

Reform for Resilience - Evidence Paper

Hygiene Behaviour is the Foundation of Biosecurity

Executive summary

Health resilience. A pertinent topic considering the COVID-19 pandemic which has swept the globe. Defined as being related to the processes and skills that result in positive individual and community outcomes, notwithstanding negative events, health resilience, and how we achieve it, has focused the minds of scientists and politicians across the globe. Rather than being equipped with an anticipatory approach, health systems throughout the planet found themselves in a situation which meant they were learning about, and dealing with, COVID, an infectious disease, all at once. The importance of biosecurity has become ever clearer. Threats such as infectious diseases can kill millions, cost billions and cause political and economic uncertainty. And they have no respect for international borders. Therefore, our reaction and resulting measures need to be globally integrated, multi-disciplinary and about much more than simply the lessons about COVID-19.

The importance of hygiene has been well illustrated, including how it should be considered an essential component in the biosecurity armoury. However, despite being the preventive component of the global fight against infectious diseases, and a major contributor to health and economic growth, hygiene has languished as a minority scientific and political interest for decades. In the simplest of terms, hygiene is a series of practices designed to preserve health and prevent the spread of biological threats posed to life. A basic human right, and one which needs to be front and centre in global health security strategies.

Diseases linked to water, sanitation and hygiene are one of the leading causes of death in children, and more children are killed by diarrhoea than by AIDS, tuberculosis and malaria combined. Food-borne diseases, which caused around 420,000 deaths in 2010, are a particular concern for biosecurity, especially as their levels are likely to increase with changes in demand for certain food types, as well as climate change and increasing complex supply chains. Practicing good hygiene has potential to prevent around 2.4 million deaths a year.

Improving hygiene, whether at a personal, domestic, community or national level, will reduce the spread of many types of infectious diseases. Improving hygiene, sanitation and water has impacts over and above health outcomes. Healthier people do better at school and, once employed, bring more money into household and national economies. And hygiene interventions make a significant difference to our health. The U.S. Centers for Disease Control and Prevention reported that positive flu tests in December 2020 were less than one-hundredth of those recorded for the year previous with the precautions taken due to COVID risk cited as the cause. A statistic difficult to argue with. Despite an acceptance that social distancing isn't the preferred state for local communities a common understanding of hygiene in its many contexts and applications is essential that our global health security strategies are rebuts.

Our historical lack of understanding of hygiene, and the inability to implement it consistently over the long term, has created an environment where pandemics can develop. This has been illustrated clearly by the global COVID-19 pandemic, which has killed over 3 million people worldwide. The COVID-19 pandemic has not only affected people's health, but it has also caused a massive fall in the global economy and global trade. Improved hygiene measures will help to instil confidence and boost investment. Surveillance, supported by governments globally, will help to predict, and potentially prevent, future pandemics.

There are challenges inherent in the process of change, and creating solutions requires a knowledge of the problems and barriers, as well as an understanding of the systems approaches that will help these changes to bed into place. We face behavioural and cultural challenges to change, and these are made more difficult by the lack of a common language and access to few quantitative measures and tools.

When talking to the policymakers, all sanitation and hygiene projects need to take into account the role of power and politics, and the importance of the political, social and historical contexts. Change using a systems approach needs to bring in people at all levels of a hierarchy, whether that's within a governmental body, a town or village, or even a family. It also needs the people implementing the change to be open to listen to opinions and discuss projects, and make changes if necessary. We believe that we can bring a holistic systems approach vital to motivating change, as well as proposing the development of a hygiene index that can identify where policy change and effort should be directed.

Introduction

Hygiene (noun)

/ˈhɪdʒiːn/

Conditions or practices conducive to maintaining health and preventing disease, especially through cleanliness

Hygiene is the collection of outcomes resulting from the activities we undertake to prevent or counteract the natural and manufactured threats in our world. The term is used casually in reference to humans, animals, plants, computers, ports, supply chains and many other areas. Here, we define hygiene more specifically. Hygiene is the set of actions people take – or the behaviours they engage in – to counter the biological threats to themselves and by extension to public health. The need for specific hygienic behaviours differs between cultures and geographies, as the threats to human health and their interpretation differ. Hygiene, under this definition, is still big; it is a human health issue, an agribusiness issue, a trade issue and a global travel/mobility issue. We demonstrate in this paper how this definition illuminates the problem in a new way and points us to a more innovative and effective course of planning and action.

