importance of building trust, improving effective communication processes with cross-country and cross-sectoral information sharing, enhancing the learning process, and in turn enhancing risk governance mechanisms. The conceptual analysis in this paper aimed to provide a structure in the countless risk mitigation measures taken around the world knowing it is a snapshot in time and lots of effort is currently being undertaken. The authors collated and clustered risk mitigation measures, using a harmonisation of the taxonomical approach, available for countries combatting the COVID-19 pandemic and investing in the limitation of the spread of the virus. Our work mainly focusses on the limitation of the spread of the SARS-CoV-2 virus causing COVID-19. Current knowledge reveals that:

- The information published on risk mitigation measures and their effectiveness is difficult to find and more and more papers are being published every day;
- COVID-19 demonstrates the weaknesses of the current systems; the world was insufficiently prepared, scientific warnings were not picked up quickly enough, there were confusing messages and trust building took too much time. Specifically, many countries started with processes such as understanding the problem from the beginning and not building upon existing knowledge and best practices of other countries. This lead to similar outcomes such as disbelief, underestimation of the scale and potential danger and losing

valuable time in jointly implementing the best risk mitigation practices. Besides the differences between countries in terms of cultures or economic prosperity, this pandemic demonstrates the unpreparedness of many health systems lacking mechanisms and materials to adequately respond to a quickly spreading infection, relying on societal and economic improvisation;

- It is suggested that countries where the elderly live among the general population, impose more strict restrictive mitigation measures than countries where the elderly are separated from the general population;
- Several restrictions have proven effective in slowing down the spread of COVID-19, but the highest effect is obtained by applying a combination of measures representing different aims. In this regard:
  - It is recommended for all countries to invest in preventive risk mitigation resources limiting the spread of SARS-CoV-2 comprising physical distancing measures and hygienic measures; this is particularly important for countries with fewer resources.
  - It is recommended to impose a combination of mitigation measures limiting the spread by individuals who become ill after being missed by a screening programme. To this end screening programmes need to be improved and applied on a large(r) scale, along with registering the number of hospitalisations and deaths. Contact tracing is important even if many countries are now believed to have passed this phase due to too high number of infections. New technologies could be applied in this respect.
  - It is believed that correctly wearing appropriate face masks is beneficial when physical distancing is not possible to ensure all the time. The spread of small drops containing SARS-CoV-2 is difficult to predict (think of air currents, convections and air humidity), and it is more likely that individuals will touch their face (mouth/nose) less frequently than without a mask. It seems that countries who have more effectively curtailed an expanding propagation are countries whose population used masks extensively;
- A clear and coordinated communication strategy on effective risk mitigation is crucial in building trust with the citizens in a quickly evolving situation, using all possible channels and combatting fake news.
- Existing global mechanisms need strengthened benefiting from interlinked national health mechanisms. Being part of a network of first responders, practitioners or risk mitigation stakeholders is an added value in this scenario; for example, several partner countries of the EU CBRN CoE are reporting to have greatly benefited from the structures that were put in place thanks to the Initiative and, at least in some countries, this mechanism has been found very useful to mobilise a coordinated response;
- Citizens' trust related to the degree of risk mitigation measures in place and parties involved in the communication is highly variable across countries. This is expected to influence citizens' behaviour and respective implementation and obedience of the imposed risk mitigation measures. Some countries are also creating child-friendly Covid 19 communication material such as comics<sup>30</sup>, TV and online broadcasted news<sup>31</sup>. In countries and cultures with a higher degree of trust in science, authorities, and with adequate science based communication, faster changes are expected;
- The delay in imposing risk mitigation measures is crucial and can make the difference between a local outbreak with few cases to a pandemic with countless sick and deceased citizens. The window of opportunity for full containment is believed to be limited to a situation with a very low number of infected people (maximum 40 cases);
- Proper early detection based on early warnings would lower the

<sup>29</sup> <https://eur-lex.europa.eu/legal-content/GA/TXT/?uri=CELEX:32020R0402>.

<sup>30</sup> <https://www.hse.ie/eng/services/news/newsfeatures/covid19-updates/partner-resources/>.

<sup>31</sup> <https://jeugdjournaal.nl/>.

intervention time. Such a mechanism should be based on a response time of hours, rather than days.

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## References

- Anderson, R.M., Heesterbeek, H., Klinkenberg, D., Hollingsworth, T.D., 2020. How will country-based mitigation measures influence the course of the COVID-19 epidemic? *The Lancet* 395 (10228), 931–934.
- Broughton, E., 2005. The Bhopal disaster and its aftermath: a review. *Environ. Health* 4 (1).
- Bruinen de Bruin, Y., Lahaniatis, M., Papameletiou, D., Del Pozo, C., Reina, V., Van Engelen, J., Heinemeyer, G., Viso, A.C., Rodriguez, C., Jantunen, M., 2007. Risk management measures for chemicals in consumer products: documentation, assessment, and communication across the supply chain. *J. Exposure Sci. Environ. Epidemiol.* 17 (1), S55–S66.
- Chinazzi, M., Davis, J.T., Ajelli, M., Gioannini, C., Litvinova, M., Merler, S., y Ponti, A.P., Rossi, L., Sun, K., Viboud, C., Xiong, X., 2020. The effect of travel restrictions on the spread of the 2019 novel coronavirus (2019-nCoV) outbreak. *medRxiv*.
- Cohen, J., Ensorink, M., 2009. As swine flu circles globe, scientists grapple with basic questions. *Science* 324 (5927), 572–573.
- Daszak, Peter, Olival, Kevin J., Li, Hongying, 2020. A strategy to prevent future pandemics similar to the 2019-nCoV outbreak.
- Drake, J.M., Chew, S.K., Ma, S., 2006. Societal learning in epidemics: intervention effectiveness during the 2003 SARS outbreak in Singapore. *PLoS ONE* 1 (1), e20. <https://doi.org/10.1371/journal.pone.0000020>.
- Davies, 2019. Green Populism?—Action and mortality in the Anthropocene, Centre for the Understanding of Sustainable Prosperity (CUSP), July 2019. <https://www.cusp.ac.uk/wp-content/uploads/12-Will-Davies-online.pdf>.
- Deming, D., 2005. Global warming, the politicization of science, and Michael Crichton's state of fear. *J. Sci. Exploration* 19 (2), 247–256.
- Di Nucci, M.R., Brunnengräber, A., Isodoro Losada, A.M., 2017. From the "right to know" to the "right to object" and "decide". A comparative perspective on participation in siting procedures for high level radioactive waste repositories. *Prog. Nucl. Energy* 100 (2017).
- Feng, Shuo, Shen, Chen, Xia, Nan, Song, Wei, Fan, Mengzhen, Cowling, Benjamin J., 2020. Rational use of face masks in the COVID-19 pandemic. *The Lancet Respiratory Med.* [https://doi.org/10.1016/S2213-2600\(20\)30134-X](https://doi.org/10.1016/S2213-2600(20)30134-X).
- Financial Times (April 4 2020). Coronavirus tracked: the latest figures as the pandemic spreads, <https://www.ft.com/coronavirus-latest>.
- Fox-Skelly, J., 2017. There are diseases hidden in ice, and they are waking up. BBC News. Available at: <http://www.bbc.com/earth/story/20170504-there-are-diseases-hidden-in-ice-and-they-are-waking-up> (accessed 14 October 2019).
- Frickel, Scott, Vincent, M., Bess, 2007. Hurricane Katrina, contamination, and the unintended organization of ignorance. *Technol. Soc.* 29 (2), 181–188. <https://doi.org/10.1016/j.techsoc.2007.01.007>.
- Gostic, K., Gomez, A.C., Mummalah, R.O., Kucharski, A.J., Lloyd-Smith, J.O., 2020. Estimated effectiveness of symptom and risk screening to prevent the spread of COVID-19. *Elife* 9.
- Jefferson, T., Del Mar, C.B., Dooley, L., Ferroni, E., Al-Ansary, L.A., Bawazeer, G.A., van Driel, M.L., Nair, S., Jones, M.A., Thorning, S., Conly, J.M., 2011. Physical interventions to interrupt or reduce the spread of respiratory viruses. *Cochrane Database Syst. Rev.* 2011, 7 Art. No.: CD006207. DOI: 10.1002/14651858.CD006207.pub4.
- Hellewell, J., Abbott, S., Gimma, A., Bosse, N.I., Jarvis, C.I., Russell, T.W., Munday, J.D., Kucharski, A.J., Edmunds, W.J., Sun, F., Flasche, S., 2020. Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts. *The Lancet Global Health*.
- Jasanoff, S., 2005. Judgment under siege: The three-body problem of expert legitimacy. In: Weingart, P., Maesen, S. (Eds.), *Democratization of Expertise? Exploring Novel Forms of Scientific Advice in Political Decision-Making*. Kluwer, Dordrecht, pp. 209–224.
- Kervorkian, A., Grenet, T., Galley, H., 2020. Tracking the Covid-19 pandemic: Simple visualization of the epidemic states and trajectories of select European countries & assessing the effects of delays in official response. *medRxiv*.
- Keping, Y., 2018. Governance and good governance: a new framework for political analysis. *Fudan J. Humanities Social Sci.* 11, 1–8. <https://link.springer.com/content/pdf/10.1007/s40647-017-0197-4.pdf>.
- Knowles, S., 2014. Engineering risk and disaster: disaster-STS and the American history of technology. *J. Eng. Stud.* 6 (3), 227–248.
- Koonin, L.M., 2020 Jan 1. Novel coronavirus disease (COVID-19) outbreak: Now is the time to refresh pandemic plans. *J. Business Continuity Emergency Planning* 13 (4), 1–5.
- Kwok, K.O., Florence, L.A.I., Wei, W.I., Wong, S.Y.S., Julian, T.A.N.G., 2020. Herd immunity—estimating the level required to halt the COVID-19 epidemics in affected countries. *J. Infect.*
- Lai, C.C., Shih, T.P., Ko, W.C., Tang, H.J., Hsueh, P.R., 2020. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and corona virus disease-2019 (COVID-19): the epidemic and the challenges. *Int. J. Antimicrobial Agents* 105924.
- Lee, P.I., Hsueh, P.R., 2020. Emerging threats from zoonotic coronaviruses—from SARS and MERS to 2019-nCoV. *J. Microbiol. Immunol. Infect.* Feb, 4.
- Leung, C.C., Lam, T.H., Cheng, K.K., 2020 Mar 21. Mass masking in the COVID-19 epidemic: people need guidance. *Lancet* 395 (10228), 945.
- Li, Q., Guan, X., Wu, P., Wang, X., Zhou, L., Tong, Y., Ren, R., Leung, K.S., Lau, E.H., Wong, J.Y., Xing, X., 2020. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. *N. Engl. J. Med.*
- Lin, Q., Zhao, S., Gao, D., Lou, Y., Yang, S., Musa, S.S., Wang, M.H., Cai, Y., Wang, W., Yang, L., He, D., 2020. A conceptual model for the outbreak of Coronavirus disease 2019 (COVID-19) in Wuhan, China with individual reaction and governmental action. *Int. J. Infect. Dis.*
- Long, Y., Hu, T., Liu, L., Chen, R., Guo, Q., Yang, L., Cheng, Y., Huang, J., Du, L., 2020. Effectiveness of N95 respirators versus surgical masks against influenza: A systematic review and meta-analysis. *J. Evidence-Based Med.*
- McCloskey, B., Dar, O., Zumla, A., Heymann, D.L., 2014 Oct 1. Emerging infectious diseases and pandemic potential: status quo and reducing risk of global spread. *Lancet. Infect. Dis.* 14 (10), 1001–1010.
- Mills, J.N., Gage, K.L., Khan, A.S., 2010. Potential influence of climate change on vector-borne and zoonotic diseases: a review and proposed research plan. *Environ. Health Perspect.* 118 (11), 1507–1514.
- Nicholson, A., Shah, C.M., Ogawa, V.A., 2019. National Academies of Sciences, Engineering, and Medicine. *Reflections on a Century of Infectious Disease Outbreaks and Pandemics. Exploring Lessons Learned from a Century of Outbreaks: Readiness for 2030: Proceedings of a Workshop 2019 May 8*. National Academies Press, US.
- Niud, Y., Xu, F., 2020. Deciphering the power of isolation in controlling COVID-19 outbreaks. *The Lancet Global Health* 8 (4), e452–e453.
- Okumura, T., Suzuki, K., Fukuda, A., Kohama, A., Takasu, N., Ishimatsu, S., Hinohara, S., 1998a. The Tokyo subway sarin attack: disaster management, Part 1: Community emergency response. *Acad. Emerg. Med.* 5 (6), 613–617.
- Okumura, T., Suzuki, K., Fukuda, A., Kohama, A., Takasu, N., Ishimatsu, S., Hinohara, S., 1998b. The Tokyo subway sarin attack: disaster management, part 2: hospital response. *Acad. Emerg. Med.* 5 (6), 618–624.
- Papp, S., Kimmerl, K., Gatz, J., Laue, M., Grunow, R., Kaspari, O., 2020 Feb 1. Evaluation of sporadic disinfectants for the disinfection of personal protective equipment during biological hazards. *Health Security* 18 (1), 36–48.
- Perlman, Stanley, 2020. Another decade, another coronavirus, pp. 760–762.
- Renn, O., 2008. *Risk Governance: Coping with Uncertainty in a Complex World*. Earthscan, Oxon, UK/New York.
- Seale, H., Kaur, R., Wang, Q., Yang, P., Zhang, Y., Wang, X., Li, X., Zhang, H., Zhang, Z., MacIntyre, C.R., 2011 Feb 11. Acceptance of a vaccine against pandemic influenza A (H1N1) virus amongst healthcare workers in Beijing, China. *Vaccine* 29 (8), 1605–1610.
- Simple, Sean, Cherrie, John W., 2020. Covid-19: Protecting Worker Health, *Annals of Work Exposures and Health*, wxa033, <https://doi.org/10.1093/annweh/wxa033>.
- Smith, A.W., Skilling, D.E., Castello, J.D., Rogers, S.O., 2004. Ice as a reservoir for pathogenic human viruses: specifically, caliciviruses, influenza viruses, and enteroviruses. *Med. Hypotheses* 63 (4), 560–566.
- Smith, J.D., MacDougall, C.C., Johnstone, J., Copes, R.A., Schwartz, B., Garber, G.E., 2016. Effectiveness of N95 respirators versus surgical masks in protecting health care workers from acute respiratory infection: a systematic review and meta-analysis. *CMAJ* 188 (8), 567–574.
- Sutherst, R.W., 2004. Global change and human vulnerability to vector-borne diseases. *Clin. Microbiol. Rev.* 17 (1), 136–173.
- Tompkins, E.L., Lemos, M.C., Boyd, E., 2008. A less disastrous disaster: Managing response to climate-driven hazards in the Cayman Islands and NE Brazil. *Global Environmental Change* 18 (4), 736–745.
- Wieland, W.W., 2017. Responsibility for strategic ignorance. *Synthese* 194, 4477–4497.
- World Health Organization, 2008. International health regulations (2005). World Health Organization.
- World Health Organization. WHO Director-General's opening remarks at the media briefing on COVID-19 – 11 March. Available from URL: <https://www.who.int/dg-speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19--11-march-2020> (accessed March 2020).
- Wu, Z., McGoogan, J.M., 2020. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314 cases from the Chinese Center for Disease Control and Prevention. *Jama*.
- Ye, Z.W., Yuan, S., Yuen, K.S., Fung, S.Y., Chan, C.P., Jin, D.Y., 2020. Zoonotic origins of human coronaviruses. *Int. J. Biol. Sci.* 16 (10), 1686–1697.
- Zhu, N., Zhang, D., Wang, W., Li, X., Yang, B., Song, J., Zhao, X., Huang, B., Shi, W., Lu, R., Niu, P., 2020 Jan 24. A novel coronavirus from patients with pneumonia in China, 2019. *N. Engl. J. Med.*