VITAL SIGNS

Health security in South Africa

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Abbreviations and acronyms

AEB	Atomic Energy Board
AFRA	Africa Regional Cooperative Agreement
AFRA-NEST	AFRA Network for Education in Nuclear Science and Technology
Africa CDC	Africa Center for Disease Control and Prevention
AIRT	Animal and Products Identification, Recording and Traceability
AMCU	Association of Mineworkers and Construction Union
AMD	Acid Mine Drainage
AMR	Antimicrobial resistance
AMS	Antimicrobial stewardship
ANC	African National Congress
APHF	Africa Public Health Foundation
API	application programming interface
ARC	Agricultural Research Council
ARPA	Advanced Research Projects Agency
ART	anti-retroviral therapy
ASSAF	Academy of Science of South Africa
bOPV	bivalent oral poliovirus vaccine
BRICS	Brazil, Russia, India, China and South Africa
BSL*n*	Biosafety level *n*
BTWC	Biological and Toxin Weapons Convention
CAIA	Chemical and Allied Industries Association
CAT	computer assisted tomography
CBRN	chemical, biological, radiological and nuclear
CBW	chemical and biological warfare
CDC	Centers for Disease Control and Prevention
CDW	Central Data Warehouse
CEPI	Coalition for Epidemic Preparedness Innovations
CEPPWAWU	Chemical, Energy, Paper, Printing, Wood and Allied Workers' Union
CMJAH	Charlotte Maxeke Johannesburg Academic Hospital
CoCT	City of Cape Town
CW	Chemical warfare
CWC	Chemical Weapons Convention
DAFF	Department of Agriculture, Forestry and Fisheries
DMA	Disaster Management Authority

DRC	Democratic Republic of the Congo
DURC	dual use research of concern
EAC	East African Community
EDL	Essential drug list
EFF	Economic Freedom Fighters
EID	Emerging infectious diseases
EIU	Economist Intelligence Unit
ENSO	El Niño–Southern Oscillation
EOC	Emergency Operation Centre
EPI	Expanded Program for Immunization
EQA	External Quality Assurance
EVD	Ebola Virus Disease
FETP	Field Epidemiology Training Program
GARP-SA	Global Antibiotic Resistance Partnership in South Africa
GAVI	Global Alliance for Vaccines and Immunization
GHI	Global Hunger Index
GHS Index	Global Health Security Index
GHSA	Global Health Security Agenda
GLASS	Global Antimicrobial Resistance Surveillance System
GNI	Gross National Income
HCAI	healthcare associated infection
HE²RO	Health Economics and Epidemiology Research Office
HEU	Highly-enriched uranium
HIV	Human Immunodeficiency Virus
HRD	Human Resource Development
IAEA	International Atomic Energy Agency
ICT	information and communication technology
IDSR	Integrated Disease Surveillance and Response
IHR	International Health Regulations (2005)
IoT	Internet of Things
IPC	Infection Prevention and Control
IPCC	Intergovernmental Panel on Climate Change
IPV	Inactivated poliovirus vaccine
IRI	International Research Institute for Climate and Society
ISS	Institute of Security Studies
JEE	Joint External Evaluation
KNPS	Koeberg Nuclear Power Station
LEU	Low-enriched uranium
LM	*Listeria monocytogenes*
MCM	Medical countermeasures

MECs	Members of Executive Councils
MERS	Middle East respiratory syndrome
MNORT	Multi-Sectoral National Outbreak Response Team
MoU	Memoranda of understanding
MPRDA	Mineral and Petroleum Resources Development Act (No. 28 of 2002)
MRL	Mineral Research Laboratory
NAJOINTS	National Joint Operational and Intelligence Structure
NAP	National Action Plan
NAPHISA	National Public Health Institute of South Africa
NAPHS	National Action Plan Health Security
NATHOC	National Health Operations Centre
NATJOC	National Joint Operational Centre
NCACC	National Conventional Arms Control Committee
NCID	National Institute for Communicable Diseases
NCS	National Core Standards
NDMC	National Disaster Management Centre
NDOH	National Department of Health
NDP	National Development Plan
NDR	National Dose Register
NECSA	Nuclear Energy Corporation of South Africa
NEM	National Environmental Management
NEM: AQA	Air Quality Act
NEM: WA	Waste Act
NFP	National Focal Points
NHI	National Health Insurance
NHLS	National Health Laboratory Services
NICD	National Institute for Communicable Diseases
NIOH	National Institute for Occupational Health
NMC	Notifiable Medical Conditions
NNDMP	National Nuclear Disaster Management Plan
NNR	National Nuclear Regulator
NNSA	National Nuclear Security Administration
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
NUM	National Union of Mineworkers
OMT	Oppenheimer Memorial Trust
PBMR	pebble-bed modular reactor
PER	Performance and expenditure reviews
PFMA	Public Financial Management Act
PHEIC	Public Health Emergency of International Concern
PHEOC	Public Health Emergency Operations Centre
PIH	Partners in Health

PIP	Pandemic Influenza Preparedness
PNEs	Peaceful Nuclear Explosives
POPs	Persistent Organic Pollutants
PPE	personal protective equipment
PoVS	Performance of Veterinarian Services
PVS	Pig Veterinary Society
R&D	Research and development
RCC	Regional Collaborating Center
RED	Reaching Every District
RRL	Roodeplaat Research Laboratory
RVF	Rift Valley Fever
SA-RCC	Southern Africa Regional Collaborating Center
SAAHA	South African Animal Health Association
SAASP	South African Antibiotic Stewardship Program
SACIDS	Southern African Centre for Infectious Disease Surveillance
SACOMD	South African Committee of Medical Deans
SADC	Southern African Development Community
SAFELTP	South African Field Epidemiology and Laboratory Training Program
SAGE	WHO Strategic Advisory Group of Experts on Immunization
SAICM	Strategic Approach to International Chemicals Management
SAIPS	Systems for Improved Access to Pharmaceuticals and Services
SAMRC	South African Medical Research Council
SAMS	South African Military Medical Service
SANAS	South African National Accreditation System
SARS	Severe acute respiratory syndrome
Sasol	South African Steamcoal and Oil company
SDGs	Sustainable Development Goals
SOEs	State-Owned Enterprises
STG	Standard treatment guidelines
TB	tuberculosis
TFCA	Transfrontier Conservation Areas
TRC	Truth and Reconciliation Commission
UHC	Universal Health Coverage
UN	United Nations
UNICEF	United Nations Children's Fund
UNSCR	United Nations Security Council Resolution
WEF	World Economic Forum

WHO	World Health Organization
WHO AFRO	World Health Organisation Regional Office for Africa
WHO framework	WHO biorisk spectrum
WMD	Weapons of mass destruction
XDR-TB	Extensively drug-resistant tuberculosis
ZNPHI	Zambia National Public Health Institute

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Executive overview

Vital Signs: Health Security in South Africa comes on the heels of the October 2019 release of the *Global Health Security Index*, the report of the Global Preparedness Monitoring Board in September 2019 and the June 2018 World Health Organization's voluntary assessment undertaken by the Joint External Evaluation (JEE) that measures South Africa's capacity to prevent, detect and respond to public health threats.[1] Each chapter describes the context, strengths, weaknesses and developments in the following risk domains: nuclear, environmental, chemical, infectious disease, biological, and climate-related hazards and threats. The chapters ultimately make recommendations for improving the threat environment surrounding each risk domain.

The overall recommendations resulting from *Vital Signs* are as follows:

- After conducting a spending review, the South African Treasury should construct a new health security budget framed in national security terms;
- The responsibility for leading health security should be lifted out of the Department of Health and placed in the Presidency. The Presidency would have the following responsibilities:
  - Integrating South Africa's health security, including its surge capacity, across departments and spheres of government;
  - Creating partnerships with the private sector to develop new disaster prevention, detection and response technologies and systems;
  - Working with civil society organisations to harness and leverage their reach into communities to better enable prevention, detection and response on a local level to high-consequence hazards; and
  - Collaborating regionally with the Lusaka-based Regional Collaborating Center (RCC) of the Africa Center for Disease Control and Prevention (Africa CDC) in disaster prevention, mitigation, response and recovery.

Parliament should appoint a *Standing Commission on Health Security* to provide oversight of government measures in preventing, detecting, mitigating, responding to and assisting community recovery from all nuclear, radiological, chemical, environmental, infectious disease, biological and climate-induced and other catastrophic events, assuring that they

are consistent with the Bill of Rights and the Constitution, and that the country's legislation and regulation regime is up to the task. Pointedly, the *Standing Commission* must also provide rigorous oversight over any government or clandestine illicit trade in chemical weapons, weapon-ready biologics and radioactive materials.

Government should appropriate sufficient funds to support sustainable high-level longitudinal research on current, emerging and future domestic, regional, continental and global catastrophic hazards and risks that may affect the country, undertaken by scientists located at the country's medical, industrial, agricultural, minerals and human science councils and, we propose, at newly established centers of excellence at universities.

Nuclear and radiological: changing risks from apartheid to democracy

South Africa, with a mining-oriented economy, began to develop its nuclear programme during World War II as the demand for uranium increased drastically. After its emergence in 1948, the apartheid regime began the development of its nuclear programme with the establishment of the Atomic Energy Board. South Africa was invited to observe the development of the United States' nuclear programme after joining the Atoms for Peace programme in 1953. Increased political unrest in South Africa after the 1960 Sharpeville massacre led the regime to move toward increased military self-sufficiency, which included the militarisation of its nuclear programme; much of the development of South Africa's nuclear arsenal was the result of clandestine cooperation with nations such as France and Israel. As a result, the details of the nuclear arsenal were only revealed publicly for the first time in March of 1993 in a speech to South Africa's Parliament by (then) President F.W. de Klerk. South Africa signed the Nuclear Non-Proliferation Treaty in 1991, heralding the dismantlement of the country's nuclear arms development.

The secrecy and lack of international oversight surrounding South Africa's nuclear programme generated many security gaps. This culminated in several serious breaches of nuclear facilities, including the sabotage of the Koeberg nuclear power facility's construction site in 1982, a seaborne invasion of the Koeberg facility by environmental activists in 2002, and a 2007 breach of the Nuclear Energy Corporation of South Africa (NECSA) site at Pelindaba. The breaches and the hosting of the 2010 FIFA World Cup prompted stricter regulation of nuclear security in South Africa. While compliant with its commitment to nuclear disarmament, many concerns remain regarding the safety of its nuclear energy programme. Radiation

exposure and nuclear terrorism remain a threat to South African health security. Permanent oversight by an appropriate body is called for in order to develop and maintain South Africa's capacity to detect and respond to nuclear and radiological threats, including those posed by nuclear medicine and the use of Cesium-137 and Cobalt-60 for radiotherapy in the public and commercial health sectors.

Reaction and action: chemical and environmental security

South Africa's chemical industry has been developing since the late 19th century and has become a significant contributor to the national economy. The chemical industry can be divided into two sectors: the mineral sector and the chemical processing sector. The mineral sector is comprised of mining and ore refinement while the chemical processing sector is comprised of the production of industrial grade chemicals.

The risks associated with the mineral sector are principally mining-related injuries and trauma, and illnesses associated with exposure to mining conditions. The by-products of ore refinement and mining pose significant environmental hazards. Mining-related injuries and illnesses remain a costly human consequence of the mining industry.

Risks associated with the chemicals industry include both direct contact with chemicals and indirect environmental and health risks associated with their production, use, and release into the environment. In response, the government's Industrial Policy Action Plan (IPAP) seeks to shift the chemicals and associated industries towards a green economy, a circular economy, or one with minimised emissions.

South Africa has been a producer of chemical weapons since World War I. While there has been increasing regulation of the production and accessibility of chemical weapons and their precursors since the end of the apartheid regime, a sharp increase in concern surrounding the threat of chemical and biological terrorism has emerged. This growing concern is primarily due to the country's lack of restriction regarding the sale of chemicals that have been used to carry out chemical attacks in other countries.

The 2018 WHO/JEE report found that South Africa has mechanisms in place to effectively respond to chemical events. The country would, however, benefit from much more vigorous enforcement of existing legislation and refinement of existing laws already on its books. The following recommendations for risk management of chemical hazards are made:

- Government needs to demonstrate the leadership and willingness to enforce existing legislation. The work of all those charged with inspection requires financial, technical and political support;
- As a matter of priority, the construction of back-cast scenarios toward a resilient, low-carbon future should be framed and a meeting involving all stakeholders convened. Scenarios must sensitively deal with the impact of climate change mitigation on employment and production;
- In addition to limiting the future impacts of the chemicals and minerals sectors, there is a need for remediation to address past and present impact. Provision must be made for the necessary financial and technical investment for both compensation and mitigation on the part of government and the private sector.

Biological and infectious disease risks

Recent studies from the US Institute of Medicine have shown that biological, socio-economic, ecological and anthropogenic factors are creating the perfect conditions for a storm of emerging and re-emerging zoonotic pathogens. Despite a steady decline in infectious disease rates, infectious diseases remain one of the leading causes of death in South Africa. South Africa faces both endemic and exotic microbial threats. HIV and tuberculosis are two prevalent diseases that are currently burdening the South African healthcare system.

Compared to the rest of the African continent, South Africa has an advanced and capable biocontainment and laboratory infrastructure. This allows for the effective analysis and containment of infectious disease as they are identified in the field. In order to mitigate the magnitude of infectious disease outbreaks, the spread of infectious disease throughout the African continent must be considered as well; outbreaks of diseases such as Ebola in the Democratic Republic of the Congo, and the spread of the Zika virus pose a threat to South African health security.

In order to improve South Africa's preparedness for biological and infectious disease events, a unified approach in the legal and regulatory system to deal with public health concerns is recommended. The following specific recommendations are made:

- It is in the interest of the South Africa's national and regional health security that the current high and maximum biocontainment facilities at NICD/NHLS (BSL3 and BSL4) are supported by the South African Government as being of national strategic importance. This will secure their long-term role in preparedness and response to dangerous pathogens and bioterrorism. Technical performance of the facility,

training, diagnostic and research programmers should be regularly monitored and evaluated. Reports on technical, managerial, diagnostic, science and innovation activities should be reported to parliament and the relevant departments.

- An interdepartmental framework – comprising the Departments of Health; Agriculture; Higher Education, Science and Technology; Trade and Industry; and Defence – should be established to prioritise development and research programmes on dangerous and high consequence pathogens, the construction and upgrade of containment facilities that could support multi-disciplinary and inter-institutional collaboration in conducting life sciences research of national health security significance.
- The proposed interdepartmental framework should promote the *One Health* approach to minimise the biorisk spectrum, including natural emergence, and accidental or deliberate misuse of high consequence pathogens, and strengthen the South African multi-sectoral resource capacity in the implementation and execution of the International Health Regulations and compliance with the UN Security Council Resolution 1540.
- To realise the full potential and associated benefits of BSL4 in Johannesburg (NICD/NHLS) there must be intensive and broad collaborations between African countries in the era of emerging infectious disease to ensure that African scientists are actively involved in preparedness and response programmes to counteract the emergence of dangerous, high consequence pathogens.

Climate, drought, food security and health

In recent decades climate change in South Africa has contributed to an increase in extreme weather events including heat waves, drought, and wildfires. Based on current climate change projections, the frequency of extreme weather events is expected to increase. Changes in temperature and rainfall patterns impact agricultural yields and thus affect food security. The combined effects of climate change pose significant health hazards, particularly to populations already at risk such as the elderly and those below the food-poverty line; with over a quarter of the country's population unemployed and more than half under the poverty line, climate change, drought, and food security pose a significant risk to South Africa's health security.

In the aftermath of Cape Town's 2017 water shortage emergency (Day Zero), and based on the predicted meteorological changes expected over the coming decades, the following recommendations are made:

- WHO/JEE and other risk assessments should include the capacities of national meteorological agencies to monitor and predict weather and climate disasters;
- Increase monitoring capabilities for climate sensitive health outcomes;
- More high-quality research into climate change risks and adaptation opportunities for health security;
- Multi-sectoral partnerships linking climate change, drought and food health; and
- Adaptation of infrastructure including public buildings such as schools, hospitals and indigent households to withstand extreme climate conditions.

The Chemical, Biological, Radiological and Nuclear (CBRN) threat environment

In light of the 2007 raid on the Pelindaba facility, concerns about the integrity of South Africa's public health safeguards has been raised. A review of the South Africa's threat environment in the realms of nuclear and radiological, biological, chemical, and cyber is thus warranted.

The 2007 raid on the Nuclear Energy Corporation of South Africa (NECSA) Pelindaba facility raised international concern regarding the security of South Africa's stock of highly-enriched uranium (HEU). While this security breach is certainly cause for concern, the threat of nuclear exposure due to terrorism or sabotage of a nuclear site in South Africa remains low. Of more concern is the security and safe disposal of medical isotopes such as Cesium-137 and Cobalt-60; proper disposal is costly and proper oversight will mitigate risks to public health. Cesium-137 and Cobalt-60 are the key ingredients for the making of 'dirty bombs', which can contaminate cities and neighbourhoods for many decades and centuries and therefore can radically affect human habitation and settlement patterns.

Concerns surrounding South Africa's chemical threat environment primarily surround the production of industrial chemicals and their ability to contaminate food and water supplies. After the 1993 dismantlement of the apartheid regime's chemical (and biological) weapons programme, *Project Coast,* the accessibility of chemical weapons remains low. While technically very difficult to get right, the weaponisation of toxic chemicals by non-state actors remains a credible threat.

The primary biological threats facing South Africa include outbreaks of endemic and exotic diseases, sabotage or disruption of the agricultural production chain, and a resurgence of diseases such as measles associated with vaccine hesitancy. The threat of pathogen release from South Africa's

containment facilities is negligible. Agri-terrorism could potentially harm the country's economy and disrupt food security for much of the population. Tiger Brands' March 2018 listeriosis outbreak is a recent example of how costly food contamination can be; as of yet there is no national food safety authority to regulate imports and exports or control local food. A single national body would be able to better control an outbreak by shortening response times and by coordinating the responses of various role players. Currently, the diverse food certification bodies are self-regulating; a single national authority could re-assess much of the outdated food safety protocols and oversee the implementation of new rules in a coordinated and more cost-effective manner.

With respect to cyber security, the increasing digitalisation of patient health records has caused the threat of confidential information being compromised to increase. There has been a marked increase in medical data breaches since 2016; in 2018 South Africa's per capita cost of data breaches was R36.5 million. A large scale breach of data or malware attacks in South Africa would be costly and cause tremendous harm to public trust.

In order to improve South Africa's CBRN threat environment and overall health security, the following recommendations are made:

- Criminal threats to health security can be managed by improving physical plant security, staff procedure and training and the reduction of normal operational risks associated with the different requirements for chemical, biological, radiological and nuclear safety and security;
- Upscaling biosecurity systems for laboratories and pathogen transportation logistics and providing rigorous oversight of dual-use research and emergent risks associated with the rapid advances in biotechnologies;
- Improving the formal public and private sector coordination and mobilising civic participation in response to public health threats to help with preventing and improving the response to public health threats;
- Improving, standardising, and securing medical communication platforms to capture and share in the experience of both practitioners and organisations. Latent cyber security threats must also be addressed; and
- A national food safety authority to regulate imports and exports or control local food should be established.

Investing in health security preparedness

In addition to human suffering caused by public health emergencies, the economic damages can also be significant. Outbreaks of disease lead to the disruption of economic activities through travel restrictions, employee absences, supply chain interruptions and so on. Disease outbreaks might also deter foreign investments and tourism in both the short- and long-term. Public, private, and government investment in preparedness for public health emergencies is therefore of the utmost importance; improvements in health security will be brought about by increased funding for research and development of preparedness, diagnostics, surveillance and medical countermeasures, and by a budget review within the framework of public health financing.

In order for government to consider additional investments in health security it is important to quantify both what is currently being spent and the funding need. The development of South Africa's post-JEE National Action Plan will provide an opportunity for South Africa to consider developing a new approach to health security and budgeting. This will be done by (1) extending the domains to be covered to include nuclear, environmental, climate-related and national security risks; (2) creating public-private entities and drawing in companies which have a direct and indirect longer interest in emergency and disaster prevention, detection, mitigation, response and recovery; and (3) redesigning the way in which government delivers emergency services.

What needs to be done?

In the conclusion, the capacity of the state to deliver a revised health security program on the ground is considered, and the prospects for success, given the country's immediate political history, we regard as mixed. A great deal of deep damage was done by the Government of President Jacob Zuma to our public institutions, compromising, and in some instances, crippling their ability to serve the public good. Still, there is a lot of strength in the health system on which to build. We make a case for the Presidency to lead – and find the will to lead boldly – a health security program through soft- and hard-line departments; for Parliament to establish a *Standing Commission on Health Security* with a mandate of executive oversight and accountability; for the resourcing of a longitudinal research agenda on the current, emerging and future domestic, regional, continental and global catastrophic hazards, risks and threats the nation faces, to be undertaken at our science councils and universities; and for investing in reversing the brain-drain and knowledge decay in some critical

knowledge areas, as observed by the many experts in their field who are contributors to this volume.

Introduction

Wilmot James

Ambrose Talisuna, a Congo-based representative of the *World Health Organization (WHO) Regional Office for Africa*, led a team of 13 high level health experts on a visit to South Africa between 27 November and 1 December 2017. Their purpose was to assess where the country stood in relation to its capacity to prevent, detect and respond to infectious disease outbreaks and biological, chemical and radiological events. The visit was preceded by months of preparation involving the South African human, animal and plant health sectors using, as has now become customary, a *One Health* approach to framing the issues and defining the problems to be solved. South Africa was initially a reluctant participant – for reasons that are not clear – in the global health security assessment process but, by the time Talisuna and his team arrived, their reception proved to be an 'enlightening experience'.[1] The domestic preparatory team led by the Director-General of Health, Precious Matsoso, gave, as Talisuna reported, some remarkable 'attention and dedication' to their national self-assessment. Talisuna specifically pointed out that the prepared information was collected from all relevant sectors and levels of the health sector, reaching out, by way of illustration, as far into the field as the health official working at the remote and lonesome border post between South Africa and Eswatini (previously known as Swaziland), a small landlocked monarchy surrounded by Mozambique and South Africa and known for having among the highest HIV prevalence rates in the world.

The assessment instrument Talisuna's team deployed was the product of two years of development. The first instrument came with the formation of the Global Health Security Agenda (GHSA) launched at the Obama White House in October 2014. At the time of the launch, the GHSA was a United States-led 20-member voluntary association of governments created with the purpose of accelerating country compliance with the World Health Organization's 2005 International Health Regulations (only 20 per cent of WHO Member States were compliant by 2012).[2] The original GHSA assessment instrument had 11 technical areas that required measurement, which the Atlanta-based Centers for Disease Control and Prevention (CDC)

used to build intervention tools called Action Packages which were to be utilised to detect, prevent and respond to infectious disease outbreaks. After testing the instrument in pilots administered in Georgia (the country), Peru, Portugal, Uganda and the United Kingdom, the assessment body now called the Joint External Evaluation Alliance settled on 19 technical and 48 sub-areas. For the first time the world had a system of metrics to assess individual country capacity that could double-up as a baseline for making country-to-country comparisons (but only for those countries that participated, as the GHSA was voluntary). Along the way the instrument received a formal stamp of approval from the WHO to collect metrics that later came to guide the interventions of its new Health Emergency Program launched in 2016 and led at the time by Peter Salama. Some further refinements to the assessments followed.

Talisuna's mission established that South Africa scored an average of 3.1 out of 5 for its health security, where 1 means 'no capacity', 2 'limited capacity', 3 'developed capacity', 4 'demonstrated capacity' and 5 'sustainable capacity'. The average score for the indicators (a total of 48 indicators folded into 19 technical areas of assessment were used) that measured ability to *prevent* outbreaks came in at a 3; to *detect* a likely outbreak a 3.3; to *respond* to an outbreak a 3; to *manage* disease transmission at ports of entry a 4; to *respond* to chemical events a 3; and *respond to* radiological events a 2. What these scores mean in practical terms is that South Africa is quite good at managing public health issues at ports of entry (at a good 4, there is nevertheless room for improvement to push it to a 5), less good but still demonstrably capable of detecting disease outbreaks at source (largely due to the National Laboratory Services and an improving surveillance system), average at preventing outbreaks and responding to them (including chemical events) and extremely vulnerable, like most other countries in the world, on the radiological risk front. Technically, rock bottom scores overall were awarded to the poor infection control systems at hospitals and clinics (causing high so-called nosocomial or institution-acquired infections). On the asset side, the best scores (a 5) were awarded for national vaccine access and delivery as well as for laboratory-based detection, the responsibility of the capable Johannesburg-based *National Institute for Communicable Diseases* (NICD), of priority diseases.

The October 2019 release of the 195 country Global Health Security Index (GHS Index) in Washington DC confirmed the results and extended the risk domains beyond those assessed by the WHO/JEE. In addition to assessing prevention, detection and response capacity, the GHS Index additionally assessed the quality and scale of South Africa's overall health system

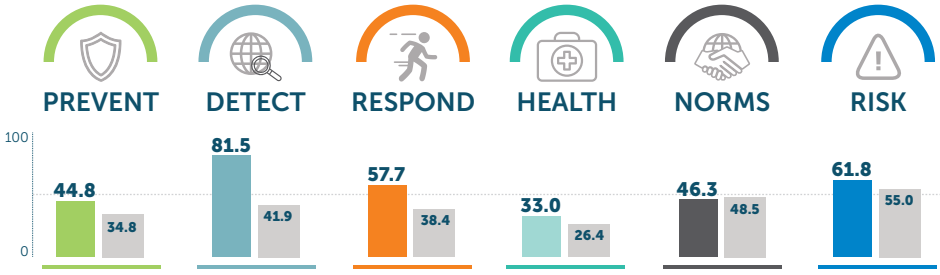
resilience, country compliance with international norms (and treaties) like the 2005 International Health Regulations and the general political and terrorist threat environment which individual countries may face.[3] Large in-country research teams led by the Economist Intelligence Unit (EIU) scoured through publicly available data and developed assessment scales between 0 (least favourable) and 100 (most favourable) for all the globe's 195 countries that assembled into three tiers: a 'bottom' or low tier for countries that came in at 0 to 33.3, a 'moderate' or middle tier for those that scored between 33.4 and 66.6 and a 'top' or upper tier for those who achieved between 66.7 and 100.

The GHS Index scored South Africa 44.8 for prevention (world average is 34.8), 81.5 was given for detection and reporting (world average is 41.9) and 57.7 for rapid response (world average is 38.4). These figures build on and are consistent with – if more nuanced than – the WHO/JEE scores. For the new domains of assessment, the GHS Index measures for health system strength came in at 33 (26.4 world average), international norm compliance 46.3 (48.5 world average) and 61.8 (55 world average) for the overall risk environment. The GHS Index figures confirm that South Africa is good at detecting disease, its ability to respond to outbreaks is average to languid, prevention capability is weak, the risk environment is externally less threatening – for now – than in many other parts of the world, international norm compliance is poor and health system performance is inadequate. While there are many pockets of strength in the health system, it is also clear that a great deal of work lies ahead to upscale preparedness. It is instructive and telling that a comparable middle-income country like Thailand fell in the top 10 best performing countries on the GHS Index (the 6th best performing of 195 countries, whereas South Africa is 34th), illustrating what is possible with a smart use of developing country resources.

To turn what is possible into reality requires political will, which in the end depends on leaders who have an appetite for success and the willingness to put a proper budget behind a clearly directed purpose. Following on the WHO/JEE assessments, participant countries were expected to put together a National Action Plan (NAP) that defined country-specific priorities backed up with a budget to finance and support it. South Africa conducted its WHO/JEE assessment exercise in December 2017 but two years on, a National Action Plan is still in development. The GHS Index awards South Africa a low of 16.7 for health system financing. To be fair, South Africa is not alone in this, as most countries in the world are in the same situation. The slow development of a health security budget may be seen as a problem but, it is also an opportunity, which

South Africa

54.8 Index Score **34**/195



	COUNTRY SCORE	AVERAGE SCORE*
PREVENTION	**44.8**	**34.8**
Antimicrobial resistance (AMR)	58.3	42.4
Zoonotic disease	53.9	27.1
Biosecurity	8	16.0
Biosafety	50	22.8
Dual-use research and culture of responsible science	0	1.7
Immunization	84.2	85.0
DETECTION AND REPORTING	**81.5**	**41.9**
Laboratory systems	100	54.4
Real-time surveillance and reporting	78.3	39.1
Epidemiology workforce	50	42.3
Data integration between human/animal/environmental health sectors	100	29.7
RAPID RESPONSE	**57.7**	**38.4**
Emergency preparedness and response planning	0	16.9
Exercising response plans	0	16.2
Emergency response operation	33.3	23.6
Linking public health and security authorities	100	22.6
Risk communication	100	39.4
Access to communications infrastructure	86	72.7
Trade and travel restrictions	100	97.4

	COUNTRY SCORE	AVERAGE SCORE*
HEALTH SYSTEM	**33.0**	**26.4**
Health capacity in clinics, hospitals and community care centers	52.6	24.4
Medical countermeasures and personnel deployment	33.3	21.2
Healthcare access	48.8	38.4
Communications with healthcare workers during a public health emergency	0	15.1
Infection control practices and availability of equipment	0	20.8
Capacity to test and approve new medical countermeasures	75	42.2
COMPLIANCE WITH INTERNATIONAL NORMS	**46.3**	**48.5**
IHR reporting compliance and disaster risk reduction	50	62.3
Cross-border agreements on public and animal health emergency response	50	54.4
International commitments	50	53.4
JEE and PVS	50	17.7
Financing	16.7	36.4
Commitment to sharing of genetic & biological data & specimens	66.7	68.1
RISK ENVIRONMENT	**61.8**	**55.0**
Political and security risks	78.6	60.4
Socio-economic resilience	76.6	66.1
Infrastructure adequacy	58.3	49.0
Environmental risks	56.9	52.9
Public health vulnerabilities	38.3	46.9

**Average: all 195 countries*

Scores are normalized (0–100, where 100 = most favorable)

www.ghsindex.org

is this: the concept of health security is a novel one, covering the health, environmental, agriculture, labour, science, technology, foreign affairs and defence sectors – and possibly more portfolios depending on the country. For most countries, the temptation is to spend more than they did the previous year on the same agencies residing largely in the health and social services sectors – and within the same budget framework. Given the nature of the challenge, this will not do.[4] Spending even substantially more in the same framework will help, but it will not stem the tide. Required is to spend substantially more in a different all-encompassing health security framework. To assist in this the WHO lodged a *National Action Plan Health Security (NAPHS) Planning and Costing Tool* on its website, as did Washington DC-based Georgetown University's Center for Global Health Science with its *International Health Regulations Costing Tool*. *Resolve to Save Lives* led by the former CDC Director Tom Frieden has a program to help countries develop and implement their NAPHS by providing one-time catalytic grants designed to address preparedness gaps, help to leverage global financing or identify a legal framework to support preparedness and response. These and other resources are there specifically to assist countries to develop comprehensive NAPs to take preparedness to an altogether different level worldwide.

Vital Signs: Health Security in South Africa builds on the assessment metrics provided by the WHO/JEE and the GHS Index by presenting chapters commissioned from experts and practitioners with first-hand knowledge and/or direct experience in the following risk domains: nuclear, environmental, chemical, infectious disease, biological and climate-related threats. We touch on radiological, cyber-related and bio-engineering health risks in a chapter that reviews South Africa's overall threat environment. A full chapter is devoted to the financing barriers and opportunities for health security. As additional resources we include a review of both South Africa's and Lesotho's WHO/JEE mission reports, as well as a report of a conference on health security convened by the Dean of the Faculty of Health Sciences at the University of the Witwatersrand, Martin Veller, on behalf of the Committee of Medical School Deans, which was generously funded by the Sanlam Foundation.

The chapters provide narrative descriptions and analyses of the context, strengths, weaknesses and developments in each of the risk domains. The chapters end with a set of risk-domain specific recommendations. Our overall recommendation is that after conducting a spending review, Treasury should construct a new health security budget framed in national security terms. We also recommend that the responsibility for leading health security be lifted out of the Department of Health and placed in the

Presidency with the responsibility of (1) integrating South Africa's health security systems including disaster response and surge capacity across departments and spheres of government; (2) creating partnerships with the private sector to develop new disaster response technologies and systems; and (3) working with civil society organisations to harness and leverage their reach into communities to better enable prevention, detection and response on a local level to high-consequence threats. Since disease outbreaks and other threats know no boundaries, it is of the greatest importance that South Africa collaborates with the Member States of the Lusaka-based *Regional Collaborating Centre* of the *Africa Center for Disease Control and Prevention* in developing a regional approach to prevention, detection and response.

Gratitude goes to a superb group of authors: Hannah Bender, Brett Cohen, Jonatan Davén, Jaco-Louis du Plessis, Gregory Hooks, Michael Kahn, Megan McLaren, Greg Mills, Terence McNamee, Maria Papathanasopoulos, Robbie Parks, Janusz Paweska, Ulrike Rivett, Lizeka Tandwa, Madeleine Thomson and Martin Veller. Hannah Bender, Arvin Satwani and Lewis John Rubin Thompson provided able editorial assistance. Beth Cameron and Hayley Severance of the *Nuclear Threat Initiative* and Jill Taylor of the *State of New York Health Department's Wadsworth Center Laboratories* read and provided helpful comments on an earlier version of *Vital Signs*, prompting a welcome and quite radical reworking of the material. With the support of Brenthurst Foundation's Jaco-Louis du Plessis, Tim Sheasby of Sheaf Publishing did an admirable job of editing and designing *Vital Signs*. I am very grateful to the Brenthurst Foundation executive director Greg Mills for agreeing to publish *Vital Signs* and to the Oppenheimer Memorial Trust (OMT) for funding it. I am also grateful to Ian Kirk and the Sanlam Foundation for their support in socialising *Vital Signs* with the stakeholders.