The major contributors to health and economic growth have been three-fold – nutrition, hygiene and healthcare, including pharma, biotech and medtech. While improvements in hygiene made huge

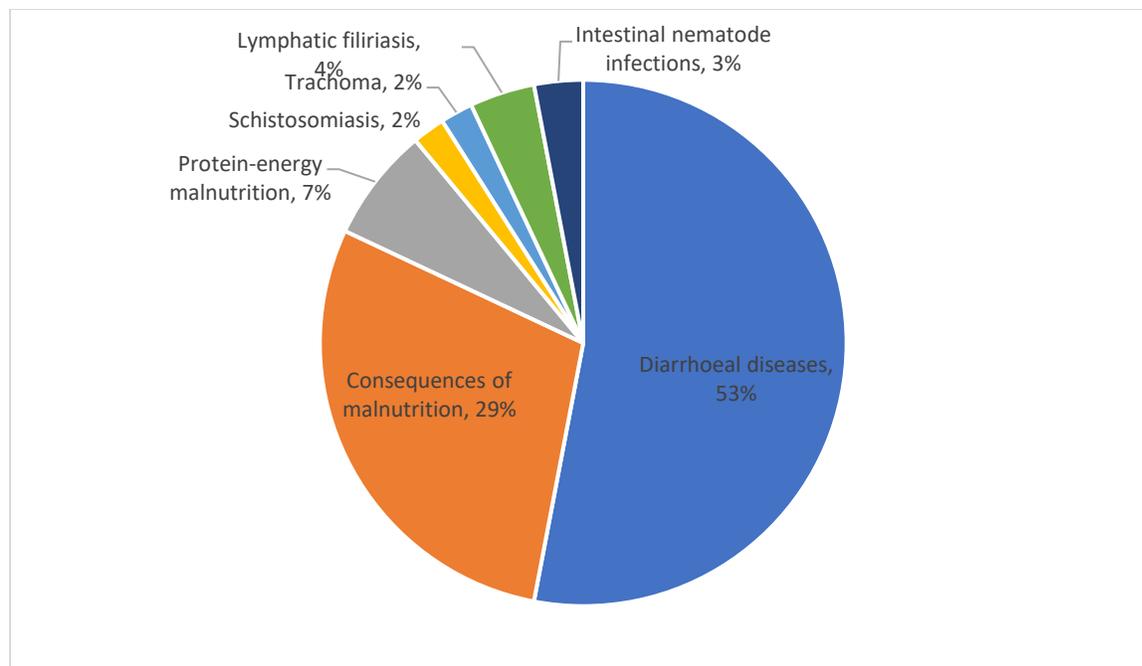
impacts on health and longevity in the 19th century in the developed world, hygiene has somewhat dropped off the agenda, eclipsed by the huge strides forward in healthcare and medicine.^{1,2}

Hygiene – or lack of it - does have major impacts, as shown by the spread of the COVID-19 pandemic around the world. The anxiety and uncertainty around epidemics and pandemics can lead to a reluctance to invest in equipment, structures and infrastructure. This, along with the allied fall in productivity, will have an impact on economic growth.³ Policymakers need to focus on how creating an infrastructure of public health, a focus on behaviour change and putting risk mitigation in place can provide confidence for investors. Governmental bodies focus on biosecurity on a national basis whereas global organisations like the WHO, and non-governmental organisations (NGOs), look to health security with a global perspective. True resilience will become more likely when **national** biosecurity is recognized as synonymous with **global** health security.

Linking disease to poor hygiene

Diseases linked to water, sanitation and hygiene are one of the leading causes of death in children. Around 2.4 million deaths could be prevented every year if people had access to good and reliable sanitation and drinking water, and practiced the right level of hygiene. Diarrhoeal diseases are transmitted via the faecal-oral route, via unwashed hands, or contaminated food or water, and are the most common sequela of poor hygiene. Diarrhoeal diseases cause the greatest health burden (Figure 1), with almost nine in ten deaths from infectious diarrhoea in children under five. More children are killed by diarrhoea than by AIDS, tuberculosis and malaria combined.^{1,4}

Figure 1: Contributions in DALYs of individual diseases to the total burden of ill-health preventable by improvements in hygiene, sanitation and water



DALY, disability-adjusted life years
Source: Bartram¹

The global burden of food-borne disease, which results from poor food safety and hygiene, is equivalent to that of malaria, HIV/AIDS or tuberculosis. Food-borne disease has a particular impact in low- and middle-income countries, and undermines the wellbeing of the population, as well as its economic productivity. Together, foodborne diseases cause 600 million cases of foodborne illnesses and 420,000 deaths. The most frequent illnesses are diarrhoeal, causing 230,000 deaths. The global burden is 33 million disability adjusted life years (DALYs), with 40% of the burden being on children under five years old. The burden is higher for people in low-income subregions.⁵⁻⁷

The impact of better hygiene

There are four key areas of hygiene – personal hygiene, water hygiene, food hygiene and hygiene during waste handling – and these can be practiced at personal, domestic, community and national levels. Carried out correctly, hygiene of all types reduces the spread of a range of diseases.^{8,9}

Diseases prevented by improved facial and hand cleanliness

- Ocular diseases, e.g., trachoma
- Respiratory infections, e.g., COVID-19, pneumonia and influenza
- Enteric infections, e.g., soil-transmitted helminthiases, shigellosis, and cryptosporidiosis

Handwashing is one of the most effective ways to prevent infections and stop pathogens spreading. In 2012, over a third of deaths from diarrhoea were due to poor hand hygiene, and hand washing with soap can reduce diarrhoea by almost 50%.^{4,10} Handwashing and food hygiene isn't just a developing world issue. Waterborne and foodborne diseases still occur, even with good access to hygiene and sanitation. As an example, improving hand hygiene in childcare centres reduces incidences of diarrhoea in developed countries.¹

Improving hygiene, sanitation and water has impacts over and above health outcomes. Healthier people do better at school and, once employed, bring more money into household and national economies. Better access to water and sanitation means less time spend collecting water or seeking places to defecate, and may improve school attendance by freeing up time and stopping girls dropping out of school after menarche.¹ However, our lack of understanding of hygiene, and the inability to implement it consistently over the long term, from food markets in the Far East to everyday interactions worldwide, has created an environment where pandemics can develop. The massive increase in uncertainty that accompanies a pandemic significantly reduces the appetite among businesses to take risks and to make investments in equipment, structures, and intellectual capital.³

Following the COVID-19 pandemic, many people are reluctant to return to shared workspaces and public transport, despite global vaccine programs in many parts of the world. This will have an impact on the

businesses based around town and city centres, such as hospitality, transport and leisure. The 'wash your hands' campaigns around the world created for the control of the COVID-19 pandemic could provide a good basis for the creation of a wider understanding of hygiene and its importance in preventing and controlling the spread of disease, as well as building trust for people who are hesitating over returning to the workplace.¹¹

The importance of hygiene in a pandemic world

In December 2019, the news broke of the identification of a new coronavirus in Wuhan in China. By May 2021, there had been 154 million cases worldwide of COVID-19 caused by the virus, named SARS-CoV-2, and 3.2 million deaths.¹² This compares with 1.1 million deaths in the Asian flu pandemic in 1957-1958, or 1 million deaths in the Hong Kong flu pandemic in 1968-1970.¹³ The WHO declared a pandemic in March 2020.¹⁴

The COVID-19 pandemic has had an enormous impact on the global economy and global trade. Global GDP fell by almost 13%. A 14.3% fall in global merchandise trade in the second quarter of 2020 was the largest ever one-period decline. Declines have a knock-on effect to individual people's incomes, as well as on physical and mental health and nutrition as a result of the impact on supplies of drugs, medical equipment and food.^{15,16}

Biosecurity and hygiene measures, by educating the public to understand non-pharmaceutical interventions such as handwashing, mask-wearing and social distancing, and enabling them to enact them, is important to reduce future impacts of epidemics and pandemics, can help to keep the flow of trade going. An example of this is putting the appropriate biosecurity arrangements in place for the movement of goods, particularly from quarantined areas.¹⁶

Rapid economic recovery post-pandemic will require policy makers to ensure stability and project confidence and competence in post-COVID investments and risk mitigation plans. Understanding how to do this, and providing clear, actionable communication will help to create a common defence against biothreats. This begins with an understanding of why hygiene is the foundation of biosecurity.

The COVID-19 pandemic isn't by any means over yet, and it won't be the last pandemic that we experience, driven by factors such as air travel, urbanisation and climate change, along with animal contact through habitat encroachment, animal husbandry and wildlife trade.¹⁷ The WHO has created a list of diseases that are prioritized for R&D in public health emergency contexts, and this includes a range of diseases that have epidemic potential, including Ebola, MERS, SARS and Zika, along with as yet unknown threats.¹⁸ The world was caught off guard by the arrival of COVID-19; continuing to track potential new diseases, being prepared for how we will react, and planning and rapid responses to data will be vital for next time.¹⁹

Public health agencies and private institutions and researchers are aware of the risk of a future pandemic, and surveillance and epidemiological investigations are already in place, supported by pathogen genomic sequence data. An example of this is the Chan Zuckerberg Biohub's California COVID Tracker, with whole genome sequencing, analysis, and interpretation of SARS-CoV-2 provided free in the

state of California to support the ongoing pandemic response. However, what can be achieved by individual and local institutions and agencies is limited, and there needs to be a unified and accessible informatic ecosystem in place to support the sharing of data, workflows and analyses. This will require governmental support on a global basis.^{20,21}

The COVID-19 pandemic has brought the role of hygiene to the fore, to reduce the risks of new pandemics, and limit their spread. Because hygiene means very different things to different people, governments, policymakers and researchers need to establish a common understanding of hygiene in its many contexts and applications, to support the preparations for the next pandemic. Unfortunately, it's likely to be when rather than if. This common understanding could be supported by the development of a hygiene index. Hygiene is an asset to our health and the economy. Inequalities in hygiene have a significant impact on global societies yet a lack of quantifiable data referencing these impacts hinders the development of beneficial interventions. A hygiene index would provide an overview as to how hygiene varies across communities as well as a more granular view which can be used to identify where intervention and associated policy change should be directed. By providing a quantitative 'diagnosis', the hygiene index would be part of a valuable toolbox for the development and provision of hygiene policies and improvements.

The challenges in creating change

There are challenges inherent in the process of change, and creating solutions requires a knowledge of the problems and barriers, as well as an understanding of the systems approaches that will help these changes to bed into place. The challenges in putting hygiene solutions in place include the barriers of behaviour and culture and how these affect people's ability to change, as well as the specific challenges seen in particular environments and groups of people. Understanding how to deal with all of these is required to be able to put suggestions together for policymakers, and to see them be effective.

Taking a systems approach is an important part of making changes. After all, looking at challenges without considering the systems that they exist within – be they political, cultural or behavioural – will not change anything. To make a difference, we need to view each challenge and its solution within a greater whole.²²

Behavioural issues

Making changes is hard. Throughout human history, people have tended towards homeostasis – following the same rules and doing the same things has kept us safe. Even in the disruption of the COVID-19 pandemic, there is an urge to return back to 'normal'. This makes it hard to change habits, including hygiene habits.²³

Diseases in hospitals often spread because of failures in handwashing by healthcare professionals (HCPs). The WHO carried out a study of doctors looking at whether their thinking style had an impact on whether they washed their hands. The overall conclusion was that hand hygiene is more experiential than rational, and that education based on logic and reasoning alone was unlikely to work, compared with a more experiential approach.²⁴ In a hospital study comparing two signs, one that read "Hand

hygiene prevents **you** from catching diseases" and the other that read "Hand hygiene prevents **patients** from catching diseases", the sign that focussed on patient safety had a greater impact on handwashing behaviour. Reminding HCPs of the impact on their patients was more effective than reminding them of the impact on themselves. This is a low cost solution that works by appealing to the HCPs' altruism, and fits easily within the existing system.²⁵

Behaviours need to be changed in time to ensure that the new infrastructure, for example shared toilets or handwashing facilities, achieves what it is supposed to. This may require behaviour change strategies to be in place before the infrastructure arrives, so that people know what they need to do. As an example, compared with parts of Asia, people in the Western world generally did not wear masks to protect themselves and others from respiratory diseases such as flu, so mask uptake in the COVID-19 was challenging at first. The experience of the COVID-19 pandemic potentially means that masks may be more commonly used during the winter season, reducing the risk of flu outbreaks.²⁶⁻²⁹ In the case of new shared toilets (see 'Urbanization and urban slums'), putting in place education about use, maintenance and cleaning before the toilets are opened for use will improve their acceptance. It will also reduce the risk of them becoming damaged and dirty, which may stop them being used and can increase rather than reduce the risk of disease.³⁰

Lack of taxonomy and measures

Behaviour change needs sustained adoption to be effective, and measuring sustained adoption needs data based on three components, measured both during and after the project:⁸

1. The behaviour
2. The frequency of the behaviour practice
3. the length of time at which this behaviour should be measured to be considered sustained

However, there is a lack of consensus on how to measure sustained adoption, and no sustained standardized outcomes or reporting formats.⁸ It's not just here where this is an issue. One of the things that makes the whole area of implementing changes in hygiene difficult is the overall lack of language and definitions, little consensus in measurements and outcomes, and few quantitative and qualitative models. Something the hygiene index would begin to address.

Some researchers are working to develop quantitative measures and tools, for example the quantitative personal hygiene assessment tool (qPHAT).⁹

Developing a quantitative personal hygiene assessment tool (qPHAT)⁹

Conventional cleanliness metrics are qualitative, and look at observations such as presence or absence of nasal and ocular discharge, dirt under nails or on finger pads and palms. The qPHAT methodology used gauze pads pre-moistened with sterile saline, wiped once around the eyes and once around the inside of the right hand. The wipes were scored against an 11-point colour scale with 10% step changes in colour saturation.

Pathogen genomic analysis is already proving to be a powerful tool in public health, with a role in detecting and tracking disease outbreaks, tracing transmission chains, and looking at the population dynamics of spread. However, there are challenges in its broader application, which require the development of an accessible, unified informatic ecosystem. This will require the creation of a consistent data model, well-documented application programming interfaces (APIs), guidelines for management and stewardship of genomic data, open-source bioinformatics software accessible to low-income settings, bioinformatics analyses and visualisations that are scalable, accessible and reproducible, and a well-trained workforce. There will also be a need to integrate genomic and traditional epidemiology, improving the power of data from both sides.²⁰

Culture

Behavioural change models must be scalable as well as culturally relevant and sustainable. Different countries and cultures have different understandings of what is hygiene, and a variety of ways to achieve it. As an example, handwashing by doctors in Europe was once considered controversial medical advice, and Austrian doctor Ignaz Semmelweis was condemned by his fellow physicians. It was only after his death that the idea of handwashing between patients was widely accepted.³¹

More recently mask-wearing as a preventive intervention against COVID-19 resulted in starkly different cultural reactions. Fuelled by the legacy of SARS those in East Asian countries responded by wearing masks en-masse very early on in the outbreak. Because of the customary nature of mask wearing it was not necessary for the government to mandate mask-wearing. In contrast, in parts of the world where mask wearing wasn't seen as second nature many individuals responded negatively claiming that its mandate was contrary to personal freedom. Health behaviour change models differ between countries and cultures, so should be developed with reference to a specific culture. For example, Western models are often based on individualism and will not suit a collective culture. The education needs to be delivered in a way that fits with the culture, and uses the people best fit to carry out the training in that environment.³²

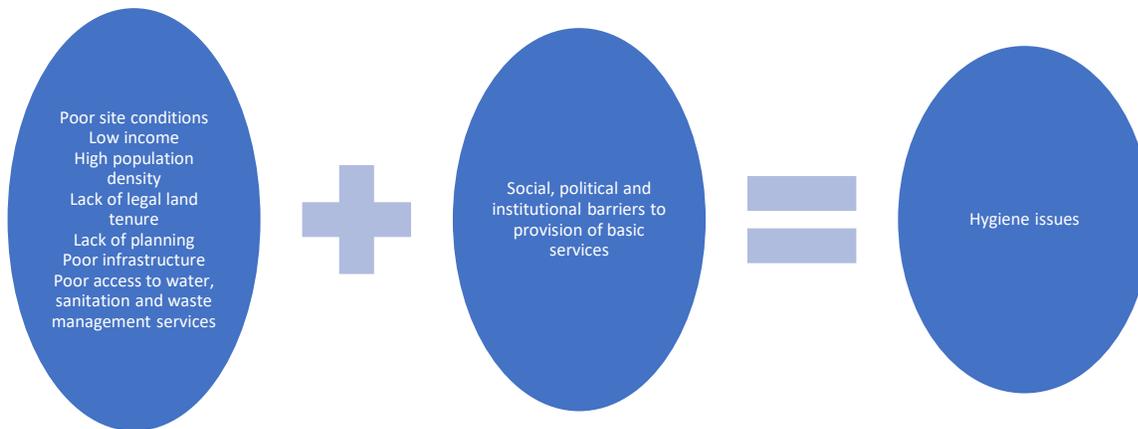
Key problem areas

Particular environments or populations have their own challenges where change is concerned. For example, these may be related to gender or location, or be the difficulty of dealing with particular disease types.

Urbanization and urban slums

One of the challenges to improving hygiene and sanitation is urbanization, where progress made can be overtaken by population growth. The poorest populations, particularly those living in informal settlements, are often those who are most affected by diseases related to hygiene (Figure 2).³³

Figure 2: Hygiene challenges in informal settlements



Adapted from Kennedy-Walker³³

Putting sanitation in place is seen as a positive move towards improving hygiene and thereby reducing disease and improve health and economic outcomes, but this doesn't always work. In the case of toilets, if these are poorly constructed, damaged, undesirable or not used regularly, they will not stop faecal contamination of the environment. Shared toilets may also worsen the situation by spreading disease if they are not cleaned or maintained regularly, or do not work properly.³⁰

Changing hygiene behaviours for shared toilets takes time, and needs to consider any constraints to keeping the facilities clean and maintained. In a study in Dhaka, Bangladesh, behaviour change interventions were delivered by community promoters, who also provided the hardware needed, and helped to support maintenance. The messages were posted up in and around the toilet cubicles, and were delivered as part of regular meetings. The information included how to flush after toilet use, how and where to dispose trash to prevent toilet blockages, and the importance of using a potty to collect and dispose of faeces for children under three years old who are unable to use the toilet. Compound property owners and caretakers were taken on board. The intervention improved the cleanliness and reduced blockages.³⁰ In slum areas, water can be scarce, and people may feel embarrassed to be seen carrying water to the toilets. A strategy as simple as providing water storage nearby the toilets improved maintenance and user satisfaction.³⁴

In urban and slum areas, hand washing is challenging because of a lack of access to clean water and soap, as well as a lack of understanding of the importance of hand hygiene. In a study looking at hand-washing in the Shikharchandi slum of Bhubaneswar, Odisha, India, 77% of women washed their hands before preparing food, and 72% washed their hands after defecation. Over 80% of the children questioned said that they washed their hands before taking food, but only 17.5% said that they used soap. While the women questioned understood the value of handwashing with soap, this did not seem to be translated into sustainable behaviour. Teachers, physicians, nurses and health workers could play an important role in improving the uptake, as well as systematic integration of health and hygiene education in schools.³⁵

Neglected diseases of neglected populations

Neglected diseases, which include a variety of parasitic, bacterial and viral infections, are often those that affect the poor, and the lack of compulsory reporting in many countries means that their disease burden is not well recorded. However, they still cause social and financial burdens for the individuals, and for their families and communities. For example, lymphatic filariasis in Orissa, India results in an average loss of 68 working days per worker. Neglected diseases also have an impact on the national economy, and on the region's economic development. Dealing with these diseases needs an intersectional approach that reduces transmission, and this includes better sanitation, improved personal and household cleanliness, better housing, and better biosecurity when animals are concerned.³⁶

The impact of food-borne disease

Foodborne diseases are linked with the safety of staple foods as well as foods that are nutrient rich but perishable, such as fish, meat, milk and vegetables. A particular concern for biosecurity, food-borne diseases are expected to increase as climate change allows the spread of disease outside its current boundaries, as well as with the increased consumption of products and produce from livestock and fish, and the increasing complexity of food supply and value chains. A lack of improvement in food safety governance will mean that these increases may spiral out of control.^{6,7}

Measuring the impact of food-borne diseases and the benefits of hygiene changes is problematic because estimates of the global burden of disease related to food-borne diseases rely on regional data, which is likely to be less accurate in low- and middle-income countries. Global burden of disease measures are based on disease rather than transmission route so do not separate out food-borne routes. Food, water, health and nutrition sectors need to collaborate to develop better measures and metrics.⁶

As food-borne diseases sit at the intersection of food and agriculture, in order to make a difference there needs to be better co-ordination and communication between agriculture, health and ecosystems, and between the fragmented parts of the health governance framework.⁶

Menstrual hygiene

Worldwide, at least half a billion women and girls lack access to facilities for adequate menstrual hygiene management; this includes access to water and period protection products, and to toilets that lock. Around a quarter of women in Nigeria don't have the privacy needed when toileting, and around 88% of women do not have handwashing facilities on their premises. Menstruation means that around three-quarters of women working in factories in Bangladesh miss an average of six paid days of work each month. About 10% of African girls and a quarter of Indian girls don't go to school while they are menstruating. Infections because of unsanitary period protection products, or the need to use old rags, mean that girls miss schoolwork or completely drop out of school. Menstruating women may also be considered as impure in some cultures. Initiatives that educate men and boys, and get them involved in supporting menstrual hygiene, reduce the stigma and increase support.^{37,38}

Communicating with policymakers

By 2030, United Nations Sustainable Development Goal 6 aims to achieve access to safe drinking water, sanitation and hygiene, particularly for women and girls, and for people in vulnerable situations.¹⁰ However, a lack of political commitment and consensus, coupled with limited capacity of leadership, management, and health systems, pose challenges to improving hygiene.^{4,39}

Policymakers need to be shown that by investing \$X, mortality will reduce by Y% and the economy will grow by Z% - but these economic models don't exist, and investment will lag until these measurements can be made. Public health has fenced itself off from corporate influence, but as corporations are good at both the quantitative and qualitative models needed to drive investment, collaboration could be beneficial.

All sanitation and hygiene projects need to take into account the role of power and politics, and the importance of the political, social and historical contexts. Planning teams should include political expertise, and need to involve people who actually have the power to make the changes. This may differ from country to country, and could be at the national, regional or even the local level.³³ To be successful, policymakers need to look to empowering communities and enhancing youth involvement, as well as promoting gender equity.⁴

Change using a systems approach needs to bring in people at all levels of a hierarchy, whether that's within a governmental body, a town or village, or even a family. It also needs the people implementing the change to be open to listen to opinions and discuss projects, and make changes if necessary. A project or program cannot succeed if it is helicoptered in; it needs to address the needs of the local population and be something that is both used and useful.²²

Biosecurity depends on hygiene: In conclusion

Hygiene is fundamental to biosecurity. However, shifting entrenched hygiene behaviours will require broad collaboration across governments, academia, NGOs, companies and the media, as well as local society on the ground. It needs openness, dialogue and discussion. Through such collaborations we will achieve key goals:

- Hygiene solutions defined at the right scale.
- Successful pilot investments that are easily translatable across geographies and cultures.

To achieve this, we need to characterize the impact of public and private hygiene behaviours and work within the current media and cultural landscape to generate locally relevant and common understandings of "common sense hygiene", using these to create and communicate practical and useful behaviour change.

Public and private incentives will need to be aligned within common policy frameworks, to ensure the key players can collaborate in creating an entrepreneurial landscape that will reward both public and private investment. We believe these behaviours are essential building blocks of hygiene and biosecurity.

Let's agree that the fundamental challenges presented by our mission to make society more resilient, are difficult and persistent. Successful resilient systems will not solve these issues, they will align our understanding and incentives to increase our chances of resisting the next pandemic. They will also support our future economic growth. Change in hygiene is incredibly difficult, and its communication is challenging. The research disciplines necessary to develop actionable insights lack a critical mass of collaboration in the hygiene space. We also lack the means of collecting insightful data: Hygienic behaviours span between very public and very private realms, and data struggles to bridge between the two.

The hygiene field lacks a neutral holistic collection and summary of the evidence base to ensure the science is presented clearly, above any partisan interpretation. Creating the rationale for hygiene behaviour change, and implementing it, depends on getting the evidence and solving the challenges. Building resilience requires a focused project to bridge these issues. Creating a system of policy and communications that gets stronger under stress, moving beyond resilience, will require us to invest in understanding these issues over the long term. We believe that we can bring a holistic systems approach vital to motivating change, as well as proposing the development of a hygiene index that can identify where policy change and effort should be directed.

In conclusion, biosecurity depends on us. No governmental agency or law will make us safe. We need to learn what keeps "us" safe and healthy. We need an educated public capable of understanding, detecting and protecting the vulnerable from unreasonable risks. And we must recognize the right to an improving human condition. Inequality in the hygiene landscape will expose us all to risk, and hygiene inequity is retarding the rapid economic growth we will need to recover from the COVID-19 pandemic.

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