1
Nuclear and radiological
changing risks from apartheid to democracy

Michael Kahn and Terence McNamee

Details of the apartheid regime's secret nuclear arsenal were revealed publicly for the first time in March 1993 in a speech to South Africa's parliament by (then) President F.W. de Klerk. He revealed that South Africa had built six of a planned seven nuclear weapons between the mid-1970s and 1989. They were developed, according to De Klerk, in response to South Africa's worsening security situation and the government's own increasing political isolation internationally.

On the face of it, the official rationale seems credible. Following the collapse of the Portuguese empire in southern Africa in the mid-1970s, avowedly hostile (i.e. anti-apartheid) Soviet-backed Marxist regimes emerged on Pretoria's northern borders, in Mozambique and Angola. Then, in 1976, the Soweto uprising began, and South Africa's international standing went into freefall. The regime's brutal crackdown of the uprising led to the mandatory UN arms embargo on South Africa, signed in November 1977. Coming on the heels of growing Western pressure to withdraw from Namibia (then South West Africa), the advent of an unsympathetic administration in Washington and South Africa's expulsion from the International Atomic Energy Agency's (IAEA) Board of Governors, the UN embargo cemented South Africa's reputation as a 'skunk among nations'.[1]

Fearful and isolated, the regime considered its options. The lure of nuclear weapons proved irresistible. South Africa had, after all, been a significant player in the nuclear age from its beginning.

Official claims that the shift from a civilian programme to a military one was implemented virtually overnight does not, however, stand up to close scrutiny. Nor does their explanation for why South Africa crossed the nuclear threshold. South Africa's nuclear past is nothing if not complicated.

To build a bomb

The specific skills associated with nuclear chemistry and detonation rested on the extensive physics, chemistry, metallurgy, instrumentation, and engineering knowledge acquired through the mining-led industrial revolution and wartime manufacturing. By the end of The Second World War, South Africa, a mining-oriented economy, was exporting substantial amounts of uranium – previously regarded as a contaminant of fine gold refining and discarded in mine dumps, slimes and tailings – including part of the supply to the Manhattan Project, which produced the atomic bombs dropped on Hiroshima and Nagasaki.

Local innovation capabilities grew as the apartheid state, which emerged after the National Party won power in 1948, consolidated. The commanding heights of the economy constructed in the form of state monopolies for power, communications, iron and steel, forestry, and other utilities.

Work on atomic physics and fissile material has a long history in the country. From the early years of the 20th century a small number of South Africa's physicists (and scientists specialising in other disciplines) travelled abroad for postgraduate studies in the leading laboratories of the United Kingdom, United States and Europe. In the process they learnt and brought home the rudiments of how to work with radioactive materials, isotope identification and separation, and the construction and use of associated instrumentation. Eminent scientists of that time included Stefan Meiring-Naudé who discovered the ^{15}N isotope, and Hendrik van der Bijl, who pioneered the development of the triode vacuum tube. Meiring-Naudé went on to head the Council for Scientific and Industrial Research, and later became scientific adviser to Prime Minister John Vorster (1966–78), while Van der Bijl initiated the power utility Eskom (Electricity Commission), steelmaker Iscor (Iron and Steel Corporation), and the Industrial Development Corporation. Between these two, and with the support of the then mining houses, the experience of production under wartime conditions, a diversified industrial economy grew through import substitution, and the later necessities of self-sufficiency in the era of political, economic, military and technology sanctions against the apartheid regime.

In 1948, increased demand for uranium persuaded the government to establish an Atomic Energy Board (AEB) with the remit to regulate the uranium industry. Uranium now had military and power-generation applications, provided that the necessary enrichment was carried out.

An invitation to South Africa to join the 'Atoms for Peace' programme, launched at the UN General Assembly in 1953 by President Dwight Eisenhower, was followed by the signing of a 'civil uses' pact with the United States, which secured a 50-year agreement on nuclear collaboration between the two countries.[2] As a consequence, South African officials were invited to monitor secret US nuclear weapons tests in the southern Atlantic in 1958, and a number of scientists and engineers received advanced training in the United States, culminating in the construction of a large research reactor, the SAFARI-1 facility at Pelindaba (meaning 'end of discussion', in the local Setswana language), 45km west of Pretoria, which became the new home of the South African National Nuclear Research Centre.[3] Two years later the US Advanced Research Projects Agency (ARPA) extended the reach of its Vela Uniform project to South Africa, funding seismic research with the covert goal of detecting underground nuclear tests.[4]

From the US point of view there were no indications that Pretoria was interested in the military application of nuclear technology at this stage. The joint monitoring of US nuclear weapons tests in 1958 were symbolic of that trust. Nevertheless, the US supply of HEU (highly-enriched uranium) was contingent on South Africa signing a safeguards agreement allowing international inspection of the facility.

But the military potential of acquiring a means for producing nuclear weapons was clear. In the 1960s South African scientists participated in the US's ill-conceived research into Peaceful Nuclear Explosives (PNEs), which proved not only commercially unviable but also a boon to would-be proliferators: South African participants quickly realised there was no practical difference between a 'PNE' and a weapon.[5]

If South African officials were intent on secretly developing a nuclear weapons capability as early as the 1950s, they could hardly have been better placed to do so. Ampie Roux, head of the AEB, readily acknowledged that South African nuclear cooperation with the West opened secret doors, particularly in research areas:

> Any [research] contribution, however small, that can be made, will assist greatly in obtaining secret information from other countries which they would not otherwise be prepared to divulge. We have already experience d this in the little work we have done in connection with the production of heavy water.

He went on to note that:

> some of the most important developments in the field of nuclear power, particularly in the more highly developed countries such as the US and the UK, have so many military implications that no reference would be found to them in the unclassified literature.[6]

This amounted to a tacit admission that the regime was penetrating the West's military nuclear secrets by means of research for 'peaceful purposes'. But did the apartheid regime have a conscious plan to do so? The rapid militarisation of South Africa that began under Prime Minister Hendrik Verwoerd in the late-1950s adds further weight to suspicions that a plan to develop a nuclear weapons capability was under consideration, if not already in place by the time of his assassination in 1966.

Militarisation

Subsequent to the 1960 Sharpeville massacre, where 69 unarmed protestors were gunned down by South African Police, and a clampdown on political activity, international isolation and perceived security threats persuaded the regime to embark on a programme of military self-sufficiency that ultimately included nuclear, chemical and biological warfare components.

In due course this gave rise to industrial-scale plants at Pelindaba and Valindaba that could produce both low-enriched uranium, and weapons grade HEU, along with artillery and ballistic missile delivery systems at nearby Irene. The nuclear production facilities included an independent coal-fired power station, a plant to produce uranium hexafluoride, an array of vortex tube cascades to separate out ^{235}U from the uranium base metal, and experimental high-power lasers for isotope separation.

A nuclear waste and underground test site were constructed in the far north-west corner of the Kalahari Desert at Vaalputs, where a narrow tongue of land stretched between today's Namibia and Botswana. The nuclear weapons innovation system further included explosive plants and test ranges in the Western Cape, and test and storage facilities at Irene, near Pretoria. It stretched across the country and included research and development conducted at the universities, and especially at the Council for Scientific and Industrial Research, as well as missile testing and production facilities. The ballistic missile test range at Arniston near Cape Agulhas faced out across the Indian Ocean, far from watchful eyes to the north. As to potential nuclear test sites, the seas near Prince Edward Islands in the sub-Antarctic Indian Ocean may have been the site of an atmospheric test – the so-called Vela Incident – in 1979.[7]

Clandestine cooperation with France and Israel underpinned the breadth of the nuclear weapons programme. Starting with the covert supply to Israel of uranium oxide 'yellowcake' by South Africa, followed by conventional armaments deals, came the co-development of weapons and delivery systems. France temporarily filled the supply vacuum that the British arms embargo opened.[8]

The purchase and 1984 commissioning of a 2 x 970 MW French-designed pressurised water nuclear power station at Koeberg on the Atlantic coast 40km north of Cape Town, completed the nuclear requirements, with Pelindaba developing the capacity to produce nuclear fuel rods to the required specifications.

Nuclear rollback and the end of apartheid

The regime manufactured its first bomber-deliverable nuclear weapon (a gun-type design similar to the Hiroshima bomb) in 1982. Thereafter production accelerated until late 1989 when the arsenal stood at six and the Y-Plant uranium enrichment facility had produced sufficient HEU for a seventh bomb, then in construction.

By 1989 South Africa's security situation had improved markedly due to the decline of Soviet power, peace settlements on its northern border and the withdrawal of hostile Cuban forces (who once numbered 50 000) from the region. It was against this backdrop that F.W. de Klerk decided to secretly dismantle the weapons. Two weeks after assuming office, he formed an *ad hoc* committee to consider the future of the country's nuclear arsenal. At their first meeting he informed those present of his decision to normalise the internal political situation of the country and that the nuclear devices would be a liability in South Africa gaining international acceptance in the process.[9] Over the next year the weapons were secretly dismantled.

De Klerk rightly saw South Africa's secret but widely rumoured nuclear arsenal as an obstacle to political reform and gaining international trust. But his order to kill the programme stunned defence officials. No one had ever discussed or considered dismantlement. The risks involved were monumental. De Klerk's predecessor, P.W. Botha, railed against him for ending the programme. Botha claimed (probably correctly) that by destroying the arsenal, De Klerk destroyed the Afrikaner state. A violent backlash, some say a military coup, was narrowly avoided.[10]

De Klerk also faced intense international pressure. Reports at the time suggested that the United States and Israel feared that if Nelson Mandela's

African National Congress (ANC) government inherited a nuclear weapons capability, they might sell off the technology to anti-Western regimes in Libya, Cuba, or Iran as payment of old debts.

But of more immediate – and justifiable – concern to De Klerk was the threat posed by disgruntled whites who worked on the nuclear program, who might divert bomb materials or designs for profit or to achieve political ends. He feared that they might even blackmail his government as a way to preserve apartheid. After all, the former head of the program, Wally Grant, was then leading a movement for the establishment of a separate Afrikaner homeland.

De Klerk knew that senior defence officials – and especially scientists and engineers who had worked on the program for decades – felt betrayed, their pride battered. But he needed to win them over. No protocol existed for nuclear dismantlement. Measures for 'demilitarising' South Africa's nuclear explosives and HEU had to be devised from scratch. In a volatile security environment, one mistake or act of sabotage could have derailed the transition he had in mind. Recalcitrant officials eventually came around to De Klerk's thinking. 'In our hearts we all knew it was the right decision,' one scientist reflected. 'These bombs are not things that can be used.'[11]

South Africa joined the Nuclear Non-Proliferation Treaty (NPT) as a non-nuclear weapons state after dismantlement was secretly completed in 1991. Accession to the NPT lifted key sanctions on the regime and underlined its commitment to reform and a new relationship with Africa and the world. Lingering suspicions that Afrikaner nationalists might use the arsenal to cling to power were quashed. Only when De Klerk stood up in Parliament a year and half later and made his shock disclosure did the opposition ANC – and (nearly all) the rest of the world – discover what the apartheid regime had done.[12]

To this day, it is difficult to pinpoint when South Africa crossed the nuclear threshold. De Klerk initially claimed that it was '1974', though other officials have stated that the programme was still 'officially' peaceful until 1978. Though technically defensible, both dates are misleading historically.

A comparison with India's nuclear weapons past is instructive. Indian leaders and scientists cloaked their own nuclear ambitions for public consumption as 'peaceful' for many years when their actual intent was otherwise. As in South Africa, India argued that it somehow had no choice, and was driven across the nuclear threshold reluctantly by the refusal of others to disarm, and by the country's vital security needs. But in both cases nuclear weapons capability was contingent on the prior development

of a wider nuclear industry, which was later connected to a sophisticated explosives and missile research programme.[13] From the 1950s, the apartheid regime devoted substantial resources to advanced nuclear research, and sought to develop extensive secret links with a number of nuclear weapon states including (perhaps most significantly) Israel. The shift to militarisation was incremental – each element of the wider nuclear project provided extra impetus to the development of a weapons programme. And the tracking of the exact date – and, indeed, the proliferation process itself – by the US and others was made more difficult by the application of civilian-based technologies and commercial facilities and equipment to manufacture the apartheid bomb.

The consensus then, as now, was that South Africa's nuclear arsenal had no military utility nor was it ever incorporated into the state's wider military strategy. Instead they were, according to De Klerk, not so much weapons as 'devices', intended to be used in what was essentially an elaborate political bluff to persuade the West to come to the regime's rescue in the event of a Soviet-inspired attack on South African territory. But the arsenal also represented something far more potent for the regime than a (dubious) political or military instrument: an *ultimate deterrent* to change. It bestowed, so they believed, an aura of permanency and invincibility. The imperilled leaders in Pretoria perceived their nuclear arsenal as a means to safeguard and perpetuate Afrikaner dominance.

While the major security changes in southern Africa during the 1970s made apartheid leaders more fearful and isolated, as an explanation for their decision to build nuclear weapons it is woolly, at best. The threat of a Soviet-backed invasion was still remote, if not non-existent; nuclear deterrence was not applicable in the region nor was the theory even understood by those in charge in Pretoria. And there is no evidence of any rigorous policy analysis within the regime which supported the initial decision to proliferate.

Nuclear weapons were inextricably linked to the discourse on the apartheid regime's survival. There was, of course, no practical mode by which the former could effect the latter (which apartheid policies were *ever* dictated by sound logic and reason?), which partly explains why more than a decade after former regime officials say South Africa crossed the nuclear threshold, Pretoria did not have an agreed nuclear strategy in place (some say that no such agreed strategy ever existed). But that is not the point. The South African experience reinforces the need to accept a level of indeterminateness in assessing how other cultures and regimes – like Iran's

or North Korea's today – might perceive the utility of nuclear weapons in the context of their wider objectives.

The dismantlement dividend

Post-1990 the entire armaments industry, both public and private, was scaled back. The Valindaba plant was stripped down, the missile test facility was largely mothballed, and private sector manufacture of materiel was largely terminated. Sections of state weapons agency Armscor that had been dedicated to weapons production and research and development were transferred to a new state-owned entity, Denel (Pty) Ltd. The Nuclear Energy Act No. 46 of 1999 then reconstituted the Atomic Energy Corporation as the Nuclear Energy Corporation of South Africa (NECSA).

The decommissioning process allowed a stock of highly-enriched, weapons grade uranium to remain in South Africa's hands. But what was certain, of course, was that the new majority-led ANC government would not possess nuclear weapons capability or an associated long-range delivery system.

Nelson Mandela and his ANC colleagues were livid at De Klerk for being left in the dark about South Africa's nuclear past. They believed he dismantled the programme because he simply didn't want the weapons to pass into the black majority's hands, in keeping with his party's racist ideology.

Re-structuring nuclear for democracy

De Klerk's main motivation in doing away with South Africa's nuclear weapons heritage will always be subject to sharply contrasting views. What is certain is that he set in motion a process of civilianisation of South Africa's nuclear sector which has not been reversed or challenged for nearly three decades. To oversee the dismantlement process, the president chose Waldo Stumpf, then deputy of the Atomic Energy Commission, and an independent auditor to supervise the process – Wynand Mouton – a retired nuclear physicist and university professor. He devoted much of his time to assessing the reliability of the scientists and technicians responsible for dismantlement. They performed superbly under highly demanding conditions. But the termination of the weapons programme led to significant loss of institutional memory and skill, as well as the sale or dispersal of plant, most notably in the transfer of the high-power lasers from Valindaba to the CSIR.

Today, South Africa's nuclear energy, research and development institutions comprise the following entities:

1. SAFARI-1 Research Reactor under the authority of NECSA that produces molybdenum-99, and other medical purpose radioisotopes such as iodine-131 and lutetium-177. These radio-chemicals are produced using LEU (low-enriched uranium), a world first for a commercial reactor. As of December 2015, more than three-quarters of target plates used in the production of medical radioisotopes have also been made with LEU targets, making SAFARI-1 and NTP pioneers in the commercial production of all-LEU radioisotopes;
2. NTP Radioisotopes SOC Ltd that distributes radioisotopes;
3. Vaalputs National Radioactive Waste Disposal site;
4. Eskom-Koeberg Nuclear Power Station;
5. National Research Foundation – iThemba cyclotron laboratory; and
6. Facilities at Pelindaba.

These are all successors to, or enhancements of prior investments.

The most important nuclear energy development post-1993 was to be the development of a pebble-bed modular reactor (PBMR) technology demonstrator. The PBMR was established in 1994 as a wholly-owned subsidiary of Eskom, and at its peak employed in excess of 2 000 staff. The intention was to replicate the original German experimental reactor design, that had been closed down in 1988. On the local side experience was gained in working with helium under conditions of high temperature and pressure. In addition, the previous expertise in producing uranium fuel rods for the Koeberg reactor had to be translated into the design and manufacture of the tennis ball-sized uranium-rich graphite 'pebbles' that would fuel the PBMR. These presented considerable technical challenges, the more so as nuclear engineering skills had dissipated.

In the event, funding in the range of R10–R30 billion was consumed by the PBMR project before it was terminated in 2010 as a consequence of the inability to retain foreign investor interest.

Whilst a new corps of nuclear instrumentation engineers was trained, the quantum of new knowledge created over its 15-year life appears to be limited. One of the main supporters and chief technology officer at the PBMR concluded that, at the end of the day, the South African nuclear industry was simply too infantile for a first-of-its-kind nuclear project such as this. The nuclear environment was not developed enough to evaluate the safety and engineering needed. Other hearsay evidence is that important technical breakthroughs were achieved in producing the nuclear pebbles. What is clear, however, is that PBMR was awarded but eight US patents during its lifetime.

Where nuclear energy will fit in the mix of sources that may be needed into the near and medium future remains highly contested, the more so as the cost and reliability of renewables sources continues to become more and more competitive in relation to fossil fuels with their inevitable greenhouse gas discharges. Nuclear or not nuclear remains undecided.

Regulation

Matters concerning the regulation and control of nuclear energy, research, materials, containment, and transportation fall to the responsibility of the National Nuclear Regulator (www.nnr.co.za) established in terms of Act 47 of 1999. That Act amended the Nuclear Energy Act of 1993 by abolishing the Council for Nuclear Safety. In addition is the National Radioactive Waste Disposal Institute Act 53 of 2008. These acts of legislation are administered by the Department of Energy.

Other relevant legislation includes:

- Hazardous Substances Act 5 of 1973;
- Dumping at Sea Control Act 73 of 1980;
- Non-Proliferation of Weapons of Mass Destruction Act 93 of 1993;
- Occupational Health and Safety Act 93 of 1993;
- National Water Act 36 of 1998;
- National Environmental Management Act 107 of 1998; and
- Mineral and Petroleum Resources Development Act 28 of 2002.

Two laws deal with related security matters:

- National Key Points Act No 102 of 1980; and
- Protection of Constitutional Democracy Against Terrorist and Related Activities Act 33 of 2004.

The National Nuclear Regulator (NNR) issues nuclear authorisations, including Nuclear Installation Licenses, Nuclear Vessel Licenses for vessels propelled by, or carrying radioactive materials, and a Certificate of Registration or a Certificate of Exemption for the use or carriage of radioactive materials.

NNR Safety Standards are in line with those of the IAEA, including Basic Safety, the Standards consistent with UK Nuclear Installation Inspectorate Safety Principles and the Western European Nuclear Regulators Association Reference levels. These standards ensure criteria such as dose limits for safe operations.

The NNR advises the Minister as an arm's-length, independent, statutory body. The NNR notes that 'Safety assessments ... must also take into

account the impact of non-radiological hazards on safety in order to ensure the protection of people and the environment, (that) Nuclear Safety and Radiation protection is approached within the precepts of transparency whilst Nuclear Security is approached in accordance to confidentiality.'

International Atomic Energy Agency's Safety Standards require maintaining records of occupational radiation doses, logged to a National Dose Register (NDR) that can track a registered worker's cumulative dose based on data provided by the authorisation holder or dosimetry service provider.

Nuclear authorisations are a matter of public record and in April 2018 comprised Authorisations (42); Certificates of Exemption (5); Certificates of Registration (263); and Nuclear Vessel License (2).[14]

It is further appropriate to consider other forms of ionising and nuclear radiation, their sources and uses. In 'normal' controlled environments, ionising and nuclear radiation include medical, industrial and agricultural uses as in:

- X-rays, especially medical, dental and computer assisted tomography (CAT);
- Fast neutron beam therapy and proton beam therapy, both of which are generated by means of cyclotron radiation. The iThemba facility offers proton beam therapy for cancer patients;
- Gamma ray emission from isotopes such as ^{192}Iridium and ^{60}Cobalt;
- Brachytherapy, involving the insertion of ^{192}Iridium-laden needles into the tumour; and
- Non-destructive testing of metal components.

In principle medical applications are regulated by the Radiation Control Division of the Department of Health, and in general in terms of the Hazardous Substances Act. Charles Herbst and Gerhard Fick point out serious deficiencies in the regulation and practice of the use of ionising radiation. Possible abuse of radioisotopes, including safe disposal, remain an ongoing problem area.[15]

Threats

Prior to 1994 the most serious incident involving a nuclear facility was the sabotage carried out at the Koeberg construction site prior to the reactor being completed and loaded. That sabotage involved a staff member who happened to be a member of the guerrilla underground, and who was provided with the necessary explosives and training. With his handlers he selected the specific locations where the detonations could cause maximum damage with low risk of loss of life. The lone wolf operative

smuggled four Soviet-made limpet mines into the Koeberg construction site, where they detonated on 18 and 19 December 1982, causing damage that resulted in an 18-month delay in the commissioning of the reactors.[16]

One serious, and one less serious incident involving the penetration of a nuclear facility occurred post-1994, namely the 2002 seaborne invasion of the Koeberg site by international environmental activists, and the 8 November 2007 breach of the NECSA site at Pelindaba by two groups of intruders.[17] As Greenpeace spokesperson Townley stated '[I]t is frightening how easy it was to get to Koeberg. We went straight from the inflatable dinghies, up the walls. People in Cape Town would be right to be shocked. After September 11, there has been a lot of talk about tightening security around nuclear plants, but around Koeberg this doesn't seem to have happened.'[18]

The subsequent coordinated penetration of Pelindaba in 2007 by two teams of raiders would thus constitute an even graver action given the warnings that the Koeberg incident ought to have conveyed.

NECSA is designated as a security 'key point' and would be expected to maintain the highest levels of security, especially as NECSA stores a stock of highly-enriched, weapons grade uranium that has never been disposed of, or transferred to international custody. According to analysts of the Center for Public Integrity,

> The first team ... showed expert knowledge of the site's electronic security systems, and they were able to find a hidden latch securing a fire truck ladder, which they used to climb to the Center's second-floor landing. ... The second group attacked the site from the opposite side but failed to breach the security perimeter. This was the third incident at Pelindaba since the end of apartheid and fuelled the perception of vulnerability to nuclear terrorism.[19]

These incidents highlight the complacency that had begun to creep into the management of security of state properties after 1994, with a reluctance, or inability to successfully prosecute individuals or groups responsible for acts of public violence leading to the theft or destruction of state property, including that of military weapons, police vehicles and transport infrastructure. This culture of background violence commenced in the 1976 revolt, gained momentum in the insurrectionary years through to 1994, but has continued unabated, though with very limited loss of life.

A final note on research related to nuclear and radiological security. An appropriate keyword search is the following:

('nuclear security' OR 'nuclear terror' OR 'nuclear regulat*' OR 'medical isotope' OR 'nuclear dos*' OR 'health finance*' OR 'nuclear proliferation' OR 'nuclear safe*' OR 'nuclear threat' OR 'nuclear detect*' OR 'nuclear test' OR 'nuclear containment' or 'radiation leakage' or 'nuclear waste' or 'radioactive waste' or 'radiation detection' or 'radiation protection' or 'radi* poison*' or 'radiation sickness' or 'ioni* radiation' or 'uranium min' or LEU or 'nuclear power' or 'nuclear energy')*

Search from 1993 to 2017 identified 394 publications, strongly clustered on technological aspects of the industry.

Table 1.1: Nuclear security publications, by science category

Web of Science Category	Total 394	%
Nuclear Science Technology	68	17.3
Biochemistry Molecular Biology	44	11.2
Radiology Nuclear Medicine Medical Imaging	37	9.4
Entomology	24	6.1
Energy Fuels	22	5.6
Engineering Mechanical	22	5.6
Environmental Sciences	21	5.3
Pharmacology Pharmacy	20	5.1
Physics Nuclear	20	5.1
Endocrinology Metabolism	19	4.8
Public Environmental Occupational Health	16	4.1
Engineering Electrical Electronic	12	3.0
Materials Science Multi-Disciplinary	12	3.0
Physics Atomic Molecular Chemical	12	3.0
Biology	10	2.5
Chemistry Inorganic Nuclear	10	2.5
Engineering Environmental	10	2.5
Oncology	10	2.5
Astronomy Astrophysics	9	2.3
Chemistry Analytical	9	2.3
Instruments Instrumentation	9	2.3
Microbiology	9	2.3
Multi-Disciplinary Sciences	9	2.3
Engineering Chemical	8	2.0
Engineering Multi-Disciplinary	8	2.0

This low number suggests but limited interest in the research community. The University of Cape Town, with 84 publications, dominates research

output, followed by Stellenbosch University (48) and the University of the Witwatersrand (38). Nuclear accelerator institute, iThemba Labs accounted for 15, while energy utility Eskom (responsible for the Koeberg nuclear plant) came in with 10.

Perspectives

Prior to 1994, nuclear terrorism was not perceived as a local threat. The previous threat analysis was Cold War-focused rather than concerned with more general nuclear disruption, and local regulation was in its infancy. At that time responsibility was lodged in the Atomic Energy Commission that held a low level of external risk appreciation. The production of enriched uranium was inherently risky, but poorly regulated because of the need for secrecy.

Three issues dominate the present environment: competence to deal with spills, how to deal with accidents and potential acts of terrorism. Technical and regulatory competence has strengthened but response capability is yet to be tested. The safe management of medical isotopes and sources is of some concern.

On the plus side, much was learned in the hosting of the 2010 FIFA World Cup that *inter alia* required nuclear security to be of the requisite standard. Staff were trained, detection equipment sourced and installed. Protocols for detection, removal and disposal specific to that need were put in place. The benefit was a strengthened capacity to monitor possible cross border flows of radionuclides. Tracing to origin is an area that may need attention.

Up to a point the regulatory regime is satisfactory, but tends to be detailed and onerous, especially for power-related materials such as uranium, plutonium, and thorium, that all fall under the Nuclear Regulator. Other radionuclide monitoring is the task of the Department of Health. So, for example, Iridium-192, a hard gamma source, that is much more energetic and dangerous than power materials, falls under that Department, presenting a somewhat unappreciated risk. This regime may be compared with the US where all nuclear matters fall under the Nuclear Regulatory Commission.

Seen more broadly in the context of health security, the admitted weakening of public health infrastructure and the skills exodus out of the public sector are threats. It may be the case that regulatory capability has weakened. Indeed, this could apply to the monitoring of environmental and occupational health. The fact of the proliferation of bogus doctors in the health system suggests systemic weaknesses.

As to the major shortcomings in national health security policy this would lie within the overall framework needed to respond to accidents. This requires basic levels of competence, and we are unconvinced that adequate skills are in place. The Regulator appears to be competent; the Department of Health less so. Moreover, installation of port monitoring systems has lagged. What is absent is a tactical response capability, unsurprising, since there is no integrated system in place.

Regarding local and global environments, NECSA acts as the local agent of the IAEA, that provides oversight and inspection. According to standard practice there are eight scheduled and four unannounced inspections annually. These arrangements work very well.

South Africa is also important for the development of nuclear research capacity for Africa, with operational nuclear research reactors found in eight African states: Algeria, Egypt, Democratic Republic of the Congo (DRC), Ghana, Libya, Morocco, Nigeria and South Africa. These function under the supervision of the IAEA, with the earliest, Kinshasa (now under care and maintenance), dating from 1959. The reactors are used for training purposes, isotope production and the modification of specialised materials. The reactors serve as an important training ground for university postgraduates in the nuclear sciences, as well as those active in protection and security service work. Two active research reactor networks are in place for the Mediterranean and Central Africa respectively. The Africa Regional Cooperative Agreement for Research Development and Training related to Science and Technology (AFRA) has established the AFRA Network for Education in Nuclear Science and Technology (AFRA-NEST) in order to implement the AFRA strategy on Human Resource Development (HRD).

Conclusion

Despite the ANC's anger over being unaware and excluded from the process of dismantling South Africa's nuclear weapons programme at the beginning of the 1990s, that didn't stop the country's first democratically elected government from trading fruitfully on De Klerk's decision in its diplomacy after coming to power in 1994. South Africa won an enviable reputation as a saintly member of the non-nuclear club – an exemplary convert after years as one of the world's worst sinners. The government's accession to the NPT facilitated South Africa's readmission to the IAEA Board of Governors (taking the seat held by Egypt as the most advanced nuclear state in Africa) and the Zangger Committee. In 1995 the South African delegation played a key brokering role in the Review and Extension

Conference of the NPT in New York. The conference proved a 'diplomatic coup' for Pretoria as it succeeded in producing a wide margin of consensus, especially among the non-aligned countries and the Third World, for the extension of the treaty. Nuclear rollback also paved the way for the successful continent-wide negotiations on declaring Africa a nuclear-weapons-free zone, resulting in a treaty that bears the name of the place where South Africa developed its atomic bombs, Pelindaba.

Nuclear scientists Ampie Roux and Wally Grant are generally regarded as the founding members of South Africa's civil nuclear programme. They exerted a profound influence on the direction and intensity of South Africa's initial moves in the nuclear field. According to some experts, Roux and Grant were also instrumental in persuading the government to actively pursue nuclear weapons.[20] For the most part, they opted to conceal their support for a nuclear arsenal, unlike some of their closest scientific colleagues. Andries Visser, a member of the AEB board, declared in 1965 that South Africa should have atomic bombs 'to prevent aggression from loud-mouthed Afro-Asiatic states – money is no problem, the capital for such a bomb is available.'[21]

Today, South Africa's nuclear sector is mercifully unburdened by scientists pushing to release the genie of nuclear weapons from the bottle in which it was placed nearly three decades ago. The sector encounters a different set of challenges today, mostly around continuing uncertainty on the place of nuclear in the country's energy mix. As recently as 2017, South Africa seemed poised to embark on a significant expansion of activity in the sector. But with the advent of a new administration in Pretoria under President Cyril Ramaphosa the following year, nuclear build plans were shelved for at least a decade because, according to one minister, 'we don't need it right now'.

This level of political volatility and uncertainty, coupled with concerns over the direction of South Africa's foreign policy – evidenced by its stance on the International Criminal Court and ambiguous implementation of conventional arms control measures – amplifies the need to err on the side of extreme caution in ensuring South Africa's advanced nuclear energy, research and development institutions remain protected.

Of special importance is the wide sweep of the Protection of Constitutional Democracy Against Terrorist and Related Activities Act that deals with nuclear and radiation threat. The law provides a definition of terrorism that may be applied to determine whether an action constitutes mere criminality, or worse. It provides the state with the necessary sanctions to safeguard life and property. As such, read with the Nuclear Energy

Act, radiological security requires the state to display a readiness and competence to deal with threat. The present security climate in the country is fragile, with poorer communities displaying a readiness to engage in violent protest as a mechanism to draw attention to their deprivation; violence is perpetrated against economic competitors; transport infrastructure is destroyed; inter-personal and gang violence is such that the murder rate in Cape Town has reached 50 per 100 000. The impression is that state weakness, in terms of withdrawal or incompetence is a serious threat to general security.

Neither the Disaster Management Act No. 57 of 2002, nor the Disaster Management Amendment Act No. 16 of 2015 deal with the specifics of biological, chemical or radiological threat. While the National Nuclear Regulator is mandated to ensure that provisions for nuclear emergency planning are in place, evidence points to serious gaps in anticipation, intelligence gathering, and the capacity for intervention and mitigation.

Permanent oversight, lodged in the National Intelligence Agency, is called for, with the obligation to develop, and maintain the capacities for radiological threat analysis, detection, and intervention. Subject to normal security protocols, the state of disaster preparedness, and threat mitigation should be declared to the appropriate parliamentary structures, annually, and immediately if a threat manifests.

2
Reaction and action
chemical and environmental security

Michael Kahn and Brett Cohen

Background

South Africa's chemicals industry originated in the late 19th century, when new metallurgical problems established a demand for energy and chemical solutions. Building the chemicals industry in support of mining and minerals processing required high capital outlays that could only come from foreign investors. One of the earliest organisations established directly to serve the needs of the mining industry was the 1895 *Zuid Afrikaansche Fabrieken voor Ontplofbare Stoffen* (The Dynamite Company) that was established at Modderfontein, east of Johannesburg. The company introduced Nobel technologies and relied on costly foreign skills, with such investment being justified by the high value of gold that was there for the winning.

Local scientific institutions emerged alongside imported technology and skills. The following year, the South African School of Mines was founded in Kimberley, moving to the Gold Reef in 1904. The school then merged with the Transvaal Technical Institute that in 1922 became the University of the Witwatersrand. In due course mining and chemical engineering departments emerged in other universities and technical colleges across the country. Alongside was a learned society, the now century-old SA Chemical Society (http://www.saci.co.za/), publisher of the *South African Journal of Chemistry*. After World War I, in the surge of state-led industrialisation, the Department of Mines and Industry played a pivotal role on the part of government, *inter alia* establishing the Electricity Supply Commission (known today as Eskom, the national electricity utility), the Iron and Steel Corporation (Iscor, today's Arcelor-Mittal), and the Mineral Research Laboratory (MRL) that was founded in collaboration with the University of the Witwatersrand. Some 50 years later the MRL became a free-standing public research organisation, the Council for Mineral Technology, or Mintek.

Presently, the lead representative private sector organisation for the minerals industry is the Minerals Council of South Africa, successor to

the Chamber of Mines, while the apex learned professional organisation is the South African Institute of Mining and Metallurgy (www.saimm.co.za), publisher of the *South African Institute of Mining and Metallurgy Journal*. The contribution of mining, as a primary product, to GDP has been in decline since the high point of the 1980s, when it made up 21 per cent, down to some 8 per cent by 2016.[1]

Organised labour in the mining industry is represented by the National Union of Mineworkers (NUM) and the Association of Mineworkers and Construction Union (AMCU), as well as the National Union of Metalworkers of South Africa, all of whom campaign on wages, conditions of employment, and safety issues.

The growth and development of the chemical industry was largely driven by the need for cheaper explosives, with a rival to the Dynamite Factory coming into production outside Cape Town in 1902, and a third plant commissioned at Umbogitwini, Natal in 1908. In parallel, the demand for chemical fertilisers added stimulus to chemical production, including sulphuric acid that is essential in the production of nitro-glycerine, the explosive component of dynamite, and is a bulk commodity across manufacturing industries. Ammonia is another widely used industrial chemical that became centrally important to munitions and agriculture. This came about through commercialisation of the highly efficient Haber-Bosch process for synthesising ammonia from hydrogen and atmospheric nitrogen that achieved industrial scale in 1910. The growth in production of these and other basic chemicals, with their links to mining and agriculture, followed their respective international technological trajectories, be this in producing pesticides or explosives.

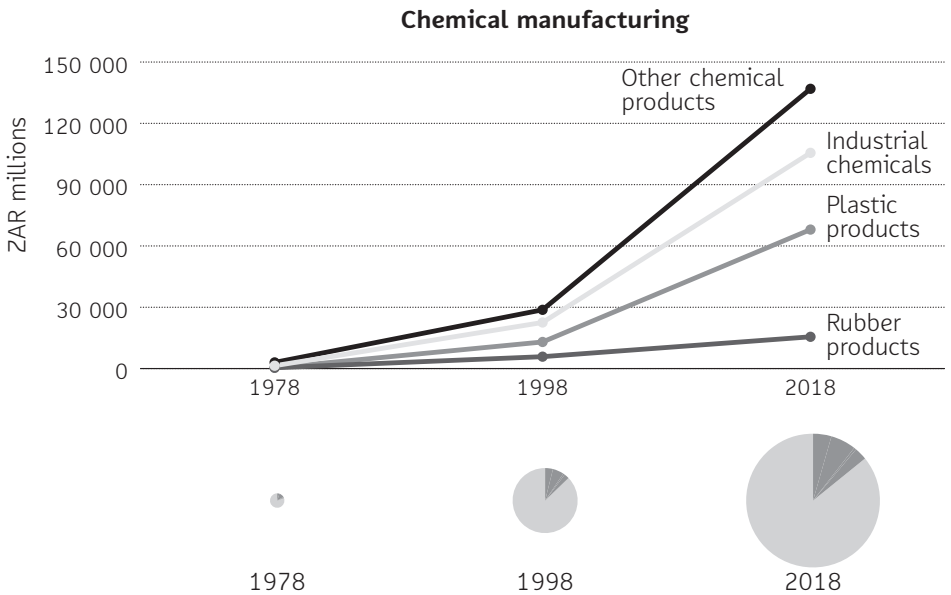
A turning point for the local chemical industry came with the establishment of the South African Steamcoal and Oil company (Sasol) in 1950. The mining house Anglovaal had trialled the implementation of the Fischer-Tropsch synthetic fuel process in the 1930s, but falling oil prices and the onset of World War II put the venture on hold. After the war, Anglovaal transferred its interests to the Industrial Development Corporation, which then founded Sasol. Sasol produces syngas from coal and gas, which is then used to produce some 200 fuels, liquids, solvents, waxes, polymers, gases and bulk chemicals. Today Sasol PLC is a transnational corporation with more than 30 000 employees and in the order of 100 US patents to its name.

The chemical industry, which includes Sasol and a number of other large and small operators, is a key player in the economy (Table 2.1), underpinning the cement, iron and steel, glass, pulp and paper, plastics,

metal products, paints, solvents, fertiliser and composites industries. It uses vast inputs of water, power and chemicals in its value chains.

Table 2.1: Industrial chemicals share of total manufacturing sales[2]

	1978	1998	2018
	R000	R000	R000
Industrial chemicals	1 386 864	22 556 040	105 564 828
Other chemical products	3 015 072	28 748 220	136 904 232
Rubber products	399 060	5 818 092	15 542 772
Plastic products	376 584	13 015 056	68 015 076
All manufacturing	**26 586 864**	**541 975 188**	**2 293 989 360**
Sector percentage	19.47%	12.94%	14.21%



Chemical manufacturing as a percentage of total manufacturing and relative size of manufacturing market

It can be seen that the share of industrial chemicals, or 'heavy' chemicals has remained fairly steady over the last four decades even as the shape of manufacturing has altered under the impact of globalisation and the information and communication technology (ICT) revolution. Imports have eroded the share of 'other chemical products' and 'rubber products' while plastics (derived from local raw materials) have increased. It is to be noted that production of ammonia, sulphuric acid and other industrial chemicals

serve as a proxy indicator for assessing the state and growth of any industrialising or industrialised economy. Because of the scales involved, chemical industries contribute to building what the World Economic Forum (WEF) denotes as the efficiency-driven phase of economic development.[3]

The leading chemicals industry association is the 125 member Chemical and Allied Industries Association (CAIA)[4] that is 'open to chemical manufacturers, distributors, traders, spill responders, drum re-conditioners, service providers, waste managers, testing laboratories and consultants. Hauliers already accredited by the SQAS-Southern Africa are also welcome to join the Association.' CAIA notes important issues facing the sub-sector to include: greenhouse gases, the impact of a carbon tax, climate change, management of environmental impact assessments, and the handling of hazardous materials and wastes. The voice of organised labour is represented by the Chemical, Energy, Paper, Printing, Wood and Allied Workers' Union (CEPPWAWU).

Mining and metallurgical, chemical and associated health and environmental research is conducted at the universities of the Witwatersrand, Pretoria, Stellenbosch, Cape Town, North-West, Johannesburg and KwaZulu-Natal. Alongside are the research laboratories of large companies including Sasol, Omnia, Anglovaal, AECI, De Beers and Eskom. The mining and chemical industries are supported by a host of SMMEs providing equipment, consulting, engineering, and scientific and technical services.

On the government side are the public research institutes of Mintek and the Council for Geosciences, successor to the National Geological Survey, and the multi-divisional CSIR. These R&D performers network with one another, addressing the problems of extraction, chemicals and minerals production and the conversion of new knowledge into products and processes. As such they contribute to innovation, and constitute what the literature refers to as a sectoral system of innovation. South Africa hosts a number of such sectoral systems of innovations in forestry, pulp and paper, armaments, viticulture, telemetry, and financial services.

Our interest here lies in the sectoral system of innovation dedicated to mining/metallurgy and chemicals. Systems of innovation require specialised inputs in the form of skilled personnel – managers, researchers, technicians and other support staff, finance, research infrastructure, utilities and communications, enabling framework conditions, all of which contribute to knowledge production and exchange. Research in mining/metallurgy, chemicals and energy-related fields by the universities, private sector and public research institutes accounts for roughly 15 per

cent of gross national expenditure on R&D. Potential innovations are thereby generated that may result in innovation outputs. These outputs include new products and processes such as trade secrets, as well as those codified in the registration of intellectual property as trademarks, registered designs or patents. In 2015 the mining/metallurgy/chemicals sectoral system of innovation accounted for one quarter of all US patents awarded to SA inventors. The patent suite includes catalysis, mineral extraction, explosive technologies, and bulk handling.

A key issue for innovation and industrial policy is the manner in which the core activities in mining/metallurgy and chemicals draw in other industrial activities through their value chains, and in turn affect the broader economy, society and environment. Of particular interest is purposeful diversification of the products and processes related to and from the mining and chemical industry value chains to and from other industry sub-sectors. An example of an inward flow is military radar and fuze technologies that are used in open-cast mining; an outward flow is x-ray detection of diamonds that is now deployed as low intensity whole body scanning technology. Often hidden and neglected are the externalities and spill-overs arising from mining activities that generate environmental health outcomes.

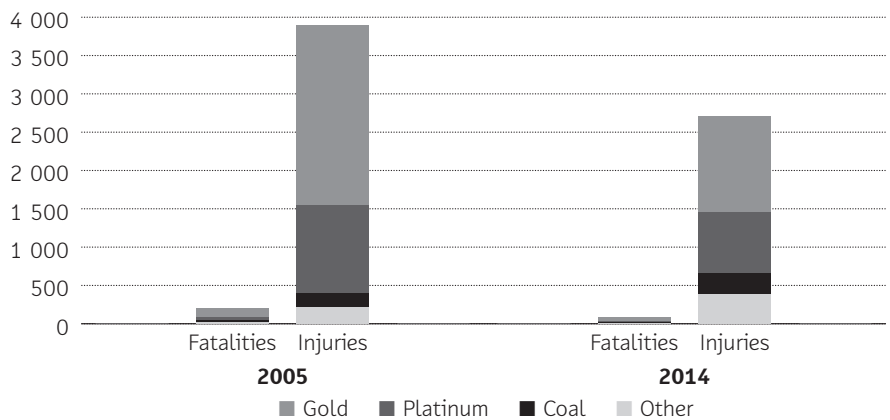
Risks associated with the minerals sector

A wide range of risks is associated with mining and minerals processing. Risks associated with the ore recovery process include dangers of rockfalls, wall bursts, fine dust inhalation, exposure to high temperatures and humidity, fires above and below ground, and toxic gases and fumes. South Africa's gold ore reserves are vast, of low grade, and now lie at depths in excess of four kilometres. Working at such depth is capital and energy intensive, and places considerable strain on mineworkers. Mines must be cooled and ventilated, and there is an ever-present danger of rock fracture due to the intense pressures. So-called 'rock bursts' are a cause of trauma injuries and deaths; explosive gases lead to fires and loss of life and equipment. Other commodities mined underground also incur such risks, although they do not all occur at the same depths as what are seen in gold production. Above ground mining has lower risks, although these are still present.

In 2003 government, labour and industry met at a mine health and safety summit, where it was decided to take the necessary measures to bring losses in line with international norms. Table 2.2 provides an indication of mining-related trauma at that time and nine years later.

Table 2.2: Fatality and injury rates per million hours, by commodity, 2005 and 2015.[5,6]

	Total 2005	Total 2014	Rate 2005	Rate 2014	% Rate change
Fatalities					
Gold	105	44	0.31	0.18	−41.9
Platinum	47	16	0.14	0.05	−64.3
Coal	16	9	0.13	0.05	−61.5
All	201	84	0.20	0.09	−55.0
Injuries					
Gold	2 338	1 243	6.85	5.1	−25.5
Platinum	1 155	796	3.54	2.5	−29.4
Coal	181	267	1.48	1.5	1.4
All	3 895	2 700	4.06	2.7	−33.5



It is interesting to observe that fatalities dropped at much higher rates than injuries. We may speculate that the former is a result of better engineering practice, while the latter relates to workforce training. Trauma-related deaths have reduced considerably in the last few years through improved safety protocols, as well as the general decline of deep mining, and mechanisation. An indicator of the changed status of gold mining as a factor in the economy is the decline in refined gold production from 1 000 tonnes in 1975 down to under 200 tonnes in 2015, so much so that Ghana has now surpassed South Africa as the largest producer of gold in Africa. There were 81 fatalities across all mining commodities in 2018, compared with some 800 in 1994.[7]

The second major cause of death is mine-related diseases, in particular the inhalation of crystalline silica that causes scarring of the lungs (silicosis) resulting in poor function. In addition, compromised immunity, with crowded conditions underground and in-mine accommodation, and dust-laden air raises the incidence of pulmonary tuberculosis, a compensable disease in terms of the Occupational Disease in Mines and Works Act. Silico-Tuberculosis refers to the combined effects of pulmonary tuberculosis and silicosis. Though asbestos mining ceased a decade ago, prior exposure means that cases of asbestosis and mesothelioma continue to be cause for concern. Furthermore, the local mining industry lagged in the order of a century behind global good practice regarding the regulation of underground dust levels, so that silicosis or 'phthisis' remained a problem until a decade ago.

Once the ore has been extracted from the ground, the refining thereof requires inputs of toxic solvents and other chemicals. Not only do these provide potential direct health risks to those exposed to the separation processes, they also result in negative environmental impacts from their production and disposal, if released into the biosphere.

The potential for toxicity impacts of minerals processes varies widely depending on the commodities and processes. As examples, mercury, cyanide, uranium and various heavy metals are associated with the gold sub-sector. Arsenic is released into the atmosphere during copper smelting and is found in seepage from the waste dumps of prior mining activity. Chromium, in the carcinogenic form of Cr (VI), is associated with the ferrochrome industry. Coal mine tailings can pollute water bodies, and coal discard dumps have the potential for spontaneous combustion. Many of the contaminants released can have long residence times in the environment. Ongoing contamination of waters, with apparent oversight failure on the part of government, led environmental lobby group, the Federation for a Sustainable Environment, to lay a criminal complaint against mining companies, resulting in a Public Protector inquiry.[8]

There is also a much larger problem facing South Africa, being that of acid mine drainage (AMD). Although AMD is formed naturally when sulphide-rich ores interact with water to produce a weak sulphuric acid solution, when fine ores, the product of mining activity, interact with water, the rate of acid production rises considerably and the acidified water becomes unfit for human, animal or irrigation use. The water also becomes contaminated with a wide range of heavy metals, including copper, lead, aluminium, manganese and uranium, thereby adding to its toxicity and potential for reuse.

The Gauteng province region, which is built on and around abandoned gold mines, is particularly affected by this issue. When the gold mines in the region were operating, water would be pumped out of the mine shafts. However, once the mines ceased to operate, water was no longer pumped, resulting in a rising water table in contact with the sulphide-rich material. This contaminated water not only has the potential to impact physical infrastructure in its direct vicinity, but once the AMD reaches the surface (as it did in 2002 in the Western Basin) it can enter wetlands, streams and rivers, killing aquatic biota and negatively impacting on agriculture that is dependent on this water.

The Department of Water Affairs[9] suggests that more than 120 such abandoned mines, established over 120 years, are present in the Gauteng region that contribute to the problem. Government has launched both a short-term programme to address the immediate problem in the Western Basin and a longer-term intervention to cover the entire affected region. The solution includes the construction of treatment plants that add lime to the water to raise the pH and precipitate out heavy metals to make the water suitable for discharge. One cost estimate for constructing the treatment plants alone, prior to operating them, is R12 billion.[10] There have, however, been criticisms of the way in which government has managed the process of consultation and decision-making.[11,12]

Formation of AMD is also a concern for abandoned coal mines and dumps. Here the impacts on both urban infrastructure and agricultural land are largely experienced in Mpumalanga province where the bulk of coal mining has historically been undertaken. However, the scale of the problem is not yet as significant as in the Gauteng region.

In the past, underground mining, coupled with poor living conditions for the legions of manual workers, managed as 'temporary sojourners' in sprawling compounds, gave rise to a significant burden of disease among the semi-permanent mine workers, that in some cases impacted on neighbouring communities, for example the impacts of asbestos exposure on miners and local communities in the Northern Cape. Some 200 cases of the mesothelioma are reported annually; estimated deaths to 2002 stand at 2 700.[13] This in turn called forth a health science response to identify, mitigate, and treat resultant diseases such as silicosis, asbestosis, and black lung, many of which were coupled with tuberculosis.[14] It is a cold, and delayed comfort, to note the 2018 out-of-court settlement of the silicosis class action brought against seven mining houses on behalf of miners who had worked for these groups since 1965, and who had contracted silicosis or tuberculosis.[15] A 2009 study estimated 280 000

incidents of compensable silicosis, making the incidence of this disease amongst the worst ongoing industrial failures on record.[16]

Risks associated with the chemicals industry

The risks associated with the chemicals industry include both direct contact with chemicals and indirect environmental and health risks associated with their production, use and release into the environment. Risks once again vary depending on the industry, commodity and location. Such issues were more pronounced in the early years of the industry's development, although the industry has matured over time. Having said that, industrial pollution remains high, notwithstanding the National Environmental Management Act 107 of 1998, with consequences for the biosphere.

One of the large point source contributors to local environmental pollution is Sasol, which is responsible for 55 per cent of chemical sector added value. The Sasol hydrocarbon and chemical synthesis process is necessarily fossil fuel and water intensive, consuming 134.4 million m^3 of water in 2018,[17] and has been singled out for its negative local environmental and associated health impacts in the towns of Secunda and Sasolburg where it operates. Sasol is also the second-largest contributor to South Africa's greenhouse gas emissions profile, after the power utility Eskom.[18] Sasol has secured upstream coal supplies out to 2050, suggesting no immediate large-scale reduction in its negative impacts. Recognising the climate risks of its operations, Sasol joint president and CEO Stephen Cornell has stated 'Categorically, we won't do it again … this is our last coal-to-liquids operation for the world.'[19] While the contribution of Sasol is noted here, it is recognised that other chemicals producers also have similar impacts, with environmental degradation and societal/health impacts being observed where large chemicals industry is concentrated – for example in the Gauteng region and Durban South.

In addition to the regulatory framework designed to manage such issues discussed later, various spheres of government have designed frameworks and strategies related to shift the chemicals and associated industries towards a green economy, a circular economy, or one with minimised emissions. Included among such plans is the Industrial Policy Action Plan, which makes provision for the support of green industries through:

- Developing a Policy Roadmap for Climate-Compatible Industrial Development;
- Systemised resource efficiency data collection and reporting;
- The Industrial Water Efficiency Project;

- The Industrial Energy Efficiency Project;
- Resource-efficient and cleaner production skills development; and
- Specialist skills development in resource-efficiency and cleaner production.

Such activities would both save costs and begin to directly or indirectly address various SDG goals including Goal 6 (clean water and sanitation), Goal 7 (affordable and clean energy), Goal 8 (decent work and economic growth), Goal 9 (industry innovation and infrastructure), Goal 12 (responsible production and consumption) and Goal 13 (climate action). According to the most recent assessment, 'As a region, Southern Africa is not on track to meet any of the SDGs, but neither is its performance worsening on any of the goals'.[20] The low scores reflect the high levels of poverty, inequality and infectious diseases.

Chemical weapons

South Africa was an important producer and supplier of war materiél to the Imperial war efforts of both World War I and II. Experience already gained in the production of equipment, chemicals and explosives for mining translated relatively seamlessly across to wartime production of ammunition, explosives, bombs, artillery, clothing, food, aircraft, and chemical weapons. Mustard gas was produced for field use in World War II, but there is no record of this having been used in combat. It was reported to the Truth and Reconciliation Commission (TRC) that the stocks of mustard gas had already been disposed of at sea in 1946.

From 1960 onwards, with the deepening conflict inside South Africa and with her neighbours, the authorities interacted extensively with their security peers, initially in France, Great Britain, the United States, and later with Israel, Argentina, Taiwan and Chile, to share information on counter-insurgency methods. Information exchange included interrogation techniques, psychological warfare, operations research, the use of drugs and poisons, and chemical and biological warfare. While the early challenges of crowd control were frequently addressed with the use of tear gas, water cannon and non-lethal force, the rise of armed resistance was met with a more violent response, culminating in the founding of *Project Coast*, the top-secret chemical and biological weapons program instituted by the apartheid government in 1981.

Project Coast set out to develop crowd control agents, offensive and defensive chemical and biological weapons systems, with associated training and protective clothing. It resided in the elite frontline South Africa Medical Service of the South African Defence Force. Under the

direction of Dr Wouter Basson, *Project Coast* enjoyed support from the highest level of government, and was able to establish its own cutting-edge infrastructure. This included the first of two high containment Biosafety Level 4 laboratories in Africa (the other laboratory is in Gabon), in which staff could safely work with the most virulent pathogens.

Former president F.W. de Klerk acknowledged the existence of *Project Coast* in 1993, by which time its expertise had been deployed in Angola, Mozambique, Namibia, South Africa, and Zimbabwe. The range of *Project Coast* capability was subsequently revealed to the TRC. The activities of *Project Coast* are now well-documented, revealing that 'the primary motivation for the initiation of the programme was to deal with internal political opposition rather than to develop typical chemical or biological weapons ... to be used for assassination purposes and for crowd control ... biological agents were produced that might be used to kill individuals and which had a potential to cause widespread disease ... (and) intention to develop novel and sometimes bizarre agents for crowd control'. *Project Coast* was terminated in 1995.[21]

The chemical and biological warfare (CBW) program centred on the *Project Coast* Roodeplaat Research Laboratory (RRL) and Delta G Scientific front company, located to the north of Pretoria. These facilities were most likely able to draw in the expertise and resources of higher education institutions in the Pretoria area, the state agricultural science research institutes, the South African Police Forensic Laboratory, and the chemical industry. The expertise available in the immediate vicinity of RRL included animal vaccine manufacturing capability, and expertise in insect, fungal, bacterial, and viral pathogens.

According to testimony before the TRC, *Project Coast* deployed already available pharmaceutical and chemical products for war aims, as well as conducting research to weaponise poisons, toxins, pathogens, and gases, with associated delivery mechanisms. So for example, organophosphates applied to clothing were used in the poisoning of the Rev Frank Chikane, and that of liberation force combatants in the Rhodesian War of 1961–1980 through the contamination of food and clothing dumps. Organophosphates embrace insecticides (e.g. malathion), nerve poisons (sarin, tabun, VX) and herbicides. Insecticide organophosphates are readily available. They may be colourless or odourless and use as an offensive agent may be difficult to detect. Subsequent to the official stand-down of *Project Coast*, charges were brought against Basson for dealing in the production and sale of illicit narcotics. His two-and-a-half-year trial resulted in acquittal. Chandré Gold and Peter Folb state that there was no evidentiary link between

Project Coast and the activities of the Rhodesian Security Forces. With the termination of the CBW programme, the Roodeplaat Research Laboratory was decommissioned as a site for CBW, and its infrastructure is now part of the Plant Protection Institute of the Agricultural Research Council. Production of CS gas continues at Rheinmetall Denel Munitions SOC Ltd. Among other munitions, the company now produces a new range of CS gas grenades[22] and exports other CS-filled munitions.[23] Such exports fall under the control of the National Conventional Arms Control Committee (NCACC), established through the National Conventional Arms Control Act No. 41 of 2002. The NCACC Annual Report for 2018[24] declares munitions exports to various countries, but does not indicate what proportions may be chemical weapons. The two largest 'ammunition' purchasers were the United Arab Emirates (R536 million) and the Kingdom of Saudi Arabia (R216 million). The descriptor 'chemical' is absent in the Report.

Legislation, regulation and international agreements

A comprehensive body of law is in place to regulate: (i) the production, use and disposal of chemicals and chemical wastes; (ii) the environmental (and consequential societal) impacts of the chemicals and mining and minerals processing; and (iii) worker safety. The WHO/JEE South Africa mission report confirms that the country has a strong regulatory base. Legislation is spread across a number of government departments.[25] With respect to the first of these, the Hazardous Substances Act 5 of 1973, controls substances affecting human health through being toxic, corrosive, irritant, strongly sensitising, flammable, and pressure-generating as well as certain electronic products. This includes importation, manufacture, sale, use, operation, application, modification, disposal or dumping. The National Environmental Management (NEM) Act 107 of 1988, with the associated Waste Act (NEM: WA) and Air Quality Act (NEM: AQA), address the issues associated with protection of the environment, as does the National Water Act 36 of 1988. The Mineral and Petroleum Resources Development Act (No. 28 of 2002) (MPRDA) also recognises the importance of environmental sustainability. South Africa is also currently developing climate legislation to address greenhouse gas emissions. Finally, worker protection is primarily addressed through the Occupational Health and Safety Act 85 of 1993.

Various international and multilateral agreements complement these domestic legal instruments, including:

- Stockholm Convention on Persistent Organic Pollutants (POPs);
- Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade;

- Basel Convention on the Transboundary Movement of Hazardous Wastes and their Disposal;
- Vienna Convention for the Protection of the Ozone Layer's Montreal Protocol on Substances that Deplete the Ozone Layer;
- Strategic Approach to International Chemicals Management (SAICM);
- International Oil Pollution Compensation Fund; and
- International Convention on Liability for Bunker Oil Pollution Damage.

These provisions should be read alongside the Biological Weapons Convention, Chemical Weapons Convention, and the Nuclear Non-Proliferation treaty.

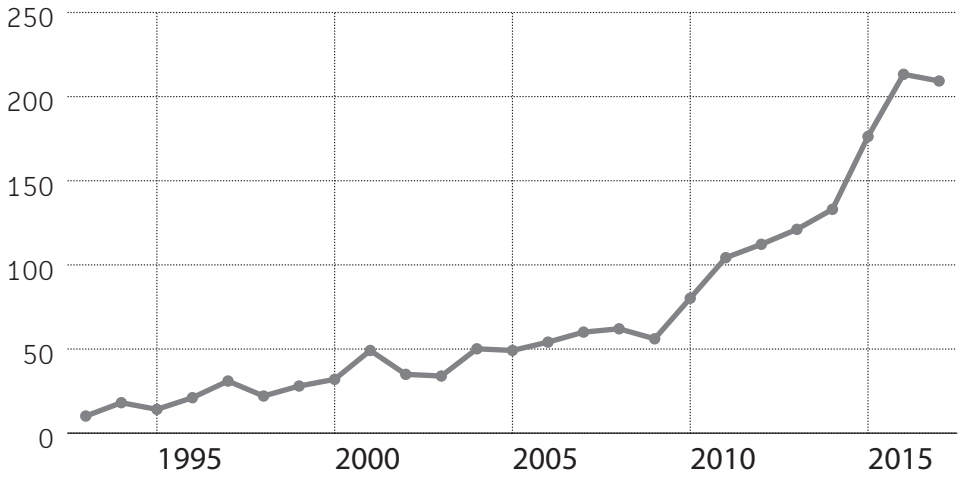
Growth in concern about chemical risk and response

From the above it is evident that chemical processes form a major underpinning of the primary and secondary sectors of the economy, and have done so since the beginnings of the formal sector. Also clear is that chemical processing, and the linked minerals sector, has major import regarding the attainment of the SDGs, and health security.

A keyword search on the Web of Science publication database was used to obtain insight into how the academic research on the risks facing the mining, chemicals and related industries in South Africa has developed since 1994. The following search string was examined:

> *((chemical warfare) OR (chemical terror*) OR (chem* regulat*) OR (chemical hazard) OR (Hazchem) OR (chemical pollution) OR (chemical spill*) OR (toxic waste) OR (chemical weapon)or (mining pollution) or (mining risk) or (chemical risk))*

Figure 2.1: Research publications on mining and chemical risk, 1993–2017



The search results are presented as Figure 2.1 showing the steep rise in relevant publications from 2010 onwards and signalling growth of interest in the topic. Indeed, over 2013–2017, publications within the above string made up 0.84 per cent of all South African publications, whereas the world proportion stood at 0.71 per cent, so that the relative activity index measures 1.18 times or some 18 per cent above the world average. Measured according to publication output, country research expertise is concentrated at the Universities of the Witwatersrand, Cape Town, Stellenbosch, North West, KwaZulu-Natal, Johannesburg and the CSIR. Further research would be required to determine the precise source of funds for research. For our purposes suffice it to note that foreign funding for research tends to be highly concentrated in health fields, such as clinical trials. Research on mining and chemical-related fields is most likely funded from local sources, including government.

WHO/JEE[26] finds that mechanisms to respond to chemical events are in place, with state-owned Armscor-Protechnik Laboratories holding responsibility to identify the agent, and to act in coordination with the Multi-Sectoral National Outbreak Response Team (MNORT). The country scores level 3 for both: 'CE.1 Mechanisms are established and functioning for detecting and responding to chemical events or emergencies'; and 'CE.2 Enabling environment is in place for management of chemical events.' This assessment is accompanied by recommendations that the availability of specialist training is under-appreciated, and that take-up tends mainly to draw in the health sector.

As to unconventional, or improvised warfare, there are numerous instances where acts of terrorism have involved poisonous substances that were weaponised in improvised laboratories, e.g. sarin in Japan. In addition, readily available oxidising chemicals are the basis for improvised explosive devices that have led to mass casualties in the United States, the United Kingdom, and many countries in Africa and the Middle East, most notably through small-scale production of acetone or nitrate-based explosives.[27] These chemicals are generally available on the open market, including over-the-counter from pharmacies. Following the outrages in the United Kingdom, restrictions on the importation and use of oxidising substances were introduced.[28] Presently no such restrictions are in place in South Africa, a country with numerous producers and suppliers of chemicals (and explosives). Effective legal intelligence gathering would appear to be the main line of defence against terrorism.

Concluding remarks

By its very nature, operations in the chemicals, mining and metallurgical industries carry a wide range of risks to persons, property and the environment. A range of good practice legislation is in place to address the risks, with a strong emphasis on human health impacts. However, enforcement of regulation is a challenge, and the sector continues to experience and demonstrate risk to human and environmental health. There is an ongoing tension between good practice and vested interests, be these of facility owners, their value chains or labour. Overtly offensive chemical weapons production has ceased, but crowd-control agents continue to be manufactured for domestic purposes and export. Consideration might also be given to restricting over-the-counter purchase of acetone and other potentially dangerous oxidants. Existing regulations for the purchase and use of explosives could serve as a template, though the wide availability of industrial and mining explosives suggest current regulatory failure.

This chapter has demonstrated that South Africa has an extensive legislative framework in place to protect the environment and limit risk. However, it is very poorly enforced.

Recommendation 1: Government needs to demonstrate a willingness to enforce existing legislation. The work of all those charged with inspection requires financial, technical and political support, in which arena the appropriate parliamentary committees should be capacitated to play a stronger oversight function.

Global disquiet in relation to greenhouse gas emissions will have significant implications for South Africa's minerals and chemicals

industries, human and environmental wellbeing. All effort is called for to bring South Africa in line with actions to combat climate change.

Recommendation 2: As a matter of priority the construction of backcast scenarios toward a resilient, low-carbon future, involving all stakeholders should be convened. Such scenarios must sensitively deal with the impact of climate change mitigation on employment and production.

In addition to limiting the future impacts of the chemicals and minerals sectors, there is a need for remediation to address past impact.

Recommendation 3: Provision must be made for the necessary financial and technical investment for compensation and mitigation both on the part of government and the private sector.

The use of chemical weapons for overtly criminal and terrorism ends has increased significantly.

Recommendation 4*:* A Standing Commission to deal with such threats is called for. The mandate of this body should embrace political, economic, social and environmental threat analysis, examination of mitigation measures consistent with the Bill of Rights and the Constitution, and impact assessment of current and intended legislation and regulations.

3
Biological and infectious disease risks

Lizeka Tandwa and Janusz T. Paweska

In a publication by the US Institute of Medicine entitled *Microbial Threats to Health, Emergence, Detection and Response*[1], the authors suggested that a group of factors are swirling and converging to create a perfect microbial storm. This metaphor helps describe the conditions and dynamics that have produced a new era of emerging infectious diseases (EID) that began approximately 40 years ago. From the centre, or eye, of the perfect storm, a group of zoonotic pathogens of significant public health concern are emerging. Biological, socio-economic, ecological and anthropogenic factors are creating the perfect conditions for a storm of emerging and re-emerging zoonoses.

We are living and working in an unprecedented era of EID with zoonotic pathogens playing a dominant role. Emerging zoonoses can occur anywhere in the world and the consequences can be severe. The interdependence of people and animals and the many different factors controlling this relationship are converging to create a conducive environment for the emergence of zoonotic pathogens. Emerging zoonoses highlight the dangers of the ability of pathogens to constantly adapt, survive and infect populations of animals and people and then rapidly move between these host populations.

The recent epidemics of severe acute respiratory syndrome, West Nile virus, avian influenza, Ebola Virus Disease (EVD) and Zika virus disease demonstrate the global significance of EID and the important role of public health and veterinary services in prevention, detection, diagnosis, surveillance, response and research activities. Emerging zoonoses of public health concern are also a sobering reminder of the tremendous socio-economic and trade damage that this group of diseases can cause.

A number of driving forces and societal changes are creating an unprecedented environment that favours the expansion and perhaps even acceleration of a group of these diseases termed emerging or re-emerging zoonoses. Of 1 415 known pathogens of humans, 62 per cent have an animal origin. Over the last several decades, there has been an average

of almost one new emerging disease each year, and approximately 75 per cent of these diseases have been zoonotic[2]. Microbes continue to evolve and adapt and now, with the tremendous acceleration and expansion of global trade, human movement and travel and the escalating population of both people and animals, the microbes have an even greater opportunity to adapt, change, and be transported to new hosts and ecosystems, often with catastrophic results. Changes in our weather, climate, ecosystem, animal production systems, economic development, and land use continue to alter the dynamic between hosts, vectors, and microbes in novel ways.

In 1800, 98 per cent of people were farmers and lived in villages. Today 54 per cent of the world's population live in urban areas/megacities, with an expected increase to 66 per cent by 2050 (6 billion). It is estimated that 90 per cent of the population increase will be in Asia and Africa. Urbanisation has resulted in challenges to meet rapidly increasing needs for housing, infrastructure, transportation, energy, employment and basic services such as education and health care. Urban areas also have a 'floating' population due to migration, largely from rural to urban areas in search for better economic and social opportunities. As the population increases in urban areas, it becomes more challenging to meet basic needs such as health care, water and sanitation and this makes the population vulnerable to increased risk of disease transmission. There are a myriad of environmental changes along with the population changes that will alter people's lives such as natural disasters, global warming and water insecurity.

Emerging infectious diseases, especially those caused by zoonotic RNA viruses and vectored by rodents, bats and arthropods pose a formidable challenge to human and animal health in countries with established endemicity and potentially elsewhere via regional and global spread. Over the last four decades, several EID caused epidemics of regional and global concern. Prediction of EID occurrence is limited as well as capacity for timely detection and response. Understanding of basic virology, epidemiology and ecology of their causative agents, developing of new generation accurate and safe point of care diagnostics and effective and safe therapeutics and vaccines are essential for their prevention and control.[3,4,5]

The South African health system is currently overstrained by the quadruple burden of diseases namely, Human Immunodeficiency Virus (HIV) and tuberculosis (TB); maternal, infant and child mortality; violence and injury and there is rise in the number in non-communicable diseases cases.[6] In 2018, it was reported that there was an estimated 7.52 million people living with HIV (13.1 per cent of the South African population) which necessitated

establishment of the largest and very expensive anti-retroviral therapy (ART) programme in the world.[7] Between 1997 and 2004 there was a steady rise in recorded infectious diseases-related mortality rates and this can be attributed to the HIV incidence at the time. Between 2004 and 2009 there was a plateau in the infectious diseases rates, followed by a decline of 14.4 per cent between 2009 and 2016.[8]

Even though there is a decline in infectious disease rates, infectious diseases remain leading causes of deaths in South Africa, mostly due to TB.[8] In 2016 alone, 124 000 people died from TB, with 80 per cent of these cases associated with HIV.[9] TB is the leading cause of deaths in six provinces, excluding Limpopo, the Western Cape and Gauteng. Influenza and pneumonia have been the leading cause of deaths in Limpopo province since 1997.[8] There is a high burden of influenza in South Africa, with approximately 11 800 influenza-associated deaths annually. Influenza and pneumonia are ranked as the fifth cause of death.[8,10] In the Western Cape and Gauteng provinces, the leading causes of death are non-communicable diseases.[8]

The public health sector bears most of the health burden of the country since it services the majority of the population. The load on the public health sector is exacerbated by resource constraints. With this considered, infectious disease threats and events could challenge the health security in South Africa and destabilise the already overburdened and under-resourced public health sector.[11]

Prevention, detection and response capacities and capabilities are essential elements that inform both the criteria and measurable targets for health security. Prevention strategies for biological risks and epidemics include developing and implementing policies, immunisations, monitoring infectious diseases and antimicrobial resistance. When an infectious disease event cannot be prevented, the timely detection of and response to an event is essential. In South Africa, the capacities to detect infectious threats for humans, including diagnostic, surveillance and outbreak response capacities, specifically for high-risk biological agents, are mostly concentrated at the National Institute for Communicable Diseases of the National Health Laboratory Service (NICD/NHLS). The Onderstepoort Veterinary Research of the Agricultural Research Council has the capacities to detect infectious threats for animal cases. Maintenance and further development of these national capacities requires an adequate number and well-trained human resources and technical expertise.

The responses to disease threats and associated events should be timeously activated and implemented, employing well-established and

fully operational emergency response strategies when necessary. The coordination between multiple sectors in preventing, detecting and responding to biological risks and epidemics is imperative. The Department of Health has a National Health Operations Centre (NATHOC) to respond to public health emergencies. In 2015, a national Emergency Operation Centre (EOC) was launched by the Department of Health and it is hosted by the NICD/NHLS. This EOC was launched during the West Africa Ebola Outbreak (2014–2016), in order to manage public health emergencies; these include both viral and bacterial outbreaks[12]. There is also National Disaster Management Centre that coordinates disaster response and risk mitigation.

Endemic and exotic microbial threats

High consequence pathogens are those that have a propensity for rapid spread, causing high rates of morbidity and mortality, and against those vaccines and therapeutics are mostly not available or have very limited and restricted availability. With regards to their local occurrence, these pathogens can be classified as endemic or exotic, and need to be handled, processed and stored in high (biosafety level 3) or maximum (biosafety level 4) security laboratories. Table 3.1 shows a list of endemic and exotic potentially high consequence pathogens in South Africa, most of which are zoonotic. Examples of high consequence pathogens events that have occurred in South Africa include importation of Marburg virus in 1975, Ebola virus in 1996, Lujo virus in 2008, Rift Valley fever outbreaks in 2008–2011, and an increasing number of human rabies cases.

Infection with rabies virus in humans, if no or inadequate post-exposure treatment is provided, results in inevitable death. From 1983 to 2007, a total of 353 human cases of rabies was laboratory diagnosed in South Africa, an average of about 14 cases per annum[13]. The number of human rabies cases are likely underestimated, due to miss- and under-diagnosis of the disease. A total of 105 human rabies cases were laboratory confirmed from 2008 to 2018, with cases reported from all the provinces of South Africa, but the Western Cape. The recent increase of human rabies cases in South Africa, including disease re-emergence in provinces previously free of the disease is of great concern. The increase in the number of human rabies cases, especially in areas of the Eastern Cape and KwaZulu-Natal provinces, relates to an increase in the number of dog rabies cases reported in these provinces. The most notable rabies outbreak to date was in 2006, with 22 confirmed human cases. There were also 49 confirmed cases of rabies in dogs from south-western Johannesburg.[14] Children and young adults were the most affected by the disease. Dog-mediated rabies in humans remains a challenge in South Africa. Intensification of efforts for

dog rabies control and health education and awareness interventions will be required to curb the trends.

Between 2008 and 2011, there was a Rift Valley Fever (RVF) epidemic in eight of the nine provinces in South Africa. There were over 14 000 animal cases and 278 human cases of RVF, which resulted in the deaths of 25 humans. The most recent report on RVF confirmed that there were 250 cases in sheep in May 2018.[15,16] There is no commercially available vaccine for RVF or treatment, and the management of cases is supportive therapy.[17]

An example of an exotic high consequence pathogen is Zika virus, which is transmitted to humans from Aedes mosquitoes. The Aedes mosquito is also the host and vector for dengue, Chikungunya and yellow fever. There is no vaccine or cure for the Zika virus. One of the major complications associated with Zika infection in pregnant women is congenital Zika syndrome, which can result in microcephaly and poor prognosis for infants[18].

A crucial similarity between the endemic and exotic examples is that animal and human interaction has a considerable effect on epidemics, illustrating the importance of zoonoses. The challenges that both endemic and exotic high consequence pathogens present are both dire and complicated. On the one hand they spread rapidly and on the other hand, there is either limited or no vaccines or treatments available. This means that the best way to control such cases is to prevent them, especially since the response measures are limited or complex. Where vaccines for animals and humans are available, it is imperative, nevertheless, to prevent cases as much as possible. Other mitigation strategies must be applied to prevent the widespread distribution of these pathogens. In addition, rapid detection is essential in order to monitor and control the number of cases of high consequence pathogens. The capability of pathogens to adapt and become resistant to treatment further complicates disease prevention and control. When treatments become ineffective, this results in infectious diseases that have clear treatment and management regimens complicated, such as the case of multi and extensively drug resistant TB.

Table 3.1: Examples of endemic and exotic pathogens for South Africa[19,20,21]

Endemic	Exotic/Non-Endemic
Viruses	
Rift Valley Fever	Dengue fever
Crimean Congo haemorrhagic fever	Zika virus
West Nile virus	Yellow fever
Sindbis	Lassa fever
Chikungunya	Ebola
Rabies	Lujo
Influenza	Nipah virus
HIV	Hendra
Marburg	Severe acute respiratory syndrome (SARS)
	Middle East respiratory syndrome (MERS)
Bacteria	
Bacillus anthracis	*Francisella tularensis*
Mycobacterium tuberculosis (incl. MDR and XDR)	*Rickettsia rickettsiae*
Vibrio cholerae	*Rickettsia prowazekii*
Brucella abortus; B. melitensis	*Bartonella quintana*
Coxiella burnetii	
Burkholderia mallei; B. pseudomallei	
Leptospira sp.	

Beyond South African borders

Studies on the risk of spread of EID point to Africa and Asia as likely to harbour the endemic settings for both conventional and emerging epidemics, especially in the human-livestock-wildlife interface areas. While the African continent suffers from one of the highest burdens of infectious diseases of humans and animals in the world, it has the least capacity for their detection, identification and monitoring as reported in the study by the UK Foresight.[22,23] Africa is a hotspot for a number of dangerous and high consequence emerging and re-emerging viruses with potential exportation outside of the continent and international spread, as exemplified by the emergence of Lassa fever, Marburg, Ebola, HIV, yellow fever, dengue, Chikungunya, Rift Valley Fever, Zika and West

Nile viruses outside their historic geographic boundaries. The African continent is also endemic for lesser-known viruses that have the potential to cause outbreaks in other parts of the world. Of the five Public Health Emergency of International Concern (PHEIC) declarations to date: (2009 H1N1 flu pandemic, 2014 polio declaration, 2014 Ebola outbreak in West Africa, 2015–16 Zika virus epidemic, 2019 Ebola epidemic in the Democratic Republic of Congo), three are due to viruses originating in Africa. A timely, streamlined, well-funded and efficient disease reporting and surveillance system is essential to monitor the threat of potential epidemics, which may not only affect population health in a particular country but may also have wider implication for regional/global health. In observing WHO International Health Regulations (2005) (IHR), each nation has to improve its own capacity in disease recognition and laboratory competence. Innovative approaches are necessary in the development of scientific capacity for surveillance and control of infectious diseases to ensure health security at community level. Some challenges hampering progress in research, response and control of EID in Africa include:

- insufficient and uncoordinated surveillance and research programmes;
- limited regional capacity to develop new and improved diagnostic assays;
- inadequate biocontainment infrastructure limiting research programmes on high consequence pathogens, lack of certification systems for commissioning of high and maximum containment facilities;
- limited capacity for strategic biobanks for long-term and secure storage of reference clinical materials, strains and preserving African pathogen biodiversity for future development of diagnostics, vaccines and therapeutics;
- lack of regional External Quality Assurance (EQA) programmes for dangerous endemic viral and bacterial pathogens.

The WHO reported that there are 69 ongoing events in Africa in September 2019, some of which are a result of high consequence pathogens.[24] Recent examples of neighbouring countries experiencing outbreaks are Zimbabwe, Mozambique and Lesotho. Zimbabwe experienced a cholera outbreak and there were 10 443 suspected cases and 59 confirmed deaths between September and December 2018. Most of the cholera cases have been reported from Harare, although there are cases in eight other provinces in Zimbabwe. During the outbreak, four cases of cholera were detected in Gauteng and Limpopo provinces in October to November 2018. Three of the four cases were confirmed to be travellers from Zimbabwe.[25] The vibrio cholera isolates that were detected are resistant

to the first-line antibiotics, including ciprofloxacin.[26] This has resulted in 'heightened awareness' for suspected cholera cases in South Africa.

In Mozambique, 1 052 cases of cholera were reported in April 2019 following *Cyclone Idai*, which left many people displaced and without basic needs. The negative effects of the cyclone include poor water and sanitation, and this has and will continue to have a direct effect on infectious diseases in that and other surrounding areas.[27]

There is an ongoing anthrax outbreak in Maseru, Lesotho reported in May 2019. Twenty-four cattle have died and there are approximately 106 cases of suspected anthrax infection in cattle, and this has resulted in over 50 deaths among local people eating meat from infected cattle. The last cases of anthrax in South Africa was in 2006, in the Northern Cape, and anthrax is rare in South Africa.[28] However, this outbreak is important to note given the proximity to Lesotho and the trading of animals. The measures that have been put in place in response to the outbreak include quarantining and restricting the movement of cattle, surveillance and vaccination of animals.

The World Health Organization declared the ongoing Ebola outbreak in the DRC a PHEIC in July 2019. At the end of August 2019 there were 3 000 confirmed cases and 2 000 deaths.[29] The NICD/NHLS has responded to this announcement by confirming that there are no confirmed or suspected cases of the EVD in South Africa. The risk of importation of Ebola cases is low, and South Africa NICD has established capacity and experience to diagnose and manage EVD.[30]

While rapid spread and treatment challenges are pertinent to high consequence pathogen events, it is evident that other factors influence the spread of infectious diseases. Environmental factors such as natural disasters and human and animal movement play a role in the spread of infectious disease. The abovementioned cases are relevant to the South African context because of proximity, relations and movement between these countries. It is important to identify the risks posed by outbreaks in neighbouring countries because borders do not limit infectious diseases. Lesotho relies on the NICD for specific diagnostic capacities; therefore, an outbreak in Lesotho actively involves South Africa. Lesotho is landlocked within South Africa and neighbouring provinces must be aware of such cases and strengthen detection mechanisms. Tourism statistics in 2017 identified the majority of South African tourists coming from Zimbabwe (28 per cent), Lesotho (24 per cent), Mozambique (18 per cent), Swaziland (12 per cent) and Botswana (9 per cent).[31] Ongoing outbreaks in neighbouring countries are important and are of public health interest to South Africa,

especially since there is a high prevalence of HIV in South Africa. There are a number of lessons that can be learned from recent epidemics in Africa and elsewhere, clearly indicating the need for:

- coordinated research through interdisciplinary centres;
- response systems and infrastructure;
- integrated surveillance systems and workforce development strategies; and
- well-coordinated and strong partnerships across national and international sectors (human health, animal health, environment) and disciplines (natural and social sciences) involving public, academic and private organisations and institutions.

High consequence pathogens and biosecurity

The WHO biorisk spectrum identifies biological risks as naturally occurring, accidental, emerging or re-emerging infectious events and deliberate misuse of biological agents (WHO framework).[32] An example of a new and emergent infectious agent that was discovered in South Africa is the Lujo virus. When it was discovered, it was an unknown arenavirus transmitted likely via rodents to an index case and then resulting in highly fatal nosocomial outbreak[33]. An example of re-emerging pathogen is the influenza virus, re-emerging as a different strain. It is important to categorise the infectious agents accordingly as this informs the preparedness and mitigation strategies that must be employed. Biorisk reduction through mitigation strategies is essential to minimising the vulnerability of humans, animals and the environment from high consequence pathogens. These strategies range from prevention and disease surveillance to laboratory biosafety and biosecurity.[34]

There are a number of factors that influence and accelerate the emergence or re-emergence of infectious diseases. These factors include microbial adaptation and change, economic development and land use and human demographics and behaviour. Other factors include, technology and industry, breakdown of public health measures, international travel and commerce and human susceptibility to infection. The environmental and political factors are climate and weather, changing ecosystems, poverty and social inequality, war and famine, lack of political will and intent to harm (bioterrorism). When considering biorisk reduction, these factors must be considered to understand the contextual confounding factors to high consequence pathogen associated events. These factors will result in a comprehensive and contextually appropriate mitigation strategy and response. If these factors are considered in the Ebola outbreak in the DRC,

at least human demographics, breakdown of public health measures, social inequality and political contextual factors contributed or contribute to current outbreaks.

Laboratory biosecurity is defined as 'the protection, control and accountability for valuable biological materials within laboratories, in order to prevent their unauthorised access, loss, theft, misuse, diversion or intentional release'.[35] Biosecurity requires controlling access and limiting access to certain materials, record-keeping (inventories), enacting approval procedures, biorisk assessments, protocols on the disposal of materials and reporting security breaches.[36] The transportation, storage and handling of dangerous pathogens and the prevention of accidental or intentional release is crucial. There are a number of biorisk models and assessment tools for biosecurity considerations that are intended to assess and reduce vulnerability and enhance institutional resilience (Bioram, Self-Scan, Vulnerability Scan, Sandia National Laboratories).[37] Some of the pertinent considerations include funding, human resources, biosecurity policy development, training and awareness.

Funding for biocontainment infrastructure: Receiving, handling, processing, storage and processing of clinical specimens potentially containing highly dangerous, exotic or yet undescribed micro-organisms requires the use of high or maximum security facilities to ensure the required level of biosafety and biosecurity when diagnostic and research activities are conducted. The physical and technical infrastructure of such facilities is very complex and expensive, not only to build, but also, to maintain. Consequently availability of high and especially maximum security facilities in Africa is limited. For example, in developed countries costs of construction and building a maximum security laboratory can be up to US$100–150 million, and their annual maintenance US$10–15 million annually. A maximum suite containment (biosafety level 4 – BSL4) is housed in South Africa at NICD/NHLS.

Inadequate biocontainment infrastructure, limitations to their access and availability not only limits African capacity to respond to threats caused by highly dangerous pathogens, but also hampers development of new and improved diagnostic assays, vaccines and therapeutics, including research on antiviral interventions. Substantial funding would be required to improve this situation. On the other hand, the SA BSL4 facility is under-utilised by the region. This is due to limited availability of local human capacity for provision of regular and long-term training for and supervision of research fellows, lack of funds/mechanisms to provide free of charge diagnostic services to affected countries, limited local capacity to attract

and use funding for BSL4 development and research work, and lack of regional/continental agreement for optimal utilisation of SA BSL4 in order to combat microbes threatening African heath security.

Availability of well-trained personnel who have the technical expertise to work with high consequence pathogens is at the heart of the functioning of the biosecurity systems. Human capacity at the front lines, those who are interacting with humans, animals, and the environment as a whole, is required. Training health personnel is very important to upscale the human resources and it is also important because they are also vulnerable to infection. In the DRC Ebola outbreak, 6 per cent of the infection cases were of health workers (between May and June 2019).[38] Similarly, in the 2010–11 RVF outbreak in South Africa, many of the human cases were farmers and health personnel. During the West Africa Ebola outbreak 11 hospitals in South Africa were designated and received Ebola prevention and awareness training. There was one designated hospital in each province and there were two hospitals in Gauteng and the Eastern Cape provinces. In addition, 100 registered nurses from the South African military health service received training in isolation techniques.[39] Enhancing the technical skills of the human resources is very important and should be proactive and continuous as opposed to reactive in order for the country to be prepared for an infectious event.

Workforce development that focuses on IHR and Performance of Veterinarian Services (PoVS) core competencies needs to be developed at provincial and district levels. The recommended numbers of field workers required are one epidemiologist per 200 000 human population.[40] To meet this requirement, a total of 275 field epidemiologists are needed in South Africa.[41] Currently the NICD/NHLS has a provincial epidemiology team that includes a senior epidemiologist at the NICD/NHLS and one epidemiologist per province.[42] The South African Field Epidemiology and Laboratory Training Program (SAFELTP) has produced 38 field epidemiologists who work at national and provincial levels. A complete capacity assessment has not been performed in South Africa, however, it is highly unlikely that the requirement is met for field epidemiologists. One veterinarian per 400 000 animal units or per 500 000 human population is also required. In South Africa there are currently 3 522 veterinarians registered with the South African Veterinarian Council. This means that there are one veterinarian per 15 616 human population, and this meets the requirement. The distribution of the veterinarians is not clear, therefore the professional to population requirement may vary amongst provinces.

Biorisk management policies need to be in place that stipulate physical, transport and information security protocols. This considers the end-to-end processes of storing, handling and using high consequence pathogens. It is important to safeguard sensitive information, to ensure that it cannot be misused or misapplied. The implementation of these policies needs to be realised at institutional levels.

Biosecurity awareness and training have been identified as an important aspect in reducing biorisks. Specific training is essential for actors who work with high consequence pathogens and at the institutional level and governance structures. These actors include directors, principal investigators, laboratory biorisk management advisors and biosafety committees. Training should be provided at different and appropriate levels for relevant actors, for example, some actors need to be aware of biosecurity and others need extensive training to ensure the safe use and storage of high consequence pathogens. Resources need to be allocated to training development as biosafety and biosecurity play a major role in vulnerability reduction.

Abayomi *et al*. reflect on the essential structures that needed to be in place for the response to the Ebola outbreak in West Africa.[43] Funding, infrastructure and technical capacities for biosafety and biosecurity were necessary. It was also emphasised that the weak legal and regulatory frameworks were a serious challenge to the Ebola outbreak, and this resulted in the lack of accountability during what was a critical period to have legal instruments implemented and accounted for.

Legal and regulatory framework in South Africa

The legislation and regulatory framework determine the processes that inform and promote health security. This framework should govern the end-to-end processes to protect against and mitigate infectious disease risks. A clear and comprehensive legal and regulatory framework which enables a realistic and effective implementation plan is important to ensure that measures are in place to prevent, detect and respond to infectious disease threats. An infectious disease legal and regulatory framework requires a multi-sectoral approach to ensure that human, animal and environmental aspects related to infectious disease risks and events are considered and accounted for. The WHO/JEE tool reviewed capacity in technical areas regarding the promulgation and implementation of International Health Regulation (2005) (IHR) on biosafety and biosecurity legal systems; scored 2 and 3, respectively.

The Academy of Science of South Africa (ASSAf) reported that the legal framework related to human and animal health and agriculture biosafety and biosecurity is comprehensive and robust.[44] South Africa has enacted a number of statutes that relate to human, animal and environmental issues regarding infectious diseases. These statutes and regulations are between Departments of Health, Agriculture, Forestry and Fisheries and Trade and Industry. The major issue identified with the legal and regulatory framework for biological and infectious diseases is that, while it is comprehensive, it is very fragmented, stagnant and poorly coordinated. For example, it has been six years since the IHR Bill was gazetted. This example is pertinent because the IHR Bill is intended to reflect the WHO IHR purpose and scope in the South African legal framework.[45]

The poor coordination of the legal and regulatory framework poses a number of challenges, which include lack of cohesion and clarity, duplication of content because there is no cross-referencing between the statutes and regulations. This is a result of poor coordination mechanisms between the relevant sectors during implementation, even when it is necessary to collaborate in the event of outbreaks of zoonotic diseases.[46] The IHR Bill adds to the legal provisions for health security; however, there is no reference to already existing statutes from the existing legal framework that attempts to coordinate and harmonise the existing statutes.

The insufficient coordination within departments mirrors the poor coordination between departments and a pertinent example of the effects of the poor coordination is the recent listeriosis outbreak. This outbreak involved 1 027 cases between January 2017 and May 2018. With more than 180 deaths, this was the largest recorded listeriosis outbreak in the world.[47] Food safety in South Africa has a stagnant and poorly coordinated legal framework. Experts in the field were predicting and expecting a food-related outbreak due to the legal and regulatory issues. However, the extent to which this legal and regulatory framework would affect the industry was underestimated.[48] This demonstrates the negative effects of a fragmented approach that is poorly regulated and coordinated. The time between a marked increase in the number of cases and the announcement of the outbreak and the recall of meat products linked to the infections was delayed. Time was very critical for those who were immunocompromised, the young and the elderly. Infectious disease awareness amongst the population is time sensitive and play an important role in the monitoring and response of an outbreak. It was identified that one of the key reasons for the coordination and compliance issues is in the

food safety industry, because there is no central authority to oversee the coordination and compliance.

The *One Health* perspective advocates for a unified approach in the legal and regulatory system, and the listeriosis outbreak is one example of why this is important. A primary consideration regarding legal and regulatory approach is the establishment of a central authority that is mandated to coordinate the different departments and stakeholders, and the legal instruments involved. This central authority ought to act as a custodian for a unified and harmonised approach in South Africa that will take ownership and accountability for the approach. The National Public Health Institute of South Africa (NAPHISA) Bill states that NAPHISA would act as the central authority to oversee and manage public health events of concern. This Bill is promising, however, the prolonged periods it takes to enact Bills in South Africa is hindering this process. The establishment of a central authority is of paramount importance and urgency, especially considering that preparedness and emergency response are technical areas that have not demonstrated adequate capacity.

Ownership is also pivotal in governance because it demonstrates political will, and this is important for enhancing legal and regulation processes to be implemented and accounted for. Tom Freiden et al. found that there is more interest in developing prevention and preparedness measures for infectious disease events in high-income countries and there is prioritisation of prevention and preparedness measures is low to middle-income countries.[49] However, it is noted that it is in the best interest of low to middle-income countries to prioritise and strengthen health security preparedness measures. Because the cost of not prioritising preparedness is exorbitant and the consequences dire, this makes sense. This can be seen in the financial loss of approximately US$53 billion resulting from the West African Ebola outbreak.[50] This loss translates to economic dislocation, medical costs, decline in tourism and investment losses, to mention a few points.

The Director General of the Department of Health is the designated person to act as the custodian for the IHR implementation. This can pose a number of challenges because the IHR implementation requires an office and a strong governance structure as opposed to one person. This further supports and necessitates a central authority with the requisite resources to function. Without the central authority and ownership, specific technical areas that are important to ensuring health security for biological risks, specifically high consequence pathogens will continue to be limited. With ownership and accountability, measures can be implemented to meet the

infrastructure, funding, human resource and awareness challenges, in order to reduce vulnerability and strengthen resilience against infectious threats and events.

Conclusion

1. It is in the interest of the South Africa's national and regional health security that the current high and maximum biocontainment facilities at NICD/NHLS (BSL3 and BSL4) are supported by the South African Government as being of national strategic importance. This will secure their long-term role in preparedness and response to dangerous pathogens and bioterrorism. Technical performance of the facility, training, diagnostic and research programmers should be regularly monitored and evaluated. Reports on technical, managerial, diagnostic, science and innovation activities should be reported to parliament and the relevant departments.
2. An interdepartmental framework – including Departments of Health; Agriculture; Higher Education, Science and Technology; Trade and Industry; and Defence – should be established to prioritise development and research programmes on dangerous and high consequence pathogens, as well as the construction and upgrade of containment facilities that could support multi-disciplinary and inter-institutional collaboration in conducting life sciences research of national health security significance.
3. The proposed interdepartmental framework should promote the *One Health* approach to minimise the biorisk spectrum, including natural emergence, and accidental or deliberate misuse of high consequence pathogens, and strengthen the South African multi-sectoral resource capacity in implementation and execution of the International Health Regulations and compliance with the UN Security Council Resolution 1540.
4. To realise the full potential and associated benefits of BSL4 in Johannesburg (NICD/NHLS) there must be intensive and broad collaborations between African countries in the era of emerging infectious diseases to ensure that African scientists are actively involved in preparedness and response programmes to counteract emergence of dangerous, high consequence pathogens.

4
Climate, drought, food security and health

Robbie Parks, Megan McLaren, Ulrike Rivett and Madeleine Thomson

Background

In October 2017, the mayor of Cape Town predicted that the city, with over four million citizens, would run out of water by the following March. The event was termed 'Day Zero', the day the city's taps would be shut off. The idea that Cape Town could be the first major advanced city in history to run out of water captured the world's attention. While the crisis was ultimately averted through the arrival of the winter rains alongside substantial water conservation measures achieved by households, it brought into sharp relief how vulnerable the population of the city, and by extension the entire country, was to extreme climate events. There are several detailed reports of impacts and lessons learned from the crisis,[1] though the long-term implications of the drought in Cape Town will take many years to fully understand. Nevertheless, the Day Zero crisis caused strain on the health and well-being of the population of Cape Town, as well as the economy. It also highlighted the potential of an environmental disaster that, if poorly managed, can plunge a modern advanced society, albeit with complicating third-world features, into a crisis.

The environmental risks associated with climate change in South Africa have grown steadily in recent decades. Climate change has contributed to an increase in extreme weather events including heat waves, drought and wildfires. The frequency of extreme weather events is predicted to further increase under climate change projections.[2]

Changing temperature and rainfall patterns impact agricultural yields.[3] The negative impacts of climate change cascade into the affordability of food.[4] South Africa possesses a large contingent of indigent households and high levels of inequality, with a quarter of the population unemployed and more than half under the poverty line.[5] Significant shifts in the affordability of food can therefore have drastic effects on the health and well-being of a large swathe of the population.[6] While only 15 per cent of South African households are directly involved with agriculture,[7] relatively low in an African context, agricultural production is important for both economic

development and food security. Agricultural yields in the country are also highly sensitive to climate. For example, the total volume of South African agriculture production for 2017 was estimated at 62.9 million tonnes compared to 50.8 million tonnes in 2016. This represented a 24 per cent increase in production, which the department of agriculture attributed to the good rainfalls during the season.[8]

The economy, security and ultimately democracy are under threat from the risks posed by climate change in South Africa. It has been estimated that climate change has caused the economy of South Africa to be 10 per cent to 20 per cent poorer than it otherwise would be today.[9] The gap between rich and poor in the country is also increasing.[10] In Cape Town during the Day Zero crisis, there were concerns of civil unrest by the authorities due to the perceived 'new segregation' that emerged from how poorer citizens, most of whom were black, were less able to procure drinking water than others.[11] The City of Cape Town also passed emergency measures to be able to change water restrictions at will. Under normal circumstances, further restrictions would have to be sanctioned by the Council of the City of Cape Town. However, under enacted 'state of emergency' laws, the Council could be bypassed.[12] The expected increase in water shortage events worldwide, like Day Zero in Cape Town, may therefore have implications on the safety of democracy, with autocratic decisions required to maintain sufficient water restrictions.

Ultimately, these issues pose a threat to health security in South Africa. Clear threats to health and wellbeing exist from the impacts of climate change, in South Africa and worldwide.[13] These impacts reduce the chance of achieving several of the United Nations' (UN) Sustainable Development Goals (SDGs), which were created with the target of ending extreme poverty worldwide by 2030. Among the SDGs disrupted by drought are SDGs 3 (Good Health), 6 (Clean Water and Sanitation), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), and 15 (Life on Land).[14] Universal access to safe and affordable drinking water and sanitation is also part of the UN New Urban Agenda.[15] SDG 2 (Zero Hunger) is under threat by disruptions to food supplies.

Impacts from climate change and associated drought and food security are also linked; negative developments in one can lead to negative outcomes in others.[16] This chapter of *Vital Signs: Health Security in South Africa* assesses how the climate, drought and food systems pose challenges and risks to health security in South Africa.

Climate change

Overview

The global climate has typically changed slowly over time. Organisms living on Earth have adapted due to the gradual changes in climate over many millions of years. In contrast, recent human-induced, or anthropogenic, climate change has caused rapid large-scale changing of weather patterns on earth. This has largely been due to the emission of greenhouse gases in the past century and the continued use of fossil fuels, deforestation and unsustainable development. The effects of anthropogenic climate change have already been seen to be wide-ranging and devastating for countries and populations around the world, and more challenging effects are expected in the future.

Extreme weather conditions (such as heatwaves and cyclones) and their environmental impacts (such as floods) have always existed. Despite humans' successful adaptation, the potential for unusual or extreme weather to disrupt society and health has been demonstrated and recognised throughout history. For example, exceptional temperature events are known via numerous European town chronicles in the 16th century.[17] Measurements in Europe of the past 500 years also demonstrate further evidence of temperature anomalies.[18] More recent periods of extreme heat, such as the 1995 Chicago heat wave,[19] or the 2003 European heat wave,[20] claimed many victims. Under climate change dangerous heat wave exposure is projected to increase worldwide.[21]

South Africa's climate is diverse.[22] Temperatures are highly variable. In the summer, temperatures regularly exceed 30°C in some areas. In the winter, temperatures can fall below freezing in higher elevations, such as in Mpumalanga province. Temperatures along the eastern coastline are about 5°C higher than the west coast due to the warm eastern Agulhas ocean current and the cold Benguela current on the west of the country. Rainfall also varies across the country, with north-western regions experiencing less than 200mm precipitation annually compared with 600mm in eastern parts. Rainfall is influenced by the El Niño–Southern Oscillation (ENSO), as well as sea-surface temperature anomalies in the Indian and South Atlantic Oceans. The main drivers of variation in climate throughout the country are the Indian Ocean in the southeast, the Atlantic Ocean in the southwest, various rainfall regimes, as well as variations in elevation throughout the country. The South African climate varies from sub-tropical climate in the southeast to Mediterranean in the Cape region.

In South Africa, average annual temperature has increased at 0.14°C per decade over the past 30 years.[23] This positive trend is true for the annual mean maximum, minimum or average daily temperatures.[24] The increase in warming has been highest in the central regions of South Africa, with lower increases along regions closer and neighbouring the coasts.[25] Estimates of future warming are in the range of 1.4°C to 4.7°C, relative to 1971–2000, by 2100.[26]

South African rainfall may also reduce annually by as much as 9 per cent by 2100, relative to 1971–2000 levels, which is estimated to lead to a 20 per cent reduction in surface water supply.[27] Projections also suggest changes in distribution of rainfall throughout the year, with more prolonged drought and dry spells along with more intense rainfall events.[28]

The increase in overall temperature, reduction in rainfall, and increase in drought due to future climate change is likely to have cascading impacts on health security in South Africa. The country has recently experienced increasing costs and impacts from natural disasters such as cyclones, floods, coastal storm surges and fires. It has been estimated that during the past four decades (1980–2016), disasters related to weather in the Southern African region have resulted in damages in the region of US$10 billion, leaving 2.47 million people homeless and affecting a further 140 million people.[29]

Cyclones are very intense low-pressure wind systems which form over tropical regions and build to form winds of hurricane force. Water drawn up by convection from the sea surface warms and causes storms to form, which are then rotated by the Earth's Coriolis force. In the South Indian Ocean, tropical cyclones have been rarer than in other parts of the world. Further, prior to 1994, cyclones originating in the South Indian Ocean had never reached a category 5 storm. In the past 20 years, however, rising sea temperatures have brought about a new risk of dangerous cyclones to South Africa, with trends in higher intensities over the past 20 years.

Impact of climate change on health security

Humans have 'inherited or acquired the behavioural, morphological, and physiological attributes necessary to avoid, tolerate, and adapt to the stresses of life'.[30] This process has included adapting to local climate along with its seasonal cycle. The Intergovernmental Panel on Climate Change (IPCC) defines climate adaptation as 'the process of adjustment to actual or expected climate and its effects'.[31] Despite humans' successful adaptation, the potential for unusual or extreme weather to disrupt society and health has been demonstrated and recognised throughout history.

The human body is in a state of normothermia, or comfortable resting temperature, between 36.5°C and 37.5°C.[32] Heat stress, or the 'perceived discomfort and physiological strain associated with exposure to a hot environment', occurs at temperatures above this range.[33] Healthy adults have efficient corrective mechanisms to regulate high body temperature by vasodilation and perspiration.[34] However, even a healthy human body has an upper limit to its endurance of excessively warm temperatures.[35]

In many parts of the African continent, elevated heat is seen as a normal part of everyday life.[36] However, trends in temperatures as well as temperature extremes could pose a danger to health and health systems in areas which are traditionally seen as tolerant to the stresses of heat. Extreme high temperatures have been reported as negatively impacting death rates in South Africa, in particular in older ages and in young children.[37] Additionally, death rates from occupational health have been shown to have elevated death rates under high temperatures.[38]

When heat stress becomes extreme, this can result in potentially deadly medical conditions such as heat stroke, heat exhaustion, heat syncope, heat rash and heat cramps.[39] In the most acute cases, heat stress can lead to multiple organ failure and rapid death.[40] The impact of periods of extreme heat on mortality is substantial. However, direct causes of death from extreme heat stress only make up a small proportion of deaths attributable to daily elevated temperatures.[41] Most temperature-related daily deaths are instead attributable to non-extreme deviations from acclimatised temperatures, which suggests other direct and indirect pathways to mortality from elevated temperatures exist.[42]

Heat waves are multi-day extreme heat events which have no standard definition, but typically take place over consecutive days over a chosen temperature threshold.[43] In South Africa, heat waves have an observed overall mean duration of five days, with the threshold set at the 95th percentile of the daily mean temperatures relative to the reference period of 1971–2000.[44] Under future climate change scenarios, it is predicted with medium confidence that the duration of heat waves will increase by up to 18 days.[45]

Elevated temperatures are especially a threat to the population across South Africa. The urban heat island effect amplifies the effect of elevated temperatures. This is due to reduced green space, as well as road surfaces and buildings retaining heat at night time. More than 60 per cent of South Africans live in urban environments of both formal and informal settings.[46] The challenge for health security in urban environments is compounded because South African cities have a large number of informal or slum

areas and specific challenges exist in dealing with heat. For example, corrugated iron roofs, common in informal dwellings, become extremely hot during heat waves.[47] Informal slum areas in South Africa do not usually have access to piped water in the household. If residents require water in elevated temperatures, they need to stand in a queue in the heat to collect it. Only 46 per cent of households in South Africa have access to piped water in their houses.[48] Schools and health facilities also have amplified heat effects on health, as they have not been optimised to deal with unusually high temperatures.[49] The poorest also live furthest away from health services, and so are potentially hardest hit during periods of elevated temperature.

Seventy per cent of the poorest households in South Africa live in rural settlements, which amounts to over 19 million people.[50] These communities are also typically furthest away from necessary facilities during heatwaves, and so stand as the most vulnerable. Further, the coverage of weather stations is much lower in rural areas in Africa, which affects the capabilities to accurately forecast and hence prepare for expected elevated heat episodes.[51] Raised temperatures and heat waves therefore disproportionally affect the poor and indigent in South Africa.

Risks to health from climate change are also multi-sectoral. The 'double burden' of disease is a potentially sleeping giant of a crisis in households in South Africa; the long-term impacts of infectious disease and undernutrition in childhood are compounded in adulthood by rising levels of obesity and non-communicable diseases including cardio-vascular disease. Heat stress exacerbated by poor quality housing and state services poses a significant risk to populations already impacted by high levels of non-communicable diseases.

In South Africa, one-sixth of the population are estimated to have a mental health disorder.[52] There is evidence, both globally,[53] as well as in South Africa,[54] that rising temperatures can exacerbate mental health problems and be deadly.

Rising intensity of cyclones is another hazard associated with climate change. Many parts of Southern Africa possess limited capacity to deal with cyclones and the resulting flooding. The increasing risk of category 5 cyclones making landfall in South Africa poses a significant threat to the health and safety of the population. Recent cyclones in southern Africa have demonstrated how dangerous even low category storms can be. The potential economic impact of cyclones in Southern Africa is significant. For example, *Cyclone Idai*, which made landfall just north of the coastal city of Beira, central Mozambique, late at night on 14 March 2019 had

been extremely well predicted. After forming in the Mozambique channel on 9 March, the storm was identified as a major threat to Mozambique and neighbouring countries by the regionally mandated official forecasting centre for the South Indian Ocean, RSMC-La Reunion. Warnings that it would bring devastating flooding to Beira were made. In the end an estimated US$1 billion of damage occurred to the infrastructure of Mozambique, Zimbabwe, and Malawi following extensive flooding across the affected countries.[55] The situation was made worse by a second cyclone (*Kenneth*) which made landfall five weeks later in the same region. A state of national disaster was declared in all three affected countries and regional and international responses were mobilised. The South African National Defence Force rescued more than 500 people from the floods in Beira alone.[56]

Though this disaster did not include South Africa, it is illustrative of the potential that cyclones in the region have to cause damage from both extreme winds and associated flooding. The floods which result from occasional cyclones bombarding the eastern part of South Africa can be deadly. Like infectious disease outbreaks, climate-related disasters know no boundaries and require a regional response. South Africa, a major power in sub-Saharan Africa, has historically deployed its Defence Force to assist and it is important that it continues to do so.

South Africa's average rainfall is variable across the country. Heavy rainfall can cause flooding. Recent floods and mudslides in Durban and KwaZulu-Natal province in April 2019 have shown that such events can be deadly and highly disruptive.[57] Women and children are particularly vulnerable during floods. Fatalities occur mainly through drowning, with other causes such as electrocution also possible. Current flood disaster management in South Africa are considered adequate at the national level.[58] However, the lack of skills and disaster management structures at the district municipalities have been judged to have led to damages to drinking water supplies, potential cholera outbreaks and loss of possessions.[59]

Increasing storm frequency and intensity related to climate change are exacerbated by the overcrowding of urban environments, with some residents in informal urban dwellings occupying flood plains.[60] These include Soweto-on-Sea near Port Elizabeth and Alexandra in Johannesburg. Flooding in urban environments can occur for several different reasons. There may be inadequate drainage which can cause localised flooding. Flooding from small streams in built-up areas may also cause flooding. Major rivers can also overflow. Coastal settlements are also under risk

from flooding from cyclones making landfall, as well as sea-level rise from climate change.

Flooding can also lead to forced migration, as rural communities become uninhabitable. This is a major driver of net migration towards urban environments worldwide.[61] As well as causing deaths directly from flooding, the water which remains can block access to health services. This is particularly problematic in indigent communities, due to the lack of nearby provision of health services.

Drought

Overview

Stress on water supplies caused by drought is a global phenomenon.[62] Increasing urbanisation and population growth have impacted existing fresh water supplies that were developed decades ago. Current modelling estimates a significantly increased frequency and severity of drought due to climate change if the rise in average global temperature exceeds 1.5°C above pre-industrial levels or more.[63] With over two-thirds of the world projected to live in urban areas by 2050,[64] solutions to maintaining urban water supply are essential to maintain the health and wellbeing of the global population. Cities and urban populations need to adapt both supply- and demand-side planning, as well as existing infrastructure, to accommodate threats to water supplies.

Cape Town, a rapidly urbanising coastal city of over four million people in the Western Cape region of South Africa, has been at risk of water scarcity for many years. Its dry climate, reliance on surface water, and relatively high per capita water consumption in formal households are at the heart of the city's water challenges. In early 2018, after three concurrent winters of low rainfall (a one-in-around-300-year event and the worst in over 100 years),[65] the City of Cape Town (CoCT) announced that the population would need to take drastic action to avoid running out of water for the first time in the city's history. On Day Zero (see Background), the majority of the water distribution system for the city would be shut off, and water would be distributed through communal standpipes to residents and limited to 25 litres (6.6 gallons) per person per day,[66] in line with the WHO minimum short-term emergency survival recommendations.[67] Sixty per cent of the population were regularly using more than 87 litres (23 gallons) at the time of the announcement.[68] The issue has been legally and politically contentious – the Constitution of South Africa guarantees the entire population the right to access 'sufficient water', so the Government of South Africa is obliged to ensure that water supplies are adequate.[69]

Impact of drought on health security

Commonly observed health impacts of drought include malnutrition, vector and airborne or dust-related diseases, water-related diseases and mental health aspects.[70] Particularly at risk to drought are children,[71] old,[72] indigent[73] or chronically-ill people, and young or pregnant women.[74] In Cape Town, drought causes potential disruption to healthcare provision, such as for teenage girls vulnerable to HIV and unwanted pregnancies, and could endanger people and property due to increased risk of serious fire or chemical injury, traditionally requiring access to water to quell.[75]

The possibility of these impacts occurring in Cape Town were considered highly likely in the event of Day Zero, particularly in relation to the spread of disease. Water is critically important in basic infection control systems, both in clinical settings and in the community. There was a concern that lack of available water would compromise antimicrobial management in these settings. Under Day Zero conditions, the allocated 25 litres (6.6 gallons) per person per day would likely be insufficient to keep a household hygienic, particularly so given the risk of cross-contamination caused by the widespread practice of using greywater, and misinformation around food hygiene practices, such as encouragement to forego washing fruit and vegetables, which spread through popular media.[76]

While formal healthcare systems in Cape Town reportedly had plans in place for dealing with water being cut off, including the installation of boreholes and alternative water supplies, they were not shared with the public.[77] In addition to this, the CoCT identified key sites in Cape Town as being of strategic importance that would continue to receive water directly during Day Zero water cut offs, and further initiatives were put into action to install boreholes and alternative water supplies at hospitals to enable them to operate independent of a municipal water supply.

Knock-on impacts of the drought on health will likely be felt in the years to come. Drought impacts on agriculture could have also had knock-on effects to health due to reduced yields of crops and livestock, leading to reduced quantity and/or quality of nutrients, making individuals more vulnerable to disease.

Food security

Overview

Food systems are essential to maintaining health and wellbeing of a population. After decades of decline, global hunger is on the rise.[78] 821 million people are currently malnourished worldwide.[79] Nearly 700

million people currently live with severe food insecurity.[80] To date, more than 820 million people still lack sufficient food worldwide.[81] With the population growing exponentially, expected to reach around 10 billion in 2050, providing food security will continue to be a great challenge to both maintain the levels of health and wellbeing in healthy populations, while bringing those lacking sufficient food out of food poverty. Maintaining and developing sustainable food systems remains an emergent challenge. The world is currently not on track to reach SDG 2, i.e., eradicating hunger by 2030. The Global Hunger Index (GHI), a measure of the level of hunger in a country, placed 52 of 110 countries in either 'serious', 'alarming' or 'extremely alarming' categories.[82] South Africa currently has a GHI rating of 'moderate', ranking 60th out of 119 qualifying countries.[83]

Of those who lack sufficient food, 204 million live in sub-Saharan Africa.[84] Poverty, unemployment, food and fuel prices, high-energy tariffs and increasing interest rates have all put pressure on the average household's ability to stay food secure. The definition of food security includes having food which is available, nutritious and safe and a secure way to procure and acquire food of good quality in a socially acceptable way.[85] A large proportion of the population in South Africa still perceive themselves as lacking a stable income to supply their basic household needs.[86]

As with water, the Constitution of South Africa guarantees the entire population the right to access 'sufficient food'.[87] This legal obligation provides an extra impetus that the authorities are seen to be helping the population maintain a secure level of food access. The recent debate about expropriation of municipal land in South Africa without compensation has led to an increased awareness of whether the country will continue to maintain its current farming activity.[88] The South African government developed the National Food Security and Nutrition Plan, coordinated by the Presidency. The country's National Development Plan (NDP) has formally established agricultural productivity and rural development as essential to improve food security in South Africa.[89]

Impact of food insecurity on health security

As of 2015, 25 per cent of South Africa's population lived below the food poverty line, defined as 'the level of consumption below which individuals are unable to purchase sufficient food to provide them with an adequate diet'.[90] Overall percentage of the population which is involved in agricultural activity as a livelihood is decreasing, down from 2.9 million households in 2011 to 2.3 million households in 2016.[91] A report by Statistics South Africa showed that while the number of people in South

Africa vulnerable to hunger has gone down in the past 15 years, it remains at 6.8 million as of 2017.[92]

Association with agricultural activity is also correlated with poverty; the provinces of South Africa with the highest levels of agricultural activity are also those with the highest levels of poverty. This includes Limpopo, Eastern Cape and KwaZulu-Natal, which are also provinces with former homelands and the least developed agricultural farming industries. Those directly involved with agricultural activities, such as farming, also rely on their activities for the food they eat, mainly due to commercial farming historically being discouraged in these areas. This indicates that those with the most vulnerability to economic fluctuations of food markets (i.e., the poor and indigent) are doubly at risk as they would also have the most to lose from poor yields from their direct farming activities. 7.5 per cent of households involved in agricultural activities use it as their main source of food. This is from a range of 18.1 per cent in Gauteng to 1.8 per cent in Limpopo.

Food security is not solely linked to the economy. External factors such as variations in the climate and water scarcity play a large direct role in the availability of food. Exports and imports influence availability of food in South Africa. Infectious diseases for plants and animals pose a risk to the food available.

Climate impacts rarely work in isolation – drought is a natural manifestation of climate variability and as such must be expected to return periodically. Droughts are made worse by high temperatures and associated evapotranspiration of water. Therefore, impacts of droughts will be compounded by climate change. During summer months drought impacts can be exacerbated by the simultaneous occurrence of heat waves that often, though certainly not always, accompany them. For example, during the 1991/92 summer drought in southern Africa an estimated three million tons of grain production were lost.[93] The extreme high temperatures associated with the drought not only devastated agricultural production but also resulted in widespread livestock mortality.[94] The region's water supply was also put under stress. The interaction of drought and heat compounded the effects of the individual impacts making 1991/1992 a disastrous year for rural populations dependent on rain-fed agriculture.

A concluding note on Cape Town

This chapter dealt with climate, drought, food and health, a wide canvas. The introduction to the narrative was Cape Town's narrowly averted water shortage disaster (Day Zero), which deserves a final comment. In South Africa, the national government has the constitutional role to provide bulk water supplies. The responsibility of cities is to provide treated clean water to residents and businesses. The drought crisis was ultimately related to an inadequate supply of bulk water. Mike Muller wrote in *Nature* magazine that serial under-investment in infrastructure to scale up supply was the real cause of the problem.[95] Practically speaking, there was no appetite for aggressively building new dams and/or desalination plants. What saved the day was emergency and perhaps necessarily high-handed methods of curbing consumption in what turned out to be a remarkable demonstration of citizen solidarity.

Disaster response was delayed because of legislative barriers to funding flows. The Municipal Finance Management Act is frustratingly inflexible and does not allow for crisis-related adjustments. It took upwards of six weeks for the national minister of finance to give special permission for emergency funds to flow. This highlights the need for greater budget flexibility in the law to allow for a proportionate response to catastrophic events which are likely to be more frequent in the future, and be more varied than just dealing with drought. Meteorological changes are expected over the coming decades and for Cape Town, most climate models predict a decline in rainfall by 2050.

Recommendations

1. WHO/JEE assessment should include the capacities of national meteorological agencies to monitor and predict weather and climate disasters.
2. Increase monitoring capabilities for climate sensitive health outcomes.
3. More high-quality research into climate change risks and adaptation opportunities for health security.
4. Multi-sectoral partnerships linking climate change, drought and food health.
5. Adaptation of infrastructure including public buildings such as schools, hospitals and indigent households to withstand extreme climate conditions.

5
The CBRN threat environment in South Africa

Jaco-Louis du Plessis, Greg Mills and Wilmot James

The 2007 raid on Pelindaba, the main research facility of the Nuclear Energy Corporation of South Africa, re-affirmed a previous United States assessment that South Africa's stock of HEU, all of which is stored at the facility, is highly vulnerable to theft. The Pelindaba campus, located a mere 40-minute drive from the capital, Pretoria, was simultaneously infiltrated by two groups of trespassers who bypassed perimeter security and subsequently gained access to the Emergency Control Centre. Of greatest concern is that the raiders' advance was not halted by an effectively integrated security protocol, but rather by a chance encounter with an off-duty firefighter who had visited his fiancée, a fellow employee who was on duty that evening. Responding to his dog barking at the intruders, he was shot once before both groups of attackers decided to flee.

An unreleased private investigative report commissioned by the South African government purportedly found that the intruders had advanced technical training and inside information which enabled them to breach what is arguably South Africa's most sensitive national key point, housing around a quarter-tonne of weapons-grade uranium 235, albeit in a secure vault elsewhere within the facility. Despite their own commissioned report finding that the infiltrators' aim was the theft of HEU, the South African government repeatedly claimed that the raid was no more than an unsophisticated break-in attempt to steal portable computer equipment.[1,2] In response, Matthew Bunn, a former White House nuclear security advisor, commented that '[n]obody breaks through a 10 000-volt security fence to steal someone's cellphone. The obvious question is, what else at the site justifies having two well-trained, knowledgeable teams at the site at the same time. The assumption [that needs] to be disproved is that they were [likely] after the highly-enriched uranium.'[3] After sustained pressure on the South African government, security at the site was later improved with United States backing.

The consequences of the theft of HEU does not need to be highlighted, with the integrity of safeguarding systems remaining of critical importance.

South Africa's significant stock of HEU is a remnant of its nuclear weapons programme, which was voluntarily decommissioned in 1991 by order of then-President F.W. de Klerk prior to the democratic handover of power in 1994. The decision to dismantle the programme also enabled South Africa's accession as a state party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) in 1991; it would otherwise have been unlawful under the terms of the NPT for South Africa to join had it still possessed its nuclear arms, and the International Atomic Energy Agency's subsequent inspections did determine that South Africa had indeed successfully disarmed.[4] Similarly, the country's chemical and biological weapons programmes were also dismantled, although without any corresponding international inspection of agent stockpiles to confirm destruction.

Regulatory and policy framework

At present, South Africa is a state party to every significant international treaty or regime that aims to control the proliferation of chemical, biological, radiological and nuclear (CBRN) technology, and is widely viewed as being a member of good standing within the field of non-proliferation. This is perhaps partly due to South Africa being the only country (with the incomparable exception of three former Soviet states: Belarus, Kazakhstan and Ukraine) to voluntarily and completely dismantle all its functional nuclear armaments. Yet, as the Pelindaba incident demonstrates, aligning national policy with international conventions does not automatically equate to effective implementation at lower levels, where the mandated organisations may not necessarily have the capacity to effectively fulfil their risk-related responsibilities. It is here, at least in South Africa's case, where there appears to be credible hazard to public health. The Pelindaba breach remains the most serious of the acknowledged, deliberate attempts to compromise South Africa's public health safeguards, though the government's subsequently dismissive diplomatic response does not allay reasonable fears of equally serious threats, whether with deliberate intent or not, to other national public health domains.

The primary legislative regimes covering the non-proliferation of weapons of mass destruction (WMD) include the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the Chemical Weapons Convention (CWC) and the Biological and Toxin Weapons Convention (BTWC). A further significant agreement adopted in 2004, the United Nations Security Council Resolution (UNSCR) 1540, seeks to prevent non-state actors from gaining access to WMDs, with the provisions of the Resolution obligating South Africa to secure the HEU at Pelindaba. Salisbury *et al.* ascribes the

motivation for its implementation to consist of two parts: the surge in global terrorism in the early 2000s, and the rise of underground public-private proliferation rings, the most well-known example being the AQ Khan network. Where state actors are entirely disregarded, the authors argue that there are two primary categories of acquisition. In the first, non-state actors actively seek to develop or acquire WMD as a goal unto itself, as Al Qaeda is known to have attempted in the 1990s. In the second, non-state actors in conflict zones may come across unsecured CBRN stocks or munitions and subsequently employ it within the conflict, as reported in recent years in Syria.[5] Yet, as far as the involvement of non-state actors are concerned, the most credible threat of proliferation remains a state actor using foreign non-state actors to help develop or resource its weapons programmes, either through knowledge transfers, illicit technical procurement, or assisting financial flows.

To counter this, Resolution 1540 *inter alia* compels all members of the following:[6]

- To refrain from providing any form of support to non-state actors that attempt to develop, acquire, manufacture, possess, transport, transfer or use nuclear, chemical or biological weapons and their means of delivery;
- To adopt, in accordance with national procedures, effective laws which prohibit any non-state actor to manufacture, acquire, possess, develop, transport, transfer or use nuclear, chemical or biological weapons and their means of delivery, in particular for terrorist purposes, as well as attempts to engage in any of the foregoing activities, participate in them as an accomplice, assist or finance them.

To take and enforce effective measures to establish domestic controls to prevent the proliferation of nuclear, chemical, or biological weapons and their means of delivery, including by establishing appropriate controls over related materials and to this end shall:

- Develop and maintain appropriate effective measures to account for and secure such items in production, use, storage or transport;
- Develop and maintain appropriate effective physical protection measures;
- Develop and maintain appropriate effective border controls and law enforcement efforts to detect, deter, prevent and combat, including through international cooperation when necessary, the illicit trafficking and brokering in such items in accordance with their national legal authorities and legislation and consistent with international law;
- Establish, develop, review and maintain appropriate effective national export and trans-shipment controls over such items, including appropriate laws and regulations to control export, transit, trans-

shipment and re-export and controls on providing funds and services related to such export and trans-shipment such as financing, and transporting that would contribute to proliferation, as well as establishing end-user controls; and

- Establishing and enforcing appropriate criminal or civil penalties for violations of such export control laws and regulations.

Despite the provisions above appearing reasonable, South Africa's attitude to the implementation of UNSCR 1540 has nevertheless been inconsistent, with the Nuclear Threat Initiative noting the country's change in approach over a multi-year period:[7] In 2004, South Africa's representative to the United Nations complained that the Resolution 'imposes obligations on UN Member States and attempts to legislate on behalf of States by prescribing the nature and type of measures that will have to be implemented by States'.[8] This position was reinforced in 2007, when South Africa announced that it 'will not accept externally imposed norms or standards, whatever their source, on matters within the jurisdiction of the South African Parliament'.[9] In a remarkable turnabout, it was therefore surprising in 2011 when South Africa, as a newly elected non-permanent Security Council member, not only served as the chairman of the 1540 Committee, but also voted to increase the scope of its mandate. While it should be observed that South Africa, due to its history and technological dominance, occupies a much higher counter-proliferation priority than other countries in sub-Saharan Africa, its leading position in the Non-Aligned Movement and in Africa makes it influential in shaping the views of its peers. South Africa's buy-in is thus significant not only insofar the physical threat of proliferation, but also that it has built consensus amongst its peers for supporting the implementation of UNSCR 1540. The inverse approach that aims to pressure (often reluctant) regional and sub-regional organisations to place counter-proliferation on the agenda has been widely criticised due to their more pressing concerns regarding ongoing conventional conflicts, for instance in the greater Sudan region. Instead, as with South Africa, exploiting the influence of regional powers on matters of non-proliferation may be the most effective vehicle for encouraging implementation.[10] In 2012, the first Africa-wide UNSCR 1540 workshop was held in Pretoria, jointly hosted by the South African Government and the African Union, with support from the Institute of Security Studies (ISS).[11] Broodryk and Stott state that just over a year later, another workshop was held, this time in Addis Ababa with 35 African Union member states in attendance. The scale of participation could indicate that far from there being a lack of will to implement Resolution 1540, it may well be a lack of capacity that has held back timely reporting by African states.

The threat environment

After the Pelindaba incident, recent concerns about the integrity of South Africa's public health safeguards have understandably focused most on the vulnerability of the country's HEU stock. Notwithstanding speculation about the consequences that would follow in the event of theft, the likelihood of the HEU vaults at Pelindaba being breached remains small. For malign non-state actors, other public health weaknesses could be exploited at much lower risk. Though threats are a function of both capability and intent, the nature of any intended malice also remains relevant to the formation of proportional safeguards within each public health domain.

Nuclear and radiological

At least in the public mind, no threat to public health demands as much attention as the risks posed by the nuclear and radiological domain. Within the South African context, the risk of deliberate terrorist targeting of a nuclear facility is assessed as low; an attack could take the form of a bombing, although the subsequent release of radioactive material would be concentrated to a small area. Nuclear facilities are also by their very nature designed and equipped to reduce the risk of widespread contamination. In South Africa's case, there is indeed a historical example of an attack against a nuclear facility: in December 1982 Rodney Wilkinson, an employee at the Koeberg Nuclear Power Station and a member of the then-banned *uMkhonto we Sizwe*, planted four bombs during the construction phase of the plant. As the plant was not yet operational, the risk of contamination was non-existent, and the attack was solely focused on causing large-scale financial and reputational damage. The party associated with the attack, the African National Congress, has now governed South Africa since 1994, and has maintained that the attack was for political propaganda purposes and not aimed at releasing radioactive material. Other attacks targeting nuclear power plants during the 1970s and 1980s were also largely intended to be propaganda actions. An Argentinian plant, Atucha-1, was raided by guerrillas who soon after vacated the site with no lasting damage to infrastructure. Two other plants were also attacked during the period: Lemoniz in Spain was repeatedly bombed by Basque separatists between 1978 and 1979, and the Superphenix reactor suffered a grenade attack in 1982.[12] In the post-9/11 paradigm of violent religious extremism where many terror groups seek to inflict the maximum loss of life as their political statement, the same reluctance to release radioactive contaminants cannot be assumed. The disagreement between the United States and South Africa over the safekeeping of the HEU at Pelindaba is

thus perhaps rooted in the former's recent experiences, and the latter's historical ideology.

As one of only four producers of medical nuclear radioisotopes in the world, the Nuclear Energy Corporation of South Africa's NTP facility, also located within the Pelindaba campus, had been one of the handful of South African State-Owned Enterprises (SOEs) that had been generating a healthy profit. Yet a series of critical safety issues in November 2017, reported to have been easily avoidable procedural errors, saw the plant being shut down for nearly a year over safety concerns, with an associated loss of market share and much-needed revenue.[13] Although not highly-enriched, the radioisotopes produced by NTP could still cause significant contamination if safety procedures are not observed, and the shutdown at least demonstrated that adequate safety cross checks exist at the plant. The greatest threat associated with low-enriched radioisotope is its use in *dirty* bombs, where the mere mention of radioactivity can create out-sized public panic in the aftermath of a terrorist bombing. In the case of NTP, with its sizeable export market, its radioisotopes would be most vulnerable to theft when in transit outside the secure confines of the Pelindaba campus. As a unique product with limited use outside of specialised medicine, even the theft of a small amount would raise public concern over possible terrorist use. There is also ongoing global concern over the safe disposal of two medical radioisotopes, Cesium-137 and Cobalt-60. As these radioisotopes are often used in nuclear medicine in low- and middle-income countries, there is a higher probability of unintended exposure resulting from a lack of local disposal capacity. In 2000, a scrapyard worker in Thailand accidentally cut open a source of Cobalt-60, which quickly led to widespread radiation poisoning and the death of at least three people within two months.[14] Due to the prohibitive cost of replacing old machines with the latest medical equipment, the only viable safeguard is to improve disposal processes in low-capacity jurisdictions with the assistance of outside partnership programmes.

Chemical

South Africa's apartheid-era chemical and biological weapons programme, *Project Coast*, was established in 1981 and operated covertly until it was officially dismantled in 1993, immediately prior to the country's first inclusive democratic election. Under the leadership of Dr Wouter Basson, a cardiologist who had been a personal physician to President P.W. Botha before later being recruited into the South African Military's Medical Service (SAMS), the programme expanded to 165 employees by 1987, with no credible civilian oversight of its operations.[15] Although it

was later admitted that small amounts of nerve agents were produced by the programme's front company, Delta G Scientific, former staff members have maintained that the primary aim of the programme was the development of non-lethal and non-persistent agents for the purpose of crowd control within South Africa's borders.[16] While it was admitted that lethal agents were used prolifically in the targeted killing of individuals opposed to the state, there has been no evidence that the programme ever managed industrial-scale manufacture of nerve agents. In addition, as necessary delivery systems such as munitions were not created, the possible proliferation of any surviving stocks have not been considered a serious public health threat in South Africa. Dr Hennie Jordaan, a former senior researcher for the chemical warfare project, testified that the weaponisation of agents was often informally discussed, but never practically attempted at scale.[17] The judgment in *The State vs Wouter Basson* also found that prototype munitions had been developed, though not put into production.

The weaponisation of toxic chemicals is technically difficult, though by no means impossible for non-state actors. In 1995 the Tokyo subway system suffered a terrorist attack that killed 13 Japanese commuters and injured hundreds more. The group responsible, a religious cult called *Aum Shinrikyo*, had managed a highly technical feat by developing sarin nerve agent, but their method of delivery was nevertheless unsophisticated, which drastically reduced the number of deaths: five attackers carried plastic bags filled with sarin liquid onto different train carriages. At a pre-determined time, the bags were punctured and the liquid slowly vaporised, leaving enough time for the attackers to flee. Despite one of the trains continuing its journey for another hour and 40 minutes, the number of fatalities were limited due to the slow vaporisation of the liquid.[18] Apart from the challenges with delivery, nerve agents are by nature difficult to synthesise, require chemical precursors that are most often controlled substances, and are unstable with long periods of storage. Within the South African setting, it is highly unlikely that non-state actors would attempt the manufacture of such agents.

There are still credible concerns over industrial chemicals, some highly toxic, that could contaminate food or water supplies. In June 2019 the South African police raided a house in Pretoria and confiscated arms and ammunition, explosives and a large quantity of arsenic and cyanide.[19] Initial speculation revealed that those arrested may have been part of an illegal gold mining syndicate, as cyanide is often used to extract gold from mined ore. The risk of ground water contamination is significant with illegal mining, where criminals do not observe any of the statutory environmental

safeguards, and even a small amount of cyanide in a public waterway or reserve would create a public health emergency. In South Africa, cyanide and arsenic have also been used for illegal wildlife poaching, most often for gathering ivory. The poisoning of natural water sources frequented by elephant or rhino leads to long-term environmental contamination and ultimately the disuse of already scarce water supplies. The fact that one of the arrested individuals was charged with the illegal possession of ivory may well indicate a link to poaching.

Biological

Most of South Africa's now defunct biological weapons capability, formerly also under the aegis of *Project Coast*, was developed at Roodeplaat Research Laboratories. As with the chemical warfare programme, the biological component of *Project Coast* was never intended for large-scale offensive use in a conventional battle.[20] Despite there having been instances of individuals being targeted with biological agents, the project largely focused on the development of protective clothing and possible treatments in response to a foreign biological attack. Due to the large number of endemic diseases in the region, the country has historically invested in its advanced public health research laboratories. The deliberate threat, or even accidental risk, of pathogen release from one of South Africa's biosafety level 3 or 4 (BSL-3/4) laboratories is negligible considering the statutory risk assessments and regular inspections that the facilities are subjected to. From a functional perspective, as biological pathogens are relatively slow acting when compared to chemical agents, there is an increased response window available for treatment, containment or quarantine, which also lowers the significance of the threat. With the fastest acting of the dangerous pathogens, for example Ebola Virus Disease (EVD), the rapid onset of symptoms would likely cause immediate alarm and trigger quarantine during a known outbreak. Despite the heavily criticised lack of medical capacity in Liberia, Sierra Leone and Guinea during the 2014–2015 EVD outbreak, the regional response to contain the outbreak was, eventually and with outside assistance, surprisingly effective when the number of fatalities is measured against population density and living conditions.

As for emerging risks, including those associated with the rapid advances in biotechnology, the Global Health Security Index (October 2019) gives South Africa a very low 8 on a scale of 0–100 for biosecurity, 50 for biosafety and a 0 for dual-use research oversight and governance.[21] Biosecurity refers to the protection, control and accountability for biological agents and toxins in order to prevent loss, theft, misuse, diversion or unauthorised

access or intentional release. Biosafety refers to containment principles, technologies and practices that prevent unintentional exposure or accidental release. Dual use research is that conducted for legitimate purposes but where the knowledge, information, technologies and products can be used with malicious intent either as individual bio-crimes and/or as bioterrorism perpetrated by groups driven by ideological, political, religious or ecological purposes. South Africa scores in the middle-tier for biosafety, but falls in the lowest of the bottom tier for biosecurity and responsible dual-use research, exposing the country to the risk of exposure to or release of high-consequence pathogens or toxins.

The threat is not an abstract one. Numerous alarming biosecurity lapses have occurred over the past 15 years worldwide, including incidents associated with recent emerging infectious disease outbreaks, occupational exposures, transmission of disease, laboratory acquired illnesses, and lax security and safety procedures for highly infectious agents.[22] The followers of the guru Bhagwan Shree Rajneesh deliberately contaminated salad bars in the US state of Oregon with Salmonella bacteria in 1984 causing severe food poisoning in over 700 people. Members of the religious cult *Aum Shinrikyo* released deadly anthrax spores in Tokyo in 1993. A week after 9/11, letters containing anthrax spores were mailed to media offices and to US Senators, killing five people and infecting 17 others. In 2002 researchers reported reconstructing the poliovirus from scratch using chemically synthesised oligonucleotides. In 2005 the influenza virus responsible for the 1918 flu pandemic was successfully reconstructed. In 2012 two independent research groups conducted so-called gain-of-function research on H5N1, sparking an intense international debate.[23]

In 2004 the US National Research Council published *Biotechnology Research in an Age of Terrorism* and introduced the term 'dual use research of concern' (DURC), referring to beneficial life science research that could be used maliciously. The report identified seven experiments of concern, which were those that:

1. Demonstrate how to render a vaccine ineffective;
2. Confer resistance to therapeutically useful antibiotics or antiviral agents;
3. Enhance the virulence of a pathogen or render a non-pathogen virulent;
4. Increase transmissibility of a pathogen;
5. Alter the host range of a pathogen;
6. Enable the evasion of diagnostic/detection modalities; and/or
7. Enable the weaponisation of a biological agent or toxin.

Since then, microbiology and synthetic biology capabilities have become more powerful, less costly and more accessible, escalating the potential for catastrophic harm caused unintentionally or deliberately.[24] High-end experiments using genome editing technologies such as CRISPR/Cas9 is not as yet in use beyond a few scientists in Africa, but it is just a matter of time when biotechnology penetration levels will pose a risk by enabling:

1. Genome editing constructs targeted to human DNA sequences, combined with potentially transmissible vectors.
2. Reconstitution of highly pathogenic viruses or closely related species.
3. Microbes or constructs that can target specific human sub-populations.
4. Microbes or constructs engineered to disrupt or damage the human microbiome.
5. Use of synthetic biology 'design, build, test' cycle to select for pathogen phenotypes associated with increased transmissibility, virulence and ability to circumvent medical countermeasures or evade detection. The relevant technologies include advanced tools for generating large-scale libraries of bacterial and viral variants with advanced screening tools for phenotype selection.

South Africa (and Kenya) are poised to become leaders in the field in Africa and therefore need to anticipate dealing with the coming risks by developing proactive strategies, protocols and policies to mitigate risk, and to co-regulate, from the bottom-up and top-down, in this emerging area. Already the Academy of Science in South Africa (ASSAF) and the Medical Research Council are convening meetings on the subject. The Washington DC-based Nuclear Threat Initiative in partnership with the Africa Centre for Disease Control and Prevention is catalysing biosecurity – including dual-use – and biosafety gap analysis, policy development and education and training programs for all the African Union Member States. South Africa has the resources, skills-base and infrastructure to take its biosecurity systems to a higher level, by upscaling preparedness at its collection of laboratories and should consider establishing a Center of Excellence at one or more of its universities using a *One Health* biosecurity approach in its human, animal and plant sectors. In doing so South Africa would enhance its compliance with the Geneva Protocol that prohibits the use of chemical and biological weapons in international armed conflicts and the 1972 Biological and Toxin Weapons Convention that bans the development, production and possession of biological weapons.

Where a non-state actor's goal may be economic sabotage, the threat of agri-terrorism becomes more relevant. The RAND Corporation identified several key vulnerabilities in the agricultural sector:[25]

1. Concentrated, intensive and crowded farming reduces the ability to contain an outbreak and may lead to the rapid spread of pathogens;
2. Livestock may be more susceptible to disease as a result of modern husbandry practices, for example the misuse of antibiotics;
3. Farms are difficult to secure against unauthorised infiltration;
4. The responsibility for reporting livestock or crop diseases lies with the producer, who may be disincentivised from doing so;
5. Local veterinarians and epidemiologists may not be familiar with foreign-introduced pathogens; and
6. Commercially-sized livestock herds preclude older practices of attending to individual animals, causing diseases to spread within a herd.

Outside of the agricultural production chain, the wider economic effects from contaminated food supplies can be devastating. On 5 March 2018, a major South African retailer, Tiger Brands, lost nearly 7pc of its total market value in a single morning when it was announced that one of their food products had been responsible for a deadly listeriosis outbreak that had by then killed over 180 consumers.[26] The loss of capitalisation was likely in anticipation of both a loss in sales revenue, as well as damages that could be awarded to the families of the victims. Where there has been wilful tampering with food products, the resulting lack of consumer confidence may be even more damaging to a business, and retailers have reacted strongly in the past to discourage any malicious attempts at doing so. Pick n Pay, one of South Africa's largest supermarket chains, fell victim to a food tampering extortion campaign in 2003. It was later proven that despite the perpetrators' threats, no tampering had taken place. The company nevertheless offered a disproportionally large reward for information that could lead to arrests.[27]

Even after the listeriosis outbreak, there is currently no national food safety authority to regulate imports and exports or control local food. A single national body would be able to better control an outbreak by shortening response times and by coordinating the responses of various role players. Currently, the diverse food certification bodies are self-regulating; a single national authority could reassess much of the outdated food safety protocols and oversee the implementation of new rules in a coordinated and more cost-effective manner.[28]

A growing non-traditional threat is the increase in vaccination hesitancy, with the associated pseudoscience being easily spread through online forums. The WHO has classified vaccine hesitancy as one its top ten threats to global health in 2019. Of concern is that diseases that were

nearly eliminated in certain geographies have seen a resurgence. Globally reported cases of measles, for example, have increased by 30 per cent in the last year, though not all this increase can be attributed to vaccine hesitancy.[29] The reasons for not vaccinating are complex; from a belief that vaccines can cause autism, to religious objections and even viewing vaccination campaigns as subversion against traditional societies. Several vaccination teams have been killed in attacks in Afghanistan, Pakistan and Nigeria, where cases of polio have spiked sharply as a result. In April 2019, Pakistan suspended its polio vaccination drive after an attack killed yet another health worker. The Pakistani government has since reported that around 700 000 children have missed their scheduled immunisations as a result.[30] In 2017, reported measles cases in South Africa increased twelvefold compared to the previous year, with the three major outbreaks largely affecting unvaccinated communities.[31] Though still low in real numbers, the year-on-year increase is of concern, especially in lower income communities where there may be more instances of compromised immunity due to poor nutrition or lack of sanitation, which in turn increases the risk of mortality. To date, vaccination efforts still rely on traditional methods to increase public awareness, with much of the burden resting with first-line healthcare workers. There has so far been little in the way of a coordinated campaign by the South African National Department of Health to counter the prolific anti-vaccination pseudo-science that is distributed online.

Cyber

Within South Africa, patient records remain the property of the medical establishment where they were created, with patients having a right to view these records under the Promotion of Access to Information Act, 2000. With the gradual changeover to electronic health records, the threat of confidential information being compromised is increasing. The 2017 Experian Data Breach Industry Forecast report estimates that there were 181 globally reported cases of medical data breaches in 2016. In one incident, there was an unauthorised release of 3,6 million patient records.[32] A later report by IBM in 2018 has found that the per capita cost of cross-sector data breaches in South Africa was a staggering R36.5 million, with the country having the highest risk globally of human error-related breaches.[33] As most data breaches are not due to hacking and often result from careless staff actions, the cyber security focus for healthcare organisations in South Africa should be both adequate training and sound data handling procedures. In a recently reported case in Singapore in 2019, the former partner of a Singaporean doctor maliciously released confidential information revealing the details of 14 200 HIV sufferers in the

country. The individual, who has since been imprisoned after he pleaded guilty to data breach charges in the United States, would not have had access to the information had his former partner not been careless with medical data procedures in his medical practice. A similar breach in South Africa would likely make the National Department of Health or private sector medical organisations liable for damages, along with causing tremendous harm to public trust.

A further significant threat is the use of malware. The 2017 WannaCry attack encrypted data on hundreds of thousands of computers globally, with the attackers demanding anonymous cryptocurrency payments as ransom.[34] Within the public health environment this threat can also be extended to medical devices that are connected to the Internet of Things (IoT). If critical infrastructure is targeted, for example national energy or health systems, it is unlikely that South Africa would be able to generate an effective response in time to prevent widespread damage. Again, the resulting loss of confidence in government would only further worsen the fallout.

A way forward

The South African threat environment is more defined by criminality and lack of local capacity than by terrorism. While threats to South Africa's health environment exist, it is not beyond resolving. The country has in fact taken steps to address some of the challenges it faces, such as the drive in recent years to improve the human capital in public health.[35] The CBRN domain has historically received much attention due to its links to the apartheid regime and the often-sensational information that was revealed during the Truth and Reconciliation Commission's enquiries of the 1990s. In reality, the country is well regarded in the world of non-proliferation, particularly in the state-to-state sense, with deliberate attempts to compromise CBRN safeguards being minimal; only the Pelindaba breach has been reported on with any significance, and subsequent American assistance and advice has restored relative confidence in the security of the facility.

Criminality can be partly managed by improving staff procedure, where the resulting improvement in work culture has the added benefit of reducing normal operational risks. Nearly all operational risks can be avoided if there is an adherence to schedules and procedures, so the burden of enforcement will remain with individual managers. Private sector organisations have consistently been more responsive in handling crises that threaten revenues, and in many cases, controversially, have

established parallel policing and investigative structures. Although the antithesis of public health, tobacco manufacturing operations in South Africa are regularly reported on as using the services of private investigative firms to safeguard their lines of procurement and sales.

The decisive task for both the private and public sector will be to improve the overall low level of skill pervasive amongst the wider South African workforce. As this is ultimately dependent on government-to-government cooperation and the ability to keep up with international best practice, the South African government should prioritise its diplomatic relations with the partner countries, for example the United States, that have expressed a consistent willingness to assist with building local capacity. The WHO's Joint External Evaluation of International Health Regulations Core Capacities (2017) reports that South Africa's prevention and response methodologies are of a high standard, and that the country possesses adequate local expertise.[36] Despite this assessment, the concern is primarily with the second tier of workers, often acting in supporting roles. It is here where the risk of compromised processes is highest.

The Public Health Emergency Operations Centre (PHEOC) and the National Joint Operational and Intelligence Structure (NAJOINTS) already form the government's hubs for coordinating the responses to public health and security incidents. Greater formal public and private sector coordination can also assist in both preventing and responding to public health crises. The regular convening of a national public health crisis group with cross-sector expertise (including private sector input) could facilitate dialogue between government bodies that are lacking know-how and capacity, and a private sector that would like to see progressive policies. Until mutual suspicion is reduced, South Africa will remain at risk of delivering lukewarm solutions to public health threats.

Improving, standardising and securing medical communication platforms will assist in capturing and sharing the experiences of both practitioners and organisations. The recent introduction of National Health Insurance (NHI) draft legislation will undoubtedly raise the question of standardising patient records into a single platform, with any implementation happening against the backdrop of the latent cyber security threat, which will also have to be addressed.

The patchwork of public health threats facing South Africa require a long-term response that is as integrated as the range of threats it seeks to counter. Malign non-state actors, who are ultimately asymmetric opponents, are creative and non-traditional in their actions. Across the public health environment, agile threat responses can only be formed

where there is a level of skill that is as deep as it is wide. South Africa would do well to make this a priority.

6
Investing in health security preparedness

Jonatan Davén, Wilmot James and Michael Kahn

Introduction

In *Governing Global Health*, Chelsea Clinton and Devi Sridhar document changes in the governance and resourcing of global health since the days post World War II when the WHO and the United Nations Children's Fund (UNICEF) were the only bodies with the delegated authority to tackle health across national boundaries.[1] In the 21st century the World Bank, the Bill and Melinda Gates Foundation, the Global Fund to Fight AIDS, Tuberculosis and Malaria, the Global Alliance for Vaccines and Immunization (GAVI) and voluntary associations such as the Red Cross and Médecins Sans Frontiers, have diversified the nature and scale of interests in global health, resourcing and reach beyond the public sector focus of 20th century institutional design, to include philanthropies, public-private partners and NGOs alongside the WHO and UNICEF.

So too for emergency preparedness and response. The WHO was the world's sole custodian of the international health regulations, until the infectious disease outbreaks of the 1980s, 1990s, and particularly the 2000s stretched the organisation beyond its capacity. Only 20 per cent of Member States were by 2012 in compliance with the updated and revised International Health Regulations of 2005 which prompted the establishment of the Global Health Security Agenda. While driven by governments, the GHSA also has a private sector council, a non-governmental network and a next-generation pipeline of young leaders. A Coalition for Epidemic Preparedness Innovations (CEPI), a public-private partnership set up to accelerate vaccine development because of market failure in this area, came into being. The World Bank housed a new facility for epidemic preparedness and finance. A Global Preparedness Monitoring Board was established in 2018.

In this chapter we review global health security finance in South Africa seen against these dynamic global trends. In the first part we examine current trends in public sector finance. In the second part we review public and private sector spending on research and development that

could be harnessed for purposes of improved disaster preparedness and response. The third part makes the business case for greater private sector involvement, up until now largely restricted to short-term insurance and reinsurance companies involved in managing logistics risks. We will argue that South Africa's post JEE National Action Plan currently under preparation must be supported by public-private partnerships in disaster preparedness and response, leveraging the resources of its considerable financial services' and insurance sectors. We also recommend that a comprehensive health security spending review is conducted that go beyond infectious disease, biological, radiological and chemical risks – which is what the WHO/JEE assessment covers – to also include nuclear, environmental, climate-related and national security risks. The current practice, of year-on-year incremental spending in the same categories, is unlikely to meet the challenges posed by the current unfolding threat environment.

Public sector finance

In addition to the human suffering caused by pandemics and other health emergencies, the economic damages can also be massive. Disease outbreaks tend to disrupt economic activities through travel restrictions, workplace absence, supply chain interruptions and so on, and also deter foreign investments and tourism both in the short and longer term.[2] It has been estimated that a pandemic influenza could result in economic losses of about US$570 billion per year (0.7 per cent of global income), mainly due to life years lost, in the coming decades[3]. The 2014 Ebola outbreak in West Africa has been estimated to cost the three most affected countries US$53 billion[4], setting back economic and human development considerably. At the same time, it has been estimated that investments between US$0.50 and US$1.50 per capita may be sufficient to fund an adequate level of epidemic preparedness and there is thus a strong economic case for investing in preparedness. Financing health security has increasingly gained attention in the global agenda with at least two Global Health Security Agenda (GHSA) ministerial meetings organised by WHO in Bali and Seoul giving particular attention to financing.[5] These have highlighted the need to both secure sustainable domestic resources for national preparedness and to establish or further develop efficient global financing mechanisms. Key recommendations from the Seoul meeting include the need to align health security plans with annual budget cycles, involving multiple stakeholders, including ministries of finance early on in planning processes, moving from reactive to proactive financing approaches and better mapping of available resources to support national action plans for health security.[6] The WHO is also developing guidelines

for planning, costing and financing for health security, and has developed an Excel-based costing tool to assist countries in costing their national action plans.[7] While calls have been made for increased financing of health security specifically, some also argue that there is a need to bridge the conventional divide between global health security and general public health systems and adopt a more integrated approach where health security is viewed through the lens of universal health coverage, and relies on resilient health systems and high-quality primary healthcare.[8,9]

In 2015, the WHO agreed to develop processes and tools to conduct Joint External Evaluations (JEE) to assess implementation of the International Health Regulations (2005) and according to the WHO, JEE dashboard 102 countries worldwide have now completed a national JEE. South Africa is one of those countries and achieved an average score of 3 out of 5. A National Action Plan to address the shortcomings identified in the JEE process is being developed but is yet to be costed and considered for funding. An in-depth review of South Africa's and Lesotho's JEE mission reports can be found in Appendix 1 of this publication. Although the JEEs have assisted countries to better understand their strengths and gaps in health security and pandemic preparedness, it has been argued that they do not fully address financing aspects.[10]

Government investments in health security

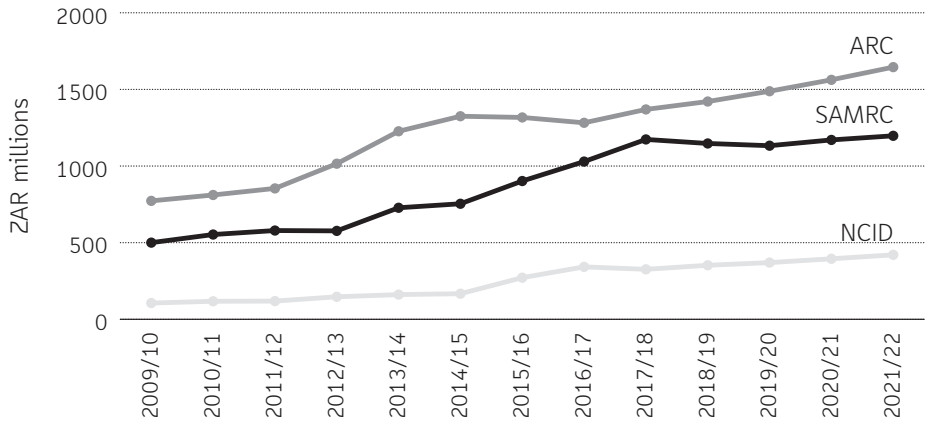
Due to the multisectoral nature of health security, government investments in this area are spread across a range of institutions and each of these institutions have a broader mandate than just health security. It is therefore difficult to estimate how much is spent and budgeted specifically for health security and together with the absence of a costed action plan, this makes it difficult to estimate whether there is a funding gap for health security in the country and what its size may be. However, reviewing the overall budget trends of these institutions can provide an indication of the availability of resources for this area.

Research councils and institutes

Figure 6.1 shows past expenditure trends (2009/10–2018/19) and projected budgets (2019/20–2021/22) for three key institutions involved in health and health security research. Average annual spending growth between 2009/10 and 2021/22 is 12.2 per cent for the National Institute for Communicable Diseases (NICD), 7.5 per cent for the South African Medical Research Council (SAMRC) and 6.5 per cent for the Agricultural Research Council (ARC). The increase was particularly prominent in the few years following 2012/13, partly as a result of government's Economic

Competitiveness and Support Package, which was introduced in that year and from which both ARC and SAMRC benefited. Going forward, budget growth is anticipated to be more moderate, particularly for SAMRC and NICD.

Figure 6.1: Expenditure (past and projected) of key research institutions, 2009/10–2021/22 (nominal prices[11])[12]



Laboratory services

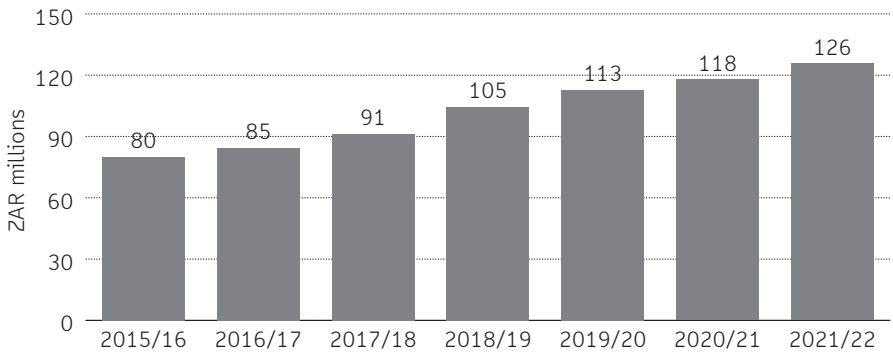
Health laboratory services in the South African public sector are carried out by the National Health Laboratory Services (NHLS). In addition to laboratory services, NHLS houses the specialised divisions, NICD and the National Institute for Occupational Health (NIOH), and also has its own research and training programmes. The JEE scored South Africa's national laboratory system relatively high with a 5 given to detection of priority diseases, a 4 to specimen referral and transport and 3 to point-of-care and laboratory-based diagnostics and to laboratory quality systems. NHLS has a budget of R9.3 billion in 2019/20, with most of its revenue (86 per cent) generated through laboratory test fees from health establishments, mainly from provincial departments of health.[13] The remaining revenue is largely derived from annual budget allocations appropriated by Parliament and transferred to NHLS by the NDOH and funds NICD, NIOH and the NHLS's research and training programmes. Going forward, the budget of NHLS as a whole is projected to grow by 7.8 per cent per year over the medium term, mainly driven by laboratory testing, with somewhat more moderate growth in other programmes.

Table 6.1: NHLS expenditure and budget by programme, 2015/16–2021/22

	Audited Outcome	Audited Outcome	Audited Outcome	Approved Budget	Medium-term estimate			Average growth rate
	2015/16 R million	2016/17 R million	2017/18 R million	2018/19 R million	2019/20 R million	2020/21 R million	2021/22 R million	2018/19 to 2021/22 %
Administration	1 203	667	691	920	985	1 045	1 107	6.3
National Institute of Communicable Diseases	272	342	326	353	370	395	421	6.1
National Institute of Occupational Health	90	93	114	125	131	140	150	6.2
Laboratory tests	4 938	8 106	5 474	6 624	7 312	7 798	8 416	8.3
Research and training	191	219	438	462	486	515	543	5.5
Total expense	6 693	9 428	7 043	8 484	9 284	9 893	10 636	7.8

Adherence of South African laboratories to international quality assurance standards is monitored by the South African National Accreditation System (SANAS), which is the national body mandated to carry out accreditations. It is mainly funded through accreditation fees but also receives a transfer from the Department of Trade and Industry and its budget is reflected in Figure 6.2. While the mechanisms to monitor the quality standards of NHLS's laboratories is commended in the JEE, it is noted that the actual compliance in laboratories vary considerably. While all NICD laboratories and the majority of laboratories at central and tertiary hospitals were SANAS accredited in 2017/18, only a small percentage of laboratories at district (3 per cent) and regional hospitals (27 per cent) were accredited[14] and the JEE mission report calls for increased investment in these laboratories to improve quality and adherence to national and international norms and standards.

Figure 6.2: SANAS expenditure and budget, 2015/16–2021/22



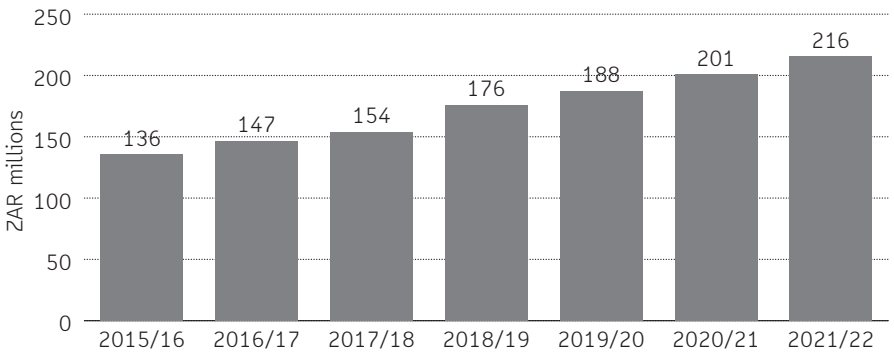
Port health services

Port health services entail 'controlling and monitoring trans-boundary movement of goods and people in order to prevent importation of communicable diseases and any events of international concern into the country'[15]. In 2015/16 the mandate to provide port health services was shifted from the provincial to the national sphere of government. This was done mainly to ensure that implementation is standardised across the country and because compliance with international commitments such as the International Health Regulations is regarded as an inherently national, rather than provincial, responsibility. The function shift entailed the transfer of budgets, human resources and assets from the provincial departments of health to the National Department of Health (NDOH). The NDOH is making efforts to strengthen port health services and the JEE mission report gave South Africa a fairly high score of 4 for both routine

capacity and effective public health response at points of entry and mentioned South Africa's processes for auditing points of entry against the IHR's core capacity standards as an example of best practice for other countries to learn from. In terms of the results of these audits, there is still scope for improvement as in 2017/18 only 10 out of 45 points of entry were found to be compliant, and the department aims to increase this number to 30 by 2021/22.[16]

The budget for port health services is clustered in the same sub-programme as environmental health so exact spending estimates are not publicly available. However, given that the NDOH's role in environmental health is one of policy and oversight rather than implementation, this budget is relatively small and the vast majority of the expenditure in the subprogramme is on port health services. Figure 6.3 shows that the budget increases from R135.7 million in 2015/16 when the function was shifted, to a projected R215.8 million in 2021/22, which represents an average annual increase of 8 per cent in nominal terms and a total increase of R25 million above inflation (2018/19 prices).

Figure 6.3: Expenditure and budget for Environmental and Port Health Services, 2015/16–2021/22[17]

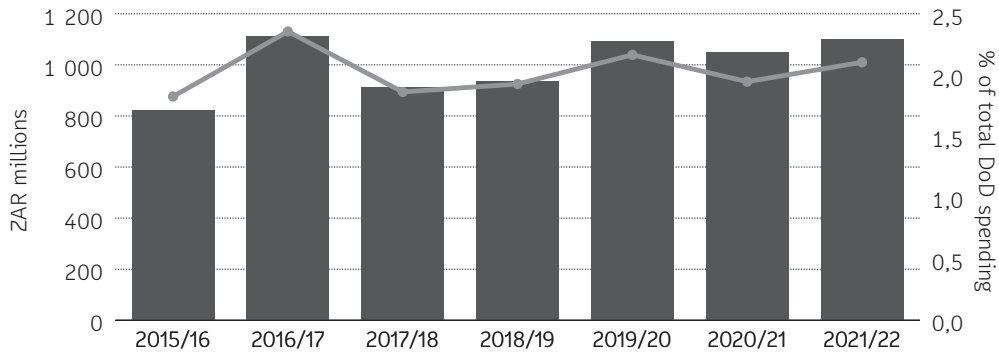


This expenditure increase has contributed to an increase in port health services personnel from 312 in 2015 to 321 in 2019, with a strong concentration of these in Gauteng, due to its hosting of the country's main airport, as well as Mpumalanga, Limpopo and KwaZulu-Natal due to their land borders and harbours.[18] However, one of the challenges in relation to port health services identified in the JEE is nevertheless the 'need to address long-term human resource requirements, as demands for inspections and preparedness and response activities will increase', so there may be a need to consider increasing port health service personnel further in coming years.

Defence spending

As noted in the South African Defence Review of 2015, the constitutional mandate of the Defence Force to 'defend and protect' goes beyond combat operations and includes military operations to support other departments against environmental and non-military threat. The Defence Force will increasingly be employed in traditionally non-military roles, with typical tasks that include consequence management and relief after man-made and natural disasters, augmentation of vital services in times of need, prevention of the spread of diseases affecting humans and livestock, the transportation and distribution of food or water during droughts, fighting major fires, search and rescue operations and so on.[19] Funding for these functions mainly resides in the *Support to the People* sub-programme in the Department of Defence's budget, which is allocated around R1.1 billion per year and accounts for approximately 2 per cent of the Department's total budget (Figure 6.4).[20]

Figure 6.4: Expenditure on *Support for the People* in R million and as a percentage of total DoD expenditure, 2015/16–2021/22[21]



Environmental Affairs spending

Environmental factors, such as clean water, air quality, and exposure to extreme weather conditions are widely recognised as key determinants of the health of human beings. The Department of Environmental Affairs' mandate is to manage, protect and conserve South Africa's environment and aims to promote sustainable use of resources, reduce air pollution, carbon emissions and ensure safe and sustainable management of chemicals and other hazardous waste. Approximately half of the Department's R7.5 billion budget (2019/20) is dedicated to the expanded public works programme aiming to create green jobs and contributing to environmental sustainability, including protection of water resources and managing sustainable land use. Considerable efforts are made to support municipalities, as these play key roles in environmental management and

environmental health. The Waste Bureau, with a budget of R400 million in 2019/20 has the mandate to provide specialist advise to municipalities and businesses to develop plans for sustainable and safe waste management.[22] In 2017 the Department of Environmental Affairs together with the Department of Planning, Monitoring and Evaluation hosted Operation Phakisa, focusing on ways to enhance South Africa's chemicals and waste economy, with ambitious targets such as reducing landfill waste by 75 per cent for industries and 50 per cent by municipalities, and to this end called for considerable increases in both public and private investments.[23]

Funding for emergencies

There are at least four different mechanisms through which government can finance responses to emergencies, namely: disaster relief grants; disaster recovery grants; use of funds for emergencies in terms of the Public Financial Management Act (PFMA); and budget adjustments for unforeseeable and unavoidable events. The National Disaster Management Centre (NDMC) was established in terms of the Disaster Management Act of 2002, and is housed within the Department of Cooperative Governance and Traditional Affairs. It has the objectives to promote an integrated and co-ordinated disaster management system throughout the three spheres of government, communities and other stakeholders, with special emphasis on prevention and mitigation. Disaster management centres have also been established in all nine provinces.[24]

The overall annual expenditure of the NDMC fluctuates considerably depending on the number and magnitude of the events it has to respond to in a particular year. While budgets for risk reduction and capacity building have increased considerably from 2018/19 and onwards, the bulk of the funding of the centre is for responding to disasters as and when they happen. As seen in Table 6.2, 93 per cent of the centre's expenditure between 2015/16 and 2018/19 was in the four conditional grants to provinces and municipalities it manages, namely the provincial and municipal disaster relief grants and the municipal and provincial disaster recovery grants. The two disaster relief grants (provincial and municipal) provide short-term funding to respond to the immediate needs following a disaster.[25] After a disaster is declared in terms of the Disaster Management Act, the relevant province or municipality can apply for funding to the NDMC, which evaluates the severity of the disaster, verifies the cost estimates and applies for approval from the National Treasury to disburse funds. In 2017/18 the grants funded a relatively wide range of services, such as provision of livestock feed to farmers affected by drought and fires and drilling boreholes to address drought conditions. The other two grants,

Table 6.2: Expenditure of the National Disaster Management Centre, 2015/16–2021/22[26]

	Audited outcome		Adjusted appro-priation	Medium-term expenditure estimate			
	2015/16 R'000	2016/17 R'000	2017/18 R'000	2018/19 R'000	2019/20 R'000	2020/21 R'000	2021/22 R'000
Management: Head of the NDMC	5 683	5 585	4 834	4 101	4 070	4 354	4 626
Disaster Risk Reduction, Capacity Building and Intervention	12 567	7 120	10 360	51 592	51 785	57 513	60 512
Legislation and Policy Management	6 120	4 479	5 658	6 352	6 785	7 241	7 684
Integrated Provincial Disaster Management Support, M&E Systems	1 825	2 696	2 166	3 405	4 834	5 182	5 510
Fire Services	–	2 698	3 332	3 259	4 712	5 480	6 033
Information Technology, Intelligence and Information Management Systems	10 254	14 629	16 231	19 648	28 700	30 428	32 180
Disaster Relief Grant	35 588	118 075	423 712	672 871	466 392	492 429	519 513
Municipal Disaster Recovery Grant	186 121	140 000	26 147	1 190 136	193 953	–	–
Provincial Disaster Recovery Grant	–	–	–	16 304	–	–	–
Total	258 158	295 282	492 440	1 967 668	761 231	602 627	636 058

the provincial and municipal disaster recovery grants have the purpose of reconstructing and rehabilitating infrastructure over the medium- to long-term following a disaster. Similar to the disaster relief grants, the NDMC first verifies the cost of damages indicated by the province or municipality and submits a funding request to the National Treasury. Depending on when in the financial year the request is received, funding can be allocated in-year (in the adjustments budget) or over the medium term (in the main budget process).

Sections 16 of the PFMA allows the Minister of Finance to authorise the use of funds from the National Revenue Fund for expenditure of 'exceptional nature' which is not provided for in the budget. Section 25 provides provincial Members of Executive Councils (MECs) with the same authority in respect of provincial revenue funds. Expenditure must be such that it cannot without seriously prejudicing public interest, wait until a future parliamentary appropriation of funds and may not exceed 2 per cent of the total Government budget for the year.

Finally, Government can also allocate funding in-year for unforeseen events through the unforeseeable and unavoidable expenditure mechanism provided for in sections 30 and 31 of the Public Financial Management Act. In the health sector, recent allocations through this mechanism have been for health infrastructure repairs due to flooding in 2018/19[27], responding to malaria outbreaks in Limpopo and Mpumalanga in 2017/18[28] and strengthening NDOH's Ebola preparedness and funding for NICD in response to the Ebola outbreak in West Africa in 2014/15.[29]

Potential for scaling up government investments

As mentioned above, the national action plan for international health regulations implementation is still being finalised and is also yet to be costed. It is therefore difficult at this point to know whether a funding gap for health security exists and, if so, how large such a gap is. While the budgets of the institutions reviewed above generally show positive growth trends, the overall budgetary climate of government is increasingly constrained due to over a decade of slow economic growth and inadequate revenue collection. Debt levels are increasingly perceived as unsustainable and annual debt service costs is now the fastest growing area of expenditure in government budgets[30]. In order to contain deficits and with the aim to consolidate the main budget balance by 2021/22, non-interest expenditure has been stagnant as a percentage of GDP in the past decade, while tax increases are gradually raising the revenue-to-GDP ratio.

In this environment, the scope to significantly increase the overall budgets of public institutions is very limited, including institutions involved in health security and health security innovation. New priorities will likely have to be funded through reprioritisation from other areas or by raising external funding through partnerships with international development partners and/or the private sector. A case in point is SAMRC, which has had some successes in using existing budgets to leverage additional funds from the private sector and international collaborators, e.g. through its joint programme with the National Institutes of Health.[31] Given the increasing prominence of health security on the global agenda, there are likely many opportunities for such international collaboration. A case in point is the World Economic Forum's Coalition for Epidemic Preparedness Innovations (CEPI), founded in 2016 with potential investments exceeding US$400 million.[32]

South Africa has relatively far-advanced plans to establish the National Public Health Institute of South Africa (NAPHISA), which may be an avenue for channelling new investments into health security as well as to foster international and public/private collaboration in this area. The new entity will be formed largely from the NICD but will also incorporate other public institutes involved in public health research. The Bill to establish NAPHISA as a public entity was initially introduced to Parliament in 2017 and has now been passed by both houses, but lapsed with the dissolution of Parliament in connection to the 2019 national elections[33] and is likely to be reintroduced to the new Parliament in due course.

There is also an urgent need to develop a national health research policy, which includes strategies for health security research and financing thereof. While a recent publication[34] gave South Africa a high national health research system barometer score of 87.3 per cent, and including a 100 per cent score on leadership governance, it also noted that many key strategic documents are now very old, such as the National Health Research of 2001 and the National Health Research Agenda of 2011. While the process of developing such strategies should likely be led by NDOH through its National Health Research Committee, it could benefit from a collaborative approach, including the National Treasury, research councils, the Department of Higher Education, Science and Technology, private sector stakeholders and international partners.

Investment in research and development

According to the generally accepted indicator of research and development (R&D) intensity, namely gross expenditure on R&D in relation to GDP, South Africa's value of 0.82 per cent suggests that she hosts a modest-

sized research system. Despite many years of advocacy, the 2008 target of attaining 1 per cent was not reached. A new target of 1.5 per cent has been set for 2030. Within the 2016/17 total R&D expenditure of R 35.7 billion, social sciences (R8.4 billion) and medical and health sciences (R6.9 billion) are the largest two research fields, whose share has risen alongside a steep decline in research fields associated with engineering sciences and the applied sciences and technologies.[35] Medical and health sciences R&D is spread across the universities (R2.41 billion), private sector (R2.28 billion), science councils, including the MRC (R0.84 billion), not-for-profits (R0.72 billion) and government departments, including NHLS (R0.62 billion). A large proportion of such expenditure relates to clinical trials in the private sector with university involvement. Available data is not disaggregated down to the level of plant and animal health, vaccine production, and so on, implying that the actual expenditure of research related to health security issues is higher than a focus on medical and health sciences research would indicate. R&D is but one among many innovation activities, implying that measuring R&D is an insufficient indicator of the likelihood of translation into new medical products such as what is known as medical application programming interfaces (API) which allow developers to seamlessly integrate their health applications with individual devices and entire ecosystems which safely stores and accesses health data.

As to R&D on preparedness, diagnostics, surveillance and medical countermeasures, bibliometric analysis may be applied to scientific publications indexed to bibliographic databases such as Clarivate Analytics 'Web of Science' or Elsevier 'Scopus' or PubMed. Analysis of the Web of Science for the period 2013 to 2017 shows that infectious diseases give rise to the largest publication count, with public, environmental and occupational health ranking third, plant sciences fifth and immunology ninth. All of these fields boast citation indices well above the world average. The research is concentrated at the universities of Cape Town, KwaZulu-Natal, Stellenbosch, Witwatersrand and Pretoria. The University of KwaZulu-Natal has been active in research on barrier methods to reduce the risk of HIV transmission. The MRC operates a number of research centres at these universities in support of such university-based efforts. Plant pathogen and vaccine research is also conducted at the Agricultural Research Council. CSIR carries out some research on malaria, and drug delivery. In the early 2000s HSRC carried out important work on nosocomial transmission of HIV. On the commercial side, Onderstepoort Biological Products is a state-owned company that produces veterinary pharmaceuticals.

The business case for preparedness investment

At the World Economic Forum (WEF) meetings held in Cape Town on 5 September 2019, the Africa Center for Disease Control and Prevention (Africa CDC) led by the virologist John Nkengasong, announced the establishment of the Africa Public Health Foundation (APHF). Modelled after the Atlanta-based CDC Foundation, the APHF is a public-private partnership project between the African Union and the World Economic Forum, having a goal of drawing in private sector companies into scaled up public sector epidemic detection, prevention and response across the vast African continent. While there has always been private sector involvement in epidemic response, it has been episodic, uncoordinated and often unstrategic, resulting in less than optimal interventions. This is likely the first time a financial mechanism will assemble and consolidate African resources, with the potential in the longer run of lessening dependence on foreign aid and donors.

South African companies, in mining, telecommunications, broadcasting, financial services/banking, retail and consulting businesses, have a substantial footprint on the African continent, a presence likely to expand given the existence of the African Continental Free Trade Agreement that concluded at the WEF in Cape Town in early September 2019. Given their exposures to disasters and catastrophes on the continent, it is arguably in the self-interest of South African businesses to invest in surveillance, epidemiological and climate science services, as well as in medical countermeasure pipeline developments, to enable countries in which they operate to mount a continuously improving and far more effective menu of interventions to detect, prevent and respond to disasters. Writing from an insiders' perspective in the World Economic Forum's *Outbreak Readiness and Business Impact*, Peter Sands remarked:

> During my time as CEO of Standard Chartered, I saw first-hand how infectious disease outbreaks like SARS, MERS and Ebola could wreak havoc on business. Customers avoided public places such as restaurants, shops and cinemas. Staff struggled to get to work, fearful of public transport and needing to look after their children once schools were closed. Supply chains and basic services faltered, as pressures and blockages built up.[36]

Effective risk management is key to successful business but, as Sands points out, Standard Chartered at the time, like most other businesses, lacked the information tools and tested interventions to deal with infectious disease outbreaks, particularly those with epidemic potential. They were, he noted, 'making things up' as the crisis moved along.

No business, and especially those with global supply chains and markets, can operate with such uncertainty and, pressured by the compelling discipline of meeting the bottom line for investors, Sands lays out a case for a much greater level of business involvement in the prevention, detection and response to epidemic outbreaks. The reasons for this may seem obvious from a business point of view, but it is worth spelling them out, as Sands did:

- *Impact on employees*: infectious disease outbreaks affect productivity, drive absenteeism rates and medical insurance costs. Healthcare costs are a significant component of operating costs. Outbreaks can limit business travel between headquarters, regional offices, suppliers and customers, compromising relationships. Companies will wish to limit workplace disease transmission, encourage contagious employees to stay at home and therefore need to design medical insurance options and telecommuting systems to enable work to continue.
- *Impact on supply chains*: infectious disease outbreaks disrupt international supply chains. Just-in-time manufacturing allow for small volume on-site inventories and rely on low defect rates, but these very characteristics of modern globalised business rely on suppliers that can deliver rapidly and on scale, rendering them extremely vulnerable to disease outbreak disruptions. To manage the risk requires comprehensive high-resolution geographic and time information, which may or may not be available, and businesses have an interest in investing in the capacity to acquire such surveillance.
- *Impact on customers*: widespread death and disease associated with severe disease outbreaks will affect many companies. Just consider the retail sectors. Even outbreaks with low infection rates and the fear of infection will depress retail and reduce entertainment spending. So too will customers turn to e-commerce shopping instead of traditional shop retail, affecting their distribution models. Some companies are better able to adjust than others.[37]

Sands used epidemic outbreaks as examples to make his case, but the argument applies to any disaster or catastrophic event. In March 2019, South Africa provided in-kind services to assist Mozambique in coping with the tropical cyclone *Idai* that landed on Africa's east coast and caused monumental havoc. It was one of the worst cyclones on record to affect Africa and the Southern Hemisphere. 1 303 people died and many more were wounded – a major humanitarian crisis where three million people were affected, and many were exposed to disease risks following in the storm's wake. Hundreds of thousands of people needed help in Madagascar, Mozambique, Zimbabwe and Malawi. Rescuers had to make

dreadful decisions about whom to rescue and whom to leave behind, many certain to die. 4 000 cholera cases were confirmed, as were many deaths. The storm left Mozambique, Zimbabwe and Malawi to deal with a scale of damage assessed at US$2.2 billion, infrastructure at US$1 billion, and this amongst the poorest countries in the world. Mozambique's GNP was US$12.33 billion, for example, in 2017.

Of course, natural disasters cannot be prevented. However, sophisticated information systems can power early warning systems and storm trajectory mapping that enables a much more precise targeting of rescue, mitigation and response interventions. Mitigation strategies can limit damage to lives, property and infrastructure. Far-reaching public health interventions by national governments, supported regionally by the Africa CDC and globally by the WHO and UNICEF, properly resourced and primed, can rapidly contain disease outbreaks. Co-ordinated regionally mounted rescue efforts supported by continental and world bodies can save more lives and treat many more of the wounded. Sources of independent energy, if they were installed and available, can be mobilised to support the basic facilities for life – refrigeration, clinics, schools and banks – during the mitigation and recovery phases. In its aftermath, city and municipal regulations must be revisited to ensure that construction on flood plains and high-risk geographies do not happen. Sensible evacuation plans, tested and gamed on a regular tested, should become routine.

In South Africa, the most telling example of why businesses should invest in better disaster prediction, detection, mitigation, response and recovery was the Cape drought and water-shortage catastrophe of 2014 to 2016 which is more than likely to recur. Many businesses were affected, the tourism, agriculture and short-term insurance sectors most directly. Statistics provided by Wesgro (Cape Town and Western Cape's tourism, trade and investment promotions entity) show a drop of 1.5 million tourists between 2014 and 2015 (down from 10 million in 2014 to 8.5 million in 2015).[38] Airline and hotel bookings went down. Tourism-related job growth stagnated between 2014 and 2015. While the tourism market recovered and showed great resilience after the end of the drought, the longer-term effects saw a sharp decline in jobs from a figure of 198 417 in 2016 to reach 174 893 by 2018, a drop of 23 524 or 12 per cent – this in a country that has an unemployment rate anywhere between 28 and 35 per cent, depending on the counting method one uses.

Sands calls on business executives to adopt a new risk approach and mindset. Aware business leaders are better able to position their organisations to avoid exposure, respond effectively and support global

health security. Companies should, he argues, extend risk management beyond medical responses to employees, important as that is, to include the securing of operations, supply and distribution channels, managing relations with employees, customers and investors, engaging in advanced logistical planning and developing plans for pre-emptive communications. Actions that are to be taken should be incorporated into routine risk management practices. Beyond their individual companies, they should leverage resources and influence through local chambers of commerce and business associations and invest in the dynamic field of climate science at local universities, national disease detection and surveillance entities such as, in the case of South Africa, the National Institute of Communicable Diseases, regional bodies like the Zambia-based regional public health office of the Africa CDC and non-governmental organisations such as the Red Cross and Médecins Sans Frontiers as well as the many non-governmental organisations involved in emergency response.

Conclusion

The development of the National Action Plan post-WHO/JEE assessment is an opportunity for South Africa to consider developing a new approach to health security planning and budgeting by (1) extending the domains to be covered to include nuclear, environmental, climate-related and national security risks; (2) creating public-private entities and drawing in companies who have a direct and indirect longer interest in emergency and disaster prevention, detection, mitigation, response and recovery; and (3) redesigning the way in which government delivers emergency services. The establishing of the long-awaited NAPHISA is an opportunity to re-engineer the country's emergency services following on a spending review of health security in all the risk domains outlined in this Report.

In order for government to consider additional investments in health security, it is important to quantify both what is currently being spent and the funding need. This chapter highlighted some key expenditure trends for public institutions involved in health security using publicly available budget data, but this is generally not granular enough to extract health security-specific spending. A comprehensive expenditure mapping exercise, such as the performance and expenditure reviews (PER) carried out by GTAC together with National Treasury and DPME[39], would greatly assist in quantifying baseline spending on health security and in evaluating the quality of this expenditure. In assessing the funding need, costing the National Action Plan is an essential step that needs to be taken urgently, and this should ideally also aim to establish baseline expenditure in each of the areas that are costed. Given the very constrained fiscal space

available in the short- to medium-term, new investments will likely need to be funded through reprioritisation within existing budgets and if and when the economy improves, more significant new funding is likely to be more plausible. Considerable focus will also need to be on ensuring value for money both within the current spending and possible additional investments.

7
Conclusion
What needs to be done?

Wilmot James and Gregory Hooks

In *Homo Deus: A Brief History of Tomorrow*, Yuval Noah Harari observed that humanity seems to have always faced three existential problems: famine, plague and war. 'For generation after generation after generation' he wrote, 'humans have prayed to every God, Angel and Saint, and have invented countless tools, institutions and social systems – but continued to die in their millions from starvation, epidemics and violence.' Yet today, Harari continues, 'at the dawn of the third millennium, humanity wakes up to an amazing realization ... in the last few decades we have managed to rein in famine, plague and war. Of course, these problems have not been completely solved, but they have been transformed from incomprehensible and uncontrollable forces of nature into manageable challenges. We don't need to pray to any God or Saint to rescue us from them. We know quite well what needs to be done in order to prevent famine, plague and war – and we usually succeed in doing it.'[1]

It is true that we have, with breathtaking speed, developed deep public health and clinical expertise, driven fast-paced innovations in biotechnology, and developed the digitised information and delivery systems to contain outbreaks at their source. It is also, however, true that to turn these 21st century health science achievements into real-world experiences that impact positively on citizens' lives require a committed political leadership and a capable state working constantly at building trust with communities and the commercial world in meeting the basic requirements of a nation's security; to put sustained investment in human expertise, technology, infrastructure and systems; to create an enabling environment of civic peace achieved by interventions to prevent or mitigate war, terrorism and domestic criminality; and to oil a functional regional inter-state cooperation regime to comply with international health security norms, obligations and treaties using multilateral diplomatic means to embrace and achieve shared goals.

As health security is largely a public sector function, having a capable state to deliver compelling social services is necessary and key,

especially in the South African context with its history of extreme social fragmentation. Established in 1994, the modern democratic South African state is 25 years in the making. It was constructed out of 11 racially defined political administrations where only those citizens defined as 'European' or 'white' had a meaningful say in the affairs of the national government based in Pretoria and Parliament in Cape Town. Nelson Mandela's post-1994 democratic state had a constitutionally defined mission to serve all, and not just some of its citizens, with the special challenge of bridging the most profoundly unequal socio-economic arrangements to be found anywhere in the world. I make this brief historical observation to affirm Henry Kissinger's insightful remark that to graft new policies onto the old without grasping a nation's history is to build superficiality and failure into design.[2] The challenge is whether the South African state has the capability to turn health security policy into reality; or to put it more directly, whether it is able to establish a meaningful health security environment for citizens as living facts on the ground.

To be honest, the prospects for success are mixed. The first serious and systematic assessment of the South African state's capability appeared in the government's National Development Plan (NDP) published in 2010, in the year of Jacob Zuma's first term as President (and one of the co-authors Wilmot James' first term as an opposition MP). The NDPs diagnosis was that there was an unevenness in state capacity (spatially speaking, strong in white areas, weak in black, an apartheid legacy), overbearing political interference in the administration of state, rapid turnover of senior bureaucrats, a skills deficit, the erosion of accountability and authority, poor organisational design, inappropriate staffing and low staff morale.[3] The NDP highlighted the tendency of government to 'jump from one quick fix or policy fad to the next, rather than pursuing a long-term sustained focus on tackling the major obstacles to improving the performance of the public service.'[4] There was too much political interference in selecting and managing senior staff. A sense of professional common purpose was missing. The critique, coming from a government created commission, was damning, honest and refreshing.

The NDP made a number of sensible recommendations that, if they were followed through, would have upscaled state capability and performance. But a cabal in (and outside of) Zuma's office cherry-picked the recommendations they liked best, ignored the hard choices that needed making, and deliberately set loose a campaign of disinformation and extreme 'silo-ism' in pursuit of a self-serving agenda to weaken democratic institutions, shield the political elite from accountability, install rogues by patronage into powerful positions and give oxygen to bitter internal

rivalries over whom should best siphon off resources and loot the state. According to the *Fragile State Index* the result of the wasted, deleterious and tragic decade of the Zuma administration was that, among the BRICS (Brazil, Russia, India, China and South Africa) family of countries, South Africa performed the worst economically, inequality increased, the brain drain accelerated, and demographic pressures on food supplies, access to clean water, life sustaining resources, health and the prevalence of disease and epidemics increased, triggering explosive unmanaged tensions between citizens and non-citizens in dramatic episodes of unseemly xenophobia. Among the BRICS countries only India was worse than South Africa in the provision of health, education, water, sanitation, transport, electricity and internet connectivity, even though our population size paled by comparison. Worst of all, the *Fragile State Index* ranked South Africa as the 'most-worsened' – a grammatical monstrosity we know – country over the preceding decades among countries not in a state of conflict, and that it had a trendline that 'matched only the likes of war-torn Libya and Syria for the magnitude of its negative rate-of-change.'[5] Jacob Zuma will be remembered as the President who turned what Kenneth Menkhaus once called a 'wicked' series of socio-political problems into a 'super-wicked' conundrum of escalating pathologies.[6]

What about health security? The NDP observed that the majority of South Africans had limited access to an under-resourced, under-staffed and poor performing public health sector and the elite to a high-performing commercial health sector financed through employment-based medical aid schemes, private insurance for those who could afford it and high out-of-pocket expenditures. The NDP recommended strategies to strengthen health systems by building a robust primary health care foundation, upscale the delivery of basic clinic, hospital and emergency services and improve the human resource professional base to serve the under-served on a progressive timescale as the Constitution requires. In one of the co-authors' (Wilmot James) time as a ranking MP from the official opposition serving on Parliament's Portfolio Committee on Health, I watched in dismay at how the NDP was ignored and the basics of health provision neglected by my African National Congress (ANC) and Economic Freedom Fighters (EFF) colleagues who were mesmerised by an unaffordable single-payer national health insurance scheme to be administered centrally by a government with such a dismal record of paralysis, corruption and, if not in all instances, incompetence. The result is health systems weakened rather than strengthened, an area of health security risk for which the *GHS Index* gave South Africa a score of 33 (out of a 100), the lowest of all the scores for the six technical areas assessed: 44.8 was awarded for Prevention, 81.5

Detection and Reporting, 57.7 Response, 46.3 Compliance with International Norms and 61.8 (managing) the Risk Environment.[7]

South Africa is at a crossroads but there is an opportunity to boldly shift gears, and it is this: to seize the opportunity provided by WHO/JEE assessment process by amending the *National Action Planning for Health Security* and embrace an all-risks approach as presented in the various chapters. The NAPHS is designed to go through three stages of development:

- *Inception*: desktop review of all existing national plans, capacity assessments, stakeholder analysis, SWOT analysis and prioritisation of technical areas of action;
- *Development*: identification and prioritisation of activities within technical areas based on risk assessment, monitoring and evaluation, detailed costing of activities, mapping resources and plan endorsement; and
- *Implementation*: reprioritisation of operational plan based on resource mapping, national health sector integration, planning, monitoring, evaluation, reporting and periodical plan updating; leading towards implementation and continued resource mobilisation.

In addition to the WHO/JEE NAPHS focus on infectious disease, biological, chemical and radiological security gaps, *Vital Signs* also examined nuclear, environmental and climate-related hazards, which we recommend be also added as risk domains. We further recommend that a review of current fragmented expenditures on health security be conducted by Treasury and a new budget framed in national security terms because of the need to bolster biodefense, nuclear security and improved controls over trade in toxins and pathogens that could be used to develop weapons of mass destruction. Because emergency response often requires a chain-of-command and governments are often pressured to suspend rights by declaring curfews, quarantines and/or close schools, we recommend that justice be included in a health security cluster to provide a balance and check on the requirements associated with taking a defence posture. The portfolios involved in health security would consist of health, agriculture, environment, higher education, science and technology, home affairs, aviation, police, justice, trade and industry, defence and state security, and international relations and cooperation. The convention is that, if a catastrophe is natural or accidental, the response is led by health; if it is caused deliberately, it is led by defence.

Because of the paralysing difficulties of bureaucratic 'silo-ism' in a domain where swift action is necessary and knowledge shared cooperatively, we

recommend that the responsibility for leading health security should be lifted out of the Department of Health and placed in Presidency with the responsibility to:

- Integrate the elements of health security, including its surge capacity, across departments and spheres of government;
- Create and build partnerships with the private sector to develop new disaster prevention, detection and response technologies and systems;
- Work with civil society organisations to reach into communities to better enable prevention, detection and response; and
- Collaborate regionally with the Lusaka-based Southern Regional Collaborating Center (RCC) of the Africa Center for Disease Control and Prevention (Africa CDC).

Vital Signs also recommend that Parliament appoint a *Standing Commission on Health Security* with a mandate to provide oversight of government measures in preventing, detecting, mitigating, responding to and assisting community recovery from nuclear, radiological, chemical, environmental, infectious disease, biological and climate-induced and other hazards and catastrophic events, assuring that they are consistent with the Bill of Rights and the Constitution, and that the country's legislation and regulation regime is up to the task. Pointedly, the *Standing Commission* must also provide rigorous oversight over any government or clandestine illicit trade in chemical weapons, weapon-ready biologics and radioactive materials.

Finally, we would like to make a case that, what with its extensive (for Africa and the developing world) medical, public health, science and research infrastructure, South African universities, science councils and high-performing special entities like the National Institute for Communicable Diseases (NICD) should be properly resourced and appropriately geared to drive the health security research and higher education needs for southern if not for Sub-Saharan Africa as a whole. Certainly, the NICD's high and maximum biocontainment facilities (BSL3 and BSL4) should be declared by Government as being of national strategic importance and their biosecurity levels upscaled. The research and development agenda should by now be clear: our continent requires high-level longitudinal research on current, emerging and future domestic, regional, continental and global catastrophic hazards, risks and threats, undertaken by established and emerging scientists located at the country's medical, industrial, agricultural, minerals and human science councils and at centers of excellence at universities networks continentally and globally. We must invest in the accelerated development of high-level

human expertise to reverse the memory loss, brain-drain and knowledge decay underway, as the many contributors, experts in their fields, have observed. Perhaps then we would approach acquiring the capabilities to take advantage of the promise of modern technologies to manage high-consequence risks and hazards, to reign in, using Yuval Noah Harari's vocabulary, the plagues, famines and wars of our times.[8]

A
The JEE Mission Reports
and health security in South Africa and Lesotho

Hannah Bender

In 2017, South Africa and Lesotho were assessed by the Joint External Evaluation (JEE) tool to determine their compliance with the core capacities of the International Health Regulations (IHR) (2005). The JEE assessment is a voluntary process, consisting of a self-evaluation that takes place over the course of a few months, followed by an external assessment that takes place over the course of only a few days. Most of the information is provided by the host country and is not independently verified. Taken together, these facts suggest that the JEE tool might work as a general indicator of preparedness, but should not be considered the final authority on national capacities. Throughout Africa, infectious diseases continue to pose some of the greatest threats to public health. A salient example of this was the Ebola Virus Disease (EVD) epidemic in West Africa in 2014, where the emergence of the zoonotic disease in a new context combined with increased global travel led to an Ebola outbreak of unprecedented magnitude. The ongoing EVD outbreak in the Democratic Republic of the Congo, declared a Public Health Emergency of International Concern on 17 July 2019,[1] illustrates that, despite actions taken in the wake of the 2014–16 West African Ebola outbreak, the issues remain relevant. Like the Severe Acute Respiratory Syndrome (SARS) outbreak of 2003 that prompted IHR revision, the 2014 EVD outbreak demonstrated the necessity of coordinating public health emergency responses both nationally and regionally on the African continent.

Given the importance of taking regional perspectives in matters of health security, it makes sense to consider South Africa and Lesotho together. Due to their geographic proximity, environmental and human health crises of one country are likely to affect the other. Collaboration between the two countries on issues related to disease surveillance in human and animal populations would therefore be highly beneficial to both.

To date, both countries have completed JEE assessments and efforts to establish a National Action Plan for Health Security (NAPHS) are ongoing. Engaging in antimicrobial stewardship (AMS) activities and improving

surveillance in animal health are major priorities for both countries. While they have experience coordinating responses to rabies and have undertaken disease-specific preparedness activities for Ebola and H1N1, it will be important to ensure that there is an enabling system for health that will allow for national and regional cooperation in the event that a new threat emerges. The international community can provide help in the form of funding and capacity-building. There have been examples of successful partnerships to support research efforts in South Africa, as well as efforts to plug gaps in health infrastructure in Lesotho. Although infectious diseases, particularly HIV and TB, will continue to require global efforts to address, it is important to support other initiatives, particularly building a *One Health* framework and beginning to address issues like nuclear and chemical security that have become increasingly important with the adoption of new technologies.

Both South Africa and Lesotho have drafted legal frameworks for implementing the IHR (2005), which have yet to be enacted into law. Before the South African Parliament are the International Health Regulations Bill, 2013, and the National Public Health Institute of South Africa (NAPHISA) Bill[2]. The JEE mission report highlights the presence of political support for implementing the IHR in South Africa, but also expresses coded concern at the fact that the bills have not yet been passed. In Lesotho, an updated Public Health Bill of 2017 has been drafted to replace the Public Health Order of 1970. The 1970 document covered only four diseases and includes an entire section on preventing the spread of smallpox, which has been eradicated since 1980, and nothing on HIV/AIDS, which currently afflicts a quarter of the country's population.[3]

Despite a present lack of legislation necessary to implement the IHR in South Africa and Lesotho, both mission reports highlighted cross-border agreements and memoranda of understanding (MoU) as strengths in the area of national legislation, policy and financing. There are MoUs between Lesotho and South Africa regarding cross-border surveillance, trade, and medical countermeasures (MCM). As members of the Southern African Development Community (SADC), both countries partake in agreements, protocols, and MoUs related to health security with other SADC countries; however, the content of these documents is very limited. The SADC Protocol on Health was passed in 1999 and contains only three sentences on managing emergencies, which essentially state that the states agree to cooperate.[4]

During the past few years, there has been substantial progress in operationalising the CDC's Regional Collaborating Centre (RCC) for

Southern Africa. The Southern Africa RCC (SA-RCC) hopes to maintain a presence at other fora in the region, such as the SADC health ministry meeting, to help ensure that efforts of the two bodies are aligned.[5] The SADC has a very broad scope, including economic, political, and environmental issues, thus, it may be beneficial to have a more robust regional body focused specifically on health. At the first meeting, held in July 2017, the SA-RCC was able to draft a framework document for governance, outline the roles and responsibilities of member states, identify public health priorities, and map out existing resources.[6] Zambia provided infrastructure and human resources to operationalise the center, and South Africa highlighted their BSL-4 laboratory and laboratory accreditation tools, a strong surveillance program, research institutions, and the South African Field Epidemiology Training Program (FETP) as potential assets for regional initiatives.[7] Regional assets will likely be enhanced in the coming years through the World Bank's Africa CDC Regional Investment Financing Program which has provided the Zambia National Public Health Institute (ZNPHI) with funding to construct, equip, staff and operate a laboratory and office complex that can serve the SA-RCC region.[8] The complex will comprise a Biosafety Level 3 (BSL-3) Laboratory suite, Public Health Emergency Operations Centre (PHEOC), Information Communication and Technology (ICT) suite, Proficiency Panel Production Center, Biomedical Equipment Maintenance Center, training facilities, Conference facilities and office accommodation. Investments such as this can help the RCCs build additional capacity to fulfil IHR (2005) obligations and realise Africa CDC's goal of creating institutions to support national, regional and international partnerships for disease control and public health security.

The ability to communicate Public Health Emergencies of International Concern (PHEIC) to WHO via National Focal Points (NFP) is another important requirement of the IHR (2005). The IHR define the role, functions, and operational requirements of the NFP, but the exact structure and organisation is left to the state. The NFP is envisioned to be an office rather than an individual in order to ensure 24/7 coverage, but South Africa has designated a single person as the national IHR focal point. Despite recommendations that South Africa work to improve the NFP, an overall score of 4 was given due to other multi-sectoral mechanisms of communication such as the Multi-Sectoral National Outbreak Response Team (MNORT); National Disaster Management Centre (NDMC); National Joint Operational Centre (NATJOC); National Joint Operational and Intelligence Structure (NATJOINTS) and other forums. Despite its score of 1, Lesotho also has relatively good multi-sectoral communication

with technical guidelines derived from the country's Integrated Disease Surveillance and Response (IDSR). With a formalised structure and SOPs for the coordination committee, it was noted that the score could be raised to a 3.

Antimicrobial resistance (AMR) is an important issue to address around the globe, and in both South Africa and Lesotho it seems particularly crucial given the high prevalence of HIV/AIDS and TB. Due to the high rates of these diseases, many people require antibiotics frequently and for extended periods of time. This increases the likelihood of missed doses which selects for resistance. TB is not the focus of the AMR National Strategy Framework in South Africa; however, the use of antimicrobials for various opportunistic HIV-associated infections is a target for antimicrobial stewardship (AMS). Overall, South Africa was able to demonstrate capacity in many of the areas related to AMR, but a lack of AMR legislation and testing capabilities in the veterinary sector brought down the overall scores. The only area in which South Africa was not able to demonstrate capacity was healthcare associated infection (HCAI) prevention and control programs. In contrast, Lesotho was found to have no capacity in all of the areas except HCAI prevention and control, where they earned a score of 3.

Efforts to address antimicrobial resistance in South Africa include the Global Antibiotic Resistance Partnership in South Africa (GARP-SA); the South African Antibiotic Stewardship Program (SAASP); and the Infection Prevention and Control (IPC) and National Core Standards (NCS) developed by the DoH.[9] SAASP coordinates advocacy at the national level and AMS activities have begun at a provincial level.[10] The Systems for Improved Access to Pharmaceuticals and Services (SIAPS) program, in partnership with USAID, has provided technical assistance to South Africa's National Essential Drug List Committee to develop the 2012 hospital-level standard treatment guidelines (STG) and essential drug list (EDL).[11] Lesotho has also received SIAPS aid in the formulation of an EDL and STGs.[12]

Three major drivers of AMR identified by the South African DoH were the total volume of antibiotics used, reliance on broad-spectrum antibiotics and acquisition of HCAIs.[13] Despite progress made in establishing prescription guidelines, adherence remains low in both countries. Similar rates of adherence to guidelines were found in both South Africa (45.1 per cent)[14] and Lesotho (42.8 per cent).[15] In Cape Town it was found that almost 20 per cent of patients who received a prescription did not require the antibiotic at all.[16] A common diagnostic error is the prescription of antibiotics for viral infections, in fact, a study in South Africa found that patients with viral bronchitis were more likely to be prescribed an

antibiotic than those with bacterial bronchitis.[17] In Lesotho, the highest rates of inappropriate prescribing of antibiotics were found in the treatment or prophylaxis of infections in inpatient settings.[18] The practices of using antibiotics prophylactically and improperly in the inpatient setting contribute substantially to the problem of resistance in HCAIs, even though they are intended to protect patients from such infections.

In January 2017, Lesotho attended the WHO Regional Office for Africa's (WHO AFRO) 2nd Regional Workshop on National Action Plan (NAP) Development and obtained funding to develop its NAP, which was to be presented to upper management in the Lesotho government in July 2017.[19] Priority actions recommended by the JEE include development of a NAP; introduction of AMR monitoring in the food production chain 'from farm to fork'; and establishment of AMS programs. Unlike South Africa, Lesotho had yet to enrol in the Global Antimicrobial Resistance Surveillance System (GLASS) as of December 2018.[20] In the Mission Report, the JEE touted Lesotho's *Infection Prevention and Control Plan 2016* and its processes to reduce and prevent nosocomial infections. Another strength/best practice identified was that IPC committees are established and functional in a number of health facilities. A recent report found that, despite their efforts, IPC committees in Lesotho remain largely ineffective due to constraints in governance, including a poor sense of competence, administrative limitations, inadequate financial support, role uncertainty, and negative staff attitudes.[21]

AMS activities in South African are guided by the *Antimicrobial Resistance National Strategy Framework: 2014–2024*, which sets out strategic objectives in governance, surveillance, prevention and control (including HCAIs), and AMS (Appendix).[22] Due to the absence of a national multi-sectoral plan, HCAI prevention was the only indicator for which South Africa received a score of 1, indicating 'no capacity'.[23] It was noted that this score could be quickly raised to a 3, were such a plan to be finalised and a national IPC focal point within the DoH identified. Because of a lack of data, the true burden of HCAIs is not well known; however, in Africa up to 50 per cent of patients in ICUs have been reported to acquire an HCAI.[24] A pilot study for an HCAI surveillance system conducted in the province of KwaZulu-Natal found that human resource limitations were a major barrier to implementing surveillance systems.[25] The researchers found that HCAI prevention and surveillance were not major priorities in the ICUs. This is reflected in the legislative structures. Although the reporting of HCAIs is a requirement in the National Core Standards for Health Establishments, it is not explicitly stated in the Strategic Plan for the National DoH and reporting of HCAIs was not required by the Provincial DoH. It was also

noted that there was a suboptimal ratio of infection control practitioners to patient beds, and the role was often neglected due to inadequate resources.[26] Surveillance of HCAIs should be integrated into existing systems for maintaining health records; however, this poses a problem when existing electronic systems cannot support this type of reporting, or when hospitals used paper-based systems and would require additional administrative roles to electronically report surveillance data. Where clinical surveillance is not possible due to limited resources, expertise, or technology infrastructure, monitoring antimicrobial prescriptions in combination with laboratory data could be a reasonable alternative.[27] Establishing these systems is possible but will require long-term efforts. This was demonstrated in a private ICU in Gauteng, South Africa, where successful implementation of surveillance was established over the course of six years.[28]

In an effort to improve governance structures, a national interdisciplinary ministerial advisory committee has been created and the Framework stipulates that each province and district should have an AMS committee as well. In surveillance, the goal is to establish a consolidated national surveillance report on AMR for South Africa, encompassing public and private data on alert MDR organisms. In South Africa, a national plan for laboratory testing of all WHO priority pathogens for AMR was launched in 2014. Testing is done by the National Health Laboratory Service (NHLS) which includes the National Institute for Communicable Diseases (NICD) where the national AMR reference laboratory is housed.[29] An example of best practice is the GERMS program at the NICD, a nationwide network of clinical microbiology laboratories in the public and private-sector which participate in an active laboratory-based surveillance program.[30] Diseases under surveillance include epidemic-prone diseases, vaccine-preventable diseases, diseases targeted for eradication or elimination, and opportunistic infections associated with HIV infection.[31]

There are plans to develop an integrated electronic database of human, animal and environmental sources of AMR pathogens; however, there is currently no program for pathogen surveillance in animal health.[32] A promising technology might be the AfyaData app, a mobile platform for reporting infectious disease that utilises community-level input. It was developed by the Southern African Centre for Infectious Disease Surveillance (SACIDS), of which South Africa is a member, and has been piloted at two sites in Tanzania.[33]

A recent review of veterinary AMS in South Africa notes that 'Food security and the management of antimicrobial resistance are complicated

by the somewhat fragmented and varied legislation in South Africa that regulates animal health'.[34] Thus, strengthening the veterinary authority for better governance was identified as an important foundation in the *South African Veterinary Strategy 2016–2026* (Appendix). This would enable other measures to improve animal health and AMR surveillance, such as regulating the use of over-the-counter products, known as stock remedies. Act no. 36 of 1947 gave farmers access to these medications because, historically, accessing a veterinarian to prescribe the medication was often not practical or possible. The South African Animal Health Association (SAAHA) has been working on a system to register stock remedies and has drafted guidelines for the registration of antimicrobials; however, these guidelines have not yet been implemented.[35] One weakness in the governance of animal health is the lack of legislation, but another is a lack of enforcement. The major regulatory body, the South African Department of Agriculture, Forestry and Fisheries (DAFF), has various compliance and enforcement responsibilities, but has initiated very few prosecutions, and the majority of the provincial veterinary departments lack the capacity to meet the legislative requirements that have been enacted.[36] In order to strengthen the veterinary authority, the strategy focuses on restoring a national chain of command and securing trade through border and quarantine security. Further pillars of the Veterinary Strategy deal with issues of animal disease surveillance, strengthening laboratory competencies, and defining the contributions of veterinary services in the larger AMR strategy framework.

A final objective of the AMR strategy is promoting appropriate use of antimicrobials in human and animal health through AMS programs. The DoH has published the *Guidelines on Implementation of the Antimicrobial Strategy in South Africa: One Health Approach & Governance, June* 2017, addressing governance structures of stewardship at national, provincial, district, and institution level.[37] South Africa received a score of 2 for AMS activities, despite the presence of this *One Health* strategy, due to weaknesses in responsible and prudent use of antimicrobials in animal health, particularly in commercial livestock. The Pig Veterinary Society (PVS) of the South African Veterinary Association put out *Guidelines for the use of antimicrobials in the South African pig industry* with the aim to 'improve pig health and welfare while preventing or reducing the selection for, emergence of and spread of antimicrobial-resistant bacteria in pigs and humans'.[38] The guidelines include an acceptable list of narrow-spectrum antimicrobials that are not important in human medicine, which may be used as antimicrobial growth promoters when indicated.[39] Successes in reducing the use of antimicrobials in the absence of disease (i.e. as growth

promoters) in the pig industry through a voluntary program could hopefully be applied to the poultry and beef industries. Efforts to pass the drafted legislation regarding the use of antimicrobials in animals and enforce it through a restored chain of command should continue, however, the agreement of the PVS demonstrates that there are viable alternatives to legal restrictions.

Despite weaknesses in the veterinary sector with respect to its role in country-wide AMR plans, the JEE summary on Zoonotic diseases closed with the glowing praise that, 'South Africa can be regarded as a model country within Africa in terms of developing a *One Health* approach to the management and response to zoonotic disease risks both within the country and internationally.' The World Bank used the Understanding Rift Valley Fever in Republic of South Africa Project, a U.S. Defence Threat Reduction Agency-funded study, as an example of best practice for resource efficiency through a *One Health* approach.[40] The study demonstrated both the scientific and economic benefits of cross-training staff and sharing resources in human, animal, and environmental health.[41] Within the country, South Africa benefits from highly effective coordination between the DoH, the DAFF and the Department of Environmental Affairs, as well as other stakeholders, such as from the national security and local government sectors. In the absence of a joint electronic real-time reporting system for human and animal health, the MNORT oversees coordination and provides the opportunity for joint discussion of domestic and international zoonotic risks at monthly meetings. Internationally, South Africa seems to have emerged as a leader within the SADC. With its faculty of veterinary science, the University of Pretoria posits itself as 'the only tertiary institution with a full set of faculties that would allow the national and regional development of the *One Health* concept within the SADC, with a focus on the animal/human/ecosystem interface'.[42] South Africa also has taken a prominent role in SACIDS, a *One Health* consortium of academic and research institutions formed in 2008 that services the SADC and fosters partnerships with research centers in high income countries.[43] The participating African countries (Democratic Republic of Congo, Mozambique, South Africa, Tanzania, and Kenya) comprise members of both the SADC and the East African Community (EAC). Although the SACIDS headquarters are located in Tanzania, the NICD in Johannesburg hosted the first *One Health* conference in Africa in July 2011, organised by the SACIDS.[44] As the home of one of two BSL-4 laboratories in Africa, the NICD has also played a role in SACIDS-related research initiatives.

One of the priority diseases for both the SADC and the SACIDS is TB, which is a notifiable disease in South Africa, but is of higher priority in Lesotho. Lesotho's surveillance capabilities with respect to TB were improved by the construction of the first BSL-3 lab in the country, opened by Partners in Health (PIH) in 2012.[45] The lab allows cases of extensively drug-resistant tuberculosis (XDR-TB) to be identified without having to send samples outside of the country (formerly it was required that samples be shipped to South Africa).[46] Overall, 10 per cent of surveillance samples are still sent to the NICD of South Africa for external validation and quality assurance. Both countries lacked laboratory capacity on the side of animal health. In Lesotho, there is no specimen transport system in the animal sector whatsoever. It is doubtful that Lesotho would have the capacity to establish and maintain such a system on its own as the budget for transportation and testing of human specimens is funded by the WHO, and 80 per cent of transport is managed by the NGO, Riders for Health. Given the limited resources for surveillance of animal pathogens in Lesotho, TB testing is conducted for export of non-slaughter cattle to South Africa only, in accordance with the DAFF import guidelines for cattle from Botswana, Lesotho, Namibia, and Swaziland.[47,48] These guidelines are consistent with South Africa's emphasis on security at points of entry. In the example of the cattle trade, South Africa's self-preservation may incentivise best practices in Lesotho. It might be worth considering other ways in which the unique relationship between the countries could strengthen health security in Lesotho through legislation, in addition to provision of resources like laboratory testing and MCM. Surveillance activities in Lesotho will likely continue to require funding and technical expertise from the WHO and NGOs like PIH and Riders for Health.

Southern Africa is the region of lowest risk for rabies within the African continent;[49] however, rabies remains a priority zoonotic disease in both countries. The JEE reported that rabies management in South Africa was one of the areas in which close to real-time cross-sectoral reporting occurs. When rabies is suspected, the medical and veterinary responses in both countries are clearly defined. In Lesotho, the animal health division is alerted on presentation of dog bites and reports of suspected anthrax or rabies prompt a field investigation by staff from the animal health laboratory. Even in a bad year, the number of rabies cases in humans remains very low; however, controlling rabies is an easy way for the government to demonstrate competent management of zoonotic diseases. Failure to do so prompts criticism and could be indicative of larger problems. After there were at least six cases of rabies in South Africa in the first four months of 2018, it prompted a professor at the University

of Pretoria to say, 'All I can assume is that state services don't have the capacity or the will or the staff or the motivation to provide sufficient vaccine coverage.'[50] Estimates indicate that at least 2.5 million dogs should be vaccinated annually, yet with 9 million dogs and about 2 million cats, the annual vaccination coverage is reported to never exceed 1.5 million pets.[51] Molecular epidemiology studies have shown that cross-border spread of rabies occurs between Lesotho and two neighbouring provinces in South Africa (Appendix).[52] Due to the porous nature of the borders between the two countries, animals can move freely between them and negatively impact rabies intervention initiatives implemented in either country. The spread of rabies between geographically-separated dog populations indicates that the movement of humans (along with their livestock and companion animals) could also play a role in ongoing exchanges.[53] These studies could be more broadly applied to indicate the importance of regional efforts to conduct surveillance and prevent the spread of diseases related to the movement of animal reservoir populations. The foundation for such efforts could be found in existing SADC legislation regarding Transfrontier Conservation Areas (TFCA), defined in the SADC Protocol on Wildlife Conservation and Law Enforcement (1999) as 'a component of a large ecological region that straddles the boundaries of two or more countries, encompassing one or more protected areas, as well as multiple resource use areas'.[54,55] The Veterinary Faculty at the University of Pretoria has begun to use these areas for education and research purposes through the Mnisi One Health Platform, which aims to investigate the interface of these parks and the communities that border them.

The governments of South Africa and Lesotho have also struggled with reaching full vaccine coverage in humans. Both countries performed well in the 'vaccine access and delivery' indicator but struggled to achieve full coverage. The vaccination program in South Africa is fully financed by the government, while in Lesotho the government finances the procurement of traditional vaccines, and co-finances that of new vaccines with help from Gavi.[56] Lesotho is eligible for Gavi support because their Gross National Income (GNI) per capita is below the US$1 580 threshold.[57,58] In contrast, South Africa is included among Gavi's donor countries.[59] Given the geographical proximity of Lesotho and South Africa, and the principles of herd immunity, a collaboration to improve vaccine access and coverage would be beneficial for the health security of both.

Data quality issues have made it difficult to determine the true extent of vaccine coverage in both countries. In South Africa, challenges with data quality stem from over-reporting, transcription error, denominator

issues, and reporting delays. In most provinces there is weak private sector involvement in the Expanded Program for Immunization (EPI) and surveillance programs, but where they are involved, private providers do not report immunisation data, thereby affecting estimates of the immunisation coverage in the country. The only weakness identified in access and delivery for South Africa was that poor vaccine estimates lead to vaccine stock outs in health facilities. Improving data quality might help address this problem. According to the UNICEF annual report, coverage data for routine immunisation in Lesotho stood at 65 per cent for Penta 3 and 57 per cent for measles, a decrease from prior years.[60] The decrease could be attributed, in part, to poor data management. There may be under-reporting of immunisation coverage, as the country tends to report higher coverages from population surveys (85 per cent for Penta 3 in 2014 Lesotho Demographic and Health Survey) and WHO/UNICEF country estimates (93 per cent for Penta 3 in 2016).[61] A lack of designated EPI staff at the district level may be another factor limiting coverage. 2018 advocacy efforts emphasised appointment of EPI officers by MoH at the district level.[62] In both countries, difficult terrain and geographically hard-to-reach populations with limited resources are challenges to achieving full coverage. Other impediments to the Reaching Every District (RED) strategy in South Africa may include resistance due to cultural/religious reasons or the activity of anti-vaccination groups. Nevertheless, South Africa scored relatively well in the areas of risk communication including a score of 4 for 'Dynamic Listening and Rumor Management'.

Lesotho had no capacity in almost every indicator for preparedness, emergency response operations, and MCM. South Africa's capacities were also relatively limited in these areas. Both countries have designated bodies responsible for coordinating emergency response operations – in Lesotho this is the Disaster Management Authority (DMA) and in South Africa, the NDMC. The efforts of the NDMC are supplemented by NATJOINTS, which specialises in matters related to national security, MNORT, which specialises in communicable disease outbreaks, and NATHOC, which coordinated EVD preparedness and response, but currently is only activated in the event of a public health emergency. A Public Health Emergency committee is also in development. South Africa has many sector-specific plans and has conducted a few risk assessments, but lacks a multi-sectoral national public health emergency plan and integrated risk assessment. Lesotho has a few emergency preparedness plans on which to build but has not done any mapping of risks or hazards. Risks related to environmental factors should be included in this assessment to aid the establishment of a more robust *One Health* system. South Africa

and Lesotho are susceptible to drought and experienced one of the worst droughts in decades brought on by El Niño in 2015.[63] Emergencies related to climate change and extreme weather events could have a major impact on various aspects of public health, including severe acute malnutrition and poor hygiene. When events that overwhelm national capacity occur, it would be helpful to provide assessments of national resources and hazards to aid organisations such as WHO, UNICEF, and the World Food Program to give them the tools necessary to identify at-risk populations and take advantage of local assets.

Environmental risks and resources also play a role in the areas of chemical, biological, nuclear, and radiation emergencies (CBRN). Lesotho has ratified a number of anti-terrorism conventions and developed an implementation action plan for the UN Security Council resolution 1540. As Lesotho does not acquire, manufacture, transport, or use chemical, biological, or nuclear weapons, an overall lack of capacity has not been a serious concern in the past and capacity building efforts have focused on issues related to trade security.[64] In recent years, medical advancements have prompted efforts to improve Lesotho's legal framework, including drafting the Toxic and Hazardous Chemicals Management Bill (2017) and Radiation Protection Bill (2017). A special institution was created to manage the radioactive materials generated by the new Cancer Treatment Center.[65] The draft of the Radiation Protection Agency Bill will culminate in the establishment of a specialised agency with capacity building provided by the International Atomic Energy Agency (IAEA).[66]

South Africa has the most advanced chemical, biological and nuclear industries in sub-Saharan Africa, along with the most thorough legislation to prevent the misuse of such materials.[67] South Africa is not currently believed to have a chemical warfare (CW) program; however, the apartheid-era government developed small quantities of CW agents, including mustard gas, sarin gas, and BZ.[68] The chemical weapons program was dismantled along with the nuclear program in 1993 by order of President F.W. de Klerk. South Africa is a leader in the field of nuclear nonproliferation and holds a special status as the only country to have built and then voluntarily dismantled nuclear weapons. The country is currently a participant in various international treaties and was one of only six African states invited to attend the 2016 Nuclear Security Summit. At this meeting, the president of South Africa remarked that acts of terrorism 'could occur anywhere in the world: in developing or developed countries, and in nuclear weapon or non-nuclear weapon states' and affirmed a commitment to international collaboration on issues related to nuclear security. The speech also highlighted support

for developing nuclear technology to harness its energy for power, health, nutrition and agriculture.[69] Despite this leadership role, the JEE gave South Africa scores of 2 for the indicators related to radiation emergencies. There are robust systems in place for the management of nuclear sources of radiation, including the Koeberg Nuclear Power Station (KNPS) and the Research Reactor for the South African Nuclear Energy Corporation (NECSA). A National Nuclear Disaster Management Plan (NNDMP) has been established for these facilities and is tested by the National Nuclear Regulator (NNR) every two years. Radioactive sources outside of the nuclear fuel cycle, which are used for medical and industrial tools like imaging devices, linear accelerators, lasers, incubators, and radio frequency-senders, are regulated by the DoH Directorate Radiation Control. Detection and response systems to address these non-nuclear radiation emergencies from a health perspective require strengthening.

Foreign aid in strengthening nuclear security has come from sources like the US National Nuclear Security Administration (NNSA). NNSA cooperated with NESCA to convert South Africa's SAFARI-1 research reactor from using HEU to LEU fuel in 2008, completely remove all US-origin HEU in South Africa in 2011, and enhance security at several buildings at NESCA's Pelindaba site in 2014.[70] NNSA also hopes to work with South Africa on the deployment of radiation detection systems at key points of entry and exit in South Africa. South Africa has worked to improve nuclear security in the region, holding a seminar in Pretoria in February 2014 to discuss new developments related to uranium mining activities. Southern Africa has various uranium mines, including ones in Zimbabwe, Botswana, and Namibia.[71] Some of the challenges addressed in the regional discussions included nuclear safety, transport and uranium ore concentrate security, safeguards, and radiological source security in the region.[72] Even in countries without mining or significant reliance on nuclear energy, increasing utilisation of radiation technology is occurring.

South Africa has worked to set up agreements and monitor what is entering and exiting the country at its 72 points of entry. Lesotho is in a unique situation because it is a landlocked country, fully surrounded by South Africa and all international commercial flights come from South Africa. Lesotho received scores of 1 for PoEs, but to a certain extent they can rely on South Africa's capacities to filter out travellers and shipments from other countries by land, air, and sea. Since Lesotho has no interface with any other country, the countries would be able to tackle the cross-border spread of disease in a more controlled environment were they to collaborate. There appears to be a positive trend of increasing collaboration on various scales: bi-national, regional, continental, and global. These

will be important initiatives to maintain; however, more resources will be necessary to implement the plans. Building human resources is an important step, for example, there is not an existing FETP in Lesotho.[73] Field epidemiologists can receive training in South Africa, and the SAFETP team has facilitated frontline courses in Lesotho,[74] a good illustration of regional collaboration; however, it will be necessary to provide incentives in both countries to retain trained personnel. The high attrition rate is related to larger socio-economic factors that also impact national-level health initiatives.

In order to maintain and expand upon the advances that have been made in the face of other constantly-emerging challenges (disease outbreaks, weather emergencies, etc.) it will be important to build health systems in a way that is most cost- and time-efficient. This will require improved data to highlight inefficiencies and best practices. Research institutions around the world can aid this effort through studies and partnerships to apply new technologies to improve capacities in disease surveillance and nuclear and biological security. Health is tied to politics, as well as economics, and it is crucial that governments treat public health as a priority and work to create a culture of collaboration.

Lesotho: scores

Technical areas	Indicators	Score
National legislation, policy and financing	Legislation, laws, regulations, administrative requirements, policies or other government instruments in place are sufficient for implementation of IHR (2005)	2
	The state can demonstrate that it has adjusted and aligned its domestic legislation, policies and administrative arrangements to enable compliance with IHR (2005)	2
IHR coordination, communication and advocacy	A functional mechanism is established for the coordination and integration of relevant sectors in the implementation of IHR	1
Antimicrobial resistance	Antimicrobial resistance detection	1
	Surveillance of infections caused by antimicrobial-resistant pathogens	1
	Health care-associated infection (HCAI) prevention and control programmes	3
	Antimicrobial stewardship activities	1
Zoonotic diseases	Surveillance systems in place for priority zoonotic diseases/pathogens	3
	Veterinary or animal health workforce	4
	Mechanisms for responding to the infections and potential zoonotic diseases are established and functional	2
Food safety	Mechanisms for multisectoral collaboration are established to ensure rapid response to food safety emergencies and outbreaks of food-borne diseases	2

Technical areas	Indicators	Score
Biosafety and biosecurity	Whole-of-government biosafety and biosecurity system is in place for human, animal and agriculture facilities	2
	Biosafety and biosecurity training and practices	2
Immunisation	Vaccine coverage (measles) as part of national programme	2
	National vaccine access and delivery	4
National laboratory system	Laboratory testing for detection for priority diseases	4
	Specimen referral and transport system	1
	Effective modern point-of-care and laboratory-based diagnostics	3
	Laboratory quality system	2
Real-time surveillance	Indicator- and event-based surveillance systems	4
	Interoperable, interconnected, electronic real-time reporting system	2
	Integration and analysis of surveillance data	3
	Syndromic surveillance systems	4
Reporting	System for efficient reporting to FAO, OIE and WHO	2
	Reporting network and protocols in country	2
Workforce development	Human resources available to implement IHR core capacity requirements	1
	FETP[75] or other applied epidemiology training programme in place	1
	Workforce strategy	2

Technical areas	Indicators	Score
Preparedness	National multi hazard public health emergency preparedness and response plan is developed and implemented	1
	Priority public health risks and resources are mapped and utilised	1
Emergency response operations	Capacity to activate emergency operations	1
	EOC operating procedures and plans	1
	Emergency operations programme	1
	Case management procedures implemented for IHR relevant hazards	2
Linking public health and security authorities	Public health and security authorities (e.g. law enforcement, border control, customs) are linked during a suspect or confirmed biological event	4
Medical countermeasures and personnel deployment	System in place for sending and receiving medical countermeasures during a public health emergency	1
	System in place for sending and receiving health personnel during a public health emergency	1
Risk communication	Risk communication systems (plans, mechanisms, etc.)	1
	Internal and partner communication and coordination	3
	Public communication	3
	Communication engagement with affected communities	1
	Dynamic listening and rumour management	2

Technical areas	Indicators	Score
Points of entry	Routine capacities established at points of entry	1
	Effective public health response at points of entry	1
Chemical events	Mechanisms established and functioning for detecting and responding to chemical events or emergencies	1
	Enabling environment in place for management of chemical events	1
Radiation emergencies	Mechanisms established and functioning for detecting and responding to radiological and nuclear emergencies	1
	Enabling environment in place for management of radiation emergencies	1

South Africa: scores

Technical areas	Indicators	Score
National legislation, policy and financing	Legislation, laws, regulations, administrative requirements, policies or other government instruments in place are sufficient for implementation of IHR (2005)	2
	The state can demonstrate that it has adjusted and aligned its domestic legislation, policies and administrative arrangements to enable compliance with IHR (2005)	2
IHR coordination, communication and advocacy	A functional mechanism is established for the coordination and integration of relevant sectors in the implementation of IHR	4
Antimicrobial oiiiiuresistance	Antimicrobial resistance detection	3
	Surveillance of infections caused by antimicrobial-resistant pathogens	3
	Health care-associated infection (HCAI) prevention and control programmes	1
	Antimicrobial stewardship activities	2
Zoonotic diseases	Surveillance systems in place for priority zoonotic diseases/pathogens	4
	Veterinary or animal health workforce	4
	Mechanisms for responding to infectious and potential zoonotic diseases are established and functional	4
Food safety	Mechanisms for multisectoral collaboration are established to ensure rapid response to food safety emergencies and outbreaks of food-borne diseases	3

Technical areas	Indicators	Score
Biosafety and biosecurity	Whole-of-government biosafety and biosecurity system is in place for human, animal and agriculture facilities	3
	Biosafety and biosecurity training and practices	3
Immunisation	Vaccine coverage (measles) as part of national programme	3
	National vaccine access and delivery	5
National laboratory system	Laboratory testing for detection for priority diseases	5
	Specimen referral and transport system	4
	Effective modern point-of-care and laboratory-based diagnostics	3
	Laboratory quality system	3
Real-time surveillance	Indicator- and event-based surveillance systems	3
	Interoperable, interconnected, electronic real-time reporting system	2
	Integration and analysis of surveillance data	4
	Syndromic surveillance systems	4
Reporting	System for efficient reporting to FAO, OIE and WHO	3
	Reporting network and protocols in country	3
Workforce development	Human resources available to implement IHR core capacity requirements	3
	FETP[76] or other applied epidemiology training programme in place	4
	Workforce strategy	2

Technical areas	Indicators	Score
Preparedness	National multi-hazard public health emergency preparedness and response plan is developed and implemented	2
	Priority public health risks and resources are mapped and utilised	3
Emergency response operations	Capacity to activate emergency operations	2
	EOC operating procedures and plans	2
	Emergency operations programme	4
	Case management procedures implemented for IHR relevant hazards	4
Linking public health and security authorities	Public health and security authorities (e.g. law enforcement, border control, customs) are linked during a suspect or confirmed biological event	4
Medical countermeasures and personnel deployment	System in place for sending and receiving medical countermeasures during a public health emergency	2
	System in place for sending and receiving health personnel during a public health emergency	2
Risk communication	Risk communication systems (plans, mechanisms, etc.)	3
	Internal and partner communication and coordination	3
	Public communication	4
	Communication engagement with affected communities	3
	Dynamic listening and rumour management	4
Points of entry	Routine capacities established at points of entry	4
	Effective public health response at points of entry	4

Technical areas	Indicators	Score
Chemical events	Mechanisms established and functioning for detecting and responding to chemical events or emergencies	3
	Enabling environment in place for management of chemical events	3
Radiation emergencies	Mechanisms established and functioning for detecting and responding to radiological and nuclear emergencies	2
	Enabling environment in place for management of radiation emergencies	2

Scores

1 = No capacity
2 = Limited capacity
3 = Developed capacity
4 = Demonstrated capacity
5 = Sustainable capacity

From the *Antimicrobial Resistance National Strategy Framework: 2014–2024*: Strategic Framework for the AMR national strategy

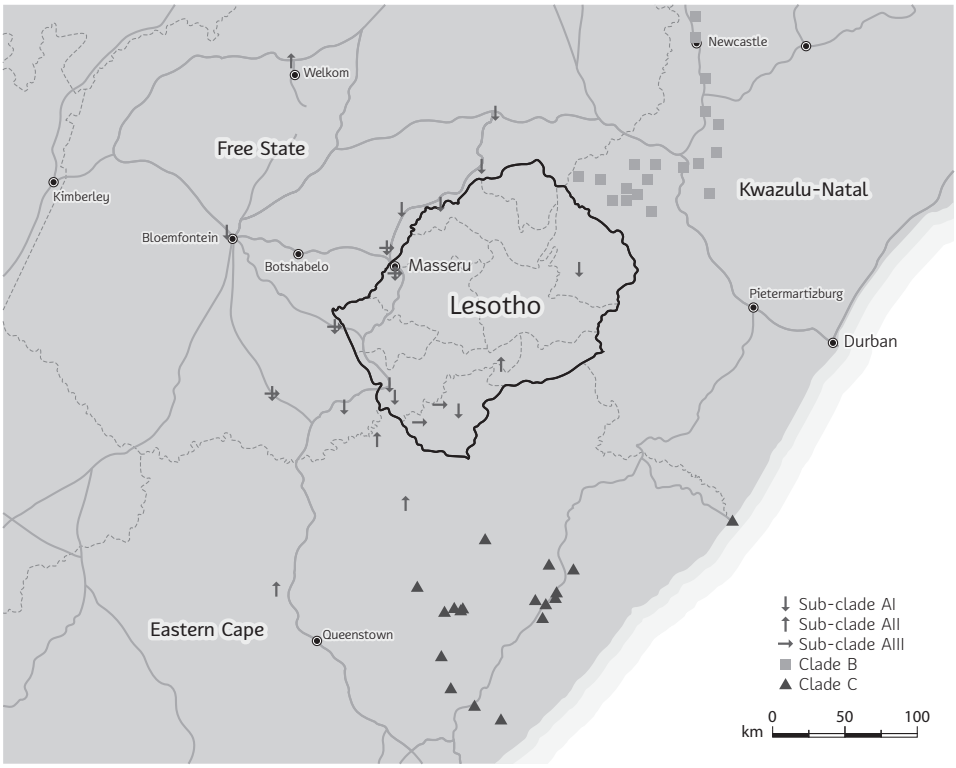
Strategic objectives	**Governance** National Intersectoral Committee Health establishment and district AMS committees and teams		
	Surveillance National surveillance system for: Resistant bacteria Antimicrobial usage Medication error reporting structures Antimicrobial quality	Prevention & Control IPC activities in the community and hospitals Immunisation against preventable infections IPC strengthening in public health (water & sanitation etc.)	Antimicrobial Stewardship Policies & Protocols Formulary restrictions Pre-authorisation Antimicrobial prescription forms National prescribing guidelines ***Stewardship at point-of-care*** Diagnosis of infection Appropriate antibiotic choice Dose optimisation, de-escalation and discontinuation
Strategic enablers	Legislative and policy reform for health systems strengthening Control of use and prescribing of antimicrobials in animal health Minimum standards and norms for health care quality systems and process (National Core Standards)		
	Education Incorporate AMR strategies into medical, nursing and allied health student curricula AMR/AMS CPD programmes for healthcare professions Sustained public health campaigns		
	Communication Patient advocacy as part of a patient-centered care approach Partnership with media, industry and other relevant stakeholders		
	Research – IPC, AMS interventions, diagnostics		

From the *South African Veterinary Strategy 2016–2026*: Prioritisation of Veterinary Strategy short-, medium- and long-term objectives

	Core Strategy	Short-term (1–3 years)	Medium-term (3–5 years)	Long-term (5–10 years)
Foundation	Strengthening of the veterinary authority for better governance	Establish specialised legal support system Establish national risk analysis unit Develop system of authorisation Veterinary and para-veterinary professional development	Develop joint programmes with stakeholders	Restore national chain of command for all aspects of veterinary services (changes in structuring)
Pillar 1	Strengthening competencies for animal health	Address the challenges of implementation of the Animal Diseases Act (Act 35 of 1984) Improve animal disease surveillance system	Run pilot project for brucellosis control in cattle (develop model) Develop and implement control programmes for other animal diseases	Establish effective and efficient administration for animal disease control
Pillar 2	Strengthening competencies for veterinary public health, feed and food safety	Define veterinary services' contribution to the national antimicrobial resistance strategy framework Consult and implements VPH strategic implementation plan (incl. IMI).	Develop a single Veterinary Medicine Act. Revise Meat Safety Act (Act 40 of 2000).	Establish effective and efficient administration for food safety system.

	Core Strategy	Short-term (1–3 years)	Medium-term (3–5 years)	Long-term (5–10 years)
Pillar 3	Strengthening competencies for veterinary laboratory diagnostics	Laboratory approval plan, including SANAS accreditation, to be further developed and consulted.	Expand laboratory capacity under veterinary services.	Expand laboratory capacity under veterinary services.
Pillar 4	Development and implementation of an Animal and Products Identification, Recording and Traceability (AIRT) System	Policy for individual animal identification and value chain traceability to be developed and consulted. Draft legislation Provide framework for animal identification. Develop government controlled database.	Implement legislation. Establish effective and efficient administration for AIRT system. Run pilot project on cattle.	Comprehensive animal movement recording and relevant controls.
Pillar 5	Strengthening competencies for animal welfare	Update/revise legislation. Establish national animal welfare unit. Animal Welfare Strategic Implementation Plan further developed and consulted.	Develop welfare guidelines for the keeping of various animal species and industries. Develop welfare guidelines for the various types of slaughter for the various animal species.	Implementation of all animal welfare legislation and standards.

Figure A.1: Map re-drawn from *Epidemiology of Rabies in Lesotho: The Importance of Routine Surveillance and Virus Characterization*



Inferred cross-border spread of endemic dog rabies between Lesotho and South Africa

B

Health Security Symposium report back

South Africa's Role in Strengthening Global Health

Security

Maria A. Papathanasopoulos and Martin Veller

Summary

The Faculty of Health Sciences at the University of the Witwatersrand, Johannesburg, South Africa, was tasked with hosting a Health Security Symposium, and did so under the auspices of the South African Committee of Medical Deans (SACOMD). It is an academic initiative which brought together experts to discuss and identify action items that South Africans can collaborate on to guide and support functions such as health surveillance (including the National Public Health Institute of South Africa or INAPHISA), the ability to respond to emergencies, and to lead and implement these action packages.

There are currently many frameworks which support countries as they prepare for health emergencies. These include the Pandemic Influenza Preparedness (PIP) framework, the Sendai Framework for Disaster Reduction, the Sustainable Development Goals (SDGs), Universal Health Coverage (UHC), and the Global Health Security Agenda, to name a few. South Africa has indicated interest in participating in the Global Health Security Agenda, and have subscribed to five packages, including being co-lead for the Laboratory systems package.

The goal of the symposium was to drive a sustained action for Health Security in South Africa, and to evaluate our role and readiness to scale up national and global efforts to prevent, detect and respond to public health emergencies. Overall, the one-day comprehensive programme stimulated discussions about a broad range of issues which affect Health Security – ranging from the impact of migration, land use change, climate change, food security and infectious (and non-infectious) disease threats. We were mindful that there was not enough time to consider all issues related to

wellbeing, bioterrorism, biosafety, etc. However, the symposium was successful in achieving its objectives, and it is envisaged that it is the first of many addressing this important issue.

The success of the meeting would not have been possible without the outstanding contributions of all participants and invited experts.

We would like to thank Sanlam for their generous financial contribution to the meeting.

The Invitation and Programme

The high-level symposium on *South Africa's role in strengthening global health security* took place on 7 March 2018, at the Michelangelo Hotel, Sandton, Johannesburg, South Africa. Attendance at the event was by invitation only, and included representatives from the Gauteng Department of Health (DoH), Limpopo DoH and Mpumalanga DoH, Medical Schools throughout the country (through SACOMD), the National Institute for Communicable Diseases (NICD), National Health Laboratory Services (NHLS), Médecins Sans Frontiers, private healthcare providers (Netcare) as well as funding organisations such as the Bill and Melinda Gates Foundation. Representatives from the Africa CDC and the WHO Regional Office for Africa were invited but unable to attend.

The event was an invaluable opportunity to hear first-hand from research leaders from various disciplines and to share details of ongoing programmes and solutions.

Symposium Programme

Welcome and opening remarks

The meeting was ceremonially opened by the Gauteng Health MEC, **Honourable Dr G. Ramokgopa**. Comments to the opening session were also provided by **Professor Martin Veller**, the Dean of the Faculty of Health Sciences, University of the Witwatersrand (Wits).

The MEC highlighted the importance of Health Security, and stressed that we – government, academia, professionals, development partners, etc. are all in it together, and must work as a team to strengthen systems and identify gaps. She discussed the 2014–2016 Ebola outbreak in West Africa, and the recent listeriosis outbreak which coincided with the measles outbreak in South Africa. She conveyed that we have the full support of the Minister of Health as well as her office in all our endeavours, and wished everyone well in their deliberations.


THE SOUTH AFRICAN COMMITTEE OF MEDICAL DEANS INVITES YOU TO ATTEND A SYMPOSIUM ON
SOUTH AFRICA'S ROLE IN STRENGTHENING GLOBAL HEALTH SECURITY
WEDNESDAY, 7 MARCH 2018
THE MICHELANGELO HOTEL, SANDTON
08H00—17H00
HOSTED BY THE UNIVERSITY OF THE WITWATERSRAND
KINDLY RSVP TO ANTONIA.APPEL@WITS.AC.ZA
UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG
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years

THE SOUTH AFRICAN COMMITTEE OF MEDICAL DEANS

SOUTH AFRICA'S ROLE IN STRENGTHENING GLOBAL HEALTH SECURITY

7 MARCH 2018, MICHELANGELO HOTEL

8.00	**REGISTRATION—*L'INCONTRO BALLROOM***
8.30	**WELCOME AND INTRODUCTION** Professor Martin Veller, Dean: Wits FHS and SACOMD Chair
8.40	**GAUTENG HEALTH MEC, Dr Gwen Ramokgopa**
8.55	**SESSION 1** All sessions will be chaired by Professor Shabir Madhi, Head: RMPRU, Wits
	ROLE OF NATIONAL PUBLIC HEALTH INSTITUTES IN HEALTH SECURITY Professor Lynn Morris, Director: NICD
	IMPLEMENTING THE INTERNATIONAL HEALTH REGULATIONS: HEALTH SECURITY FOR WHOM? Professor David Sanders, Emeritus Professor: SPH, University of the Western Cape
	SECURING THE BORDER? RESPONDING TO MIGRATION, MOBILITY AND HEALTH IN SOUTHERN AFRICA Professor Jo Vearey, Director: African Centre for Migration & Society, Wits University
	IMPACT OF FOOD AND NUTRITION SECURITY ON HEALTH OUTCOMES Professor Hettie Schönfeldt, CoE in Food Security, University of Pretoria
	VIRAL HAEMORRHAGIC FEVERS: AN ONGOING THREAT Professor Guy Richards, Academic Head: Critical care Wits & Director Critical Care CMJAH
	QUESTION TIME
11.10	**TEA**
11.30	**SESSION 2**
	PUBLIC HEALTH EMERGENCIES AND THE ROLE OF VACCINES Professor Helen Rees, Head: WRHI, Wits
	THE SOUTH AFRICAN SURVEILLANCE EFFORT IN THE GLOBAL MOMENTUM Professor Olga Perovic, GHSA Co-chair: Antimicrobial Resistance, NICD
	FULFILLING IHR REAL-TIME SURVEILLANCE REQUIREMENTS: NEW STRATEGIES FOR SURVEILLANCE OF NOTIFIABLE MEDICAL CONDITIONS IN SOUTH AFRICA Dr Portia Mutevedzi, GHSA Co-chair: Surveillance, NICD
	INNOVATIONS IN LABORATORY DIAGNOSTICS: KEY TO ADDRESSING GLOBAL HEALTH SECURITY Professor Wendy Stevens, HOD Molecular Medicine and Haematology, iLEAD, Wits/NHLS
	QUESTION TIME
13.00	**LUNCH**
14.00	**SESSION 3**
	OUTBREAK INVESTIGATION Dr Kerrigan McCarthy, Response, NICD
	BIORISK MANAGEMENT: THE CHALLENGE FOR AFRICA Dr Jacqueline Weyer, Zoonotic Disease, NICD
	PRIVATE SECTOR RESPONSE TO PUBLIC HEALTH OUTBREAKS Ms Mande Toubkin, Netcare
	PUBLIC SECTOR RESPONSE TO PUBLIC HEALTH OUTBREAKS Professor Feroza Motara, HOD: Emergency Medicine, Wits
	LAND USE CHANGE AND CLIMATE CHANGE: AMPLIFIED CONSEQUENCES FOR HEALTH Professor Barend Erasmus, Director: Global Change Institute, Wits
	QUESTION TIME
15.40	**TEA/COMFORT BREAK**
15.55	**ONE HOUR GENERAL DISCUSSION AND CLOSING REMARKS**

Summary of presentations

This report summarises themes of presentations/related presentations rather than attempting to provide a chronological summary of the discussions.

The Interim Executive Director of the NICD, **Professor Lynn Morris** provided a global context and framework of the International Health Regulations (IHR), and the Africa CDC, which was opened in January 2017, to help member states achieve compliance with the IHR, and the role of the NICD. South Africa contributes to five of the 11 packages of the Global Health Security Agenda, with staff at the NICD taking the lead on several of these. An overview of the NICD was provided – it is a national public health institute for SA, providing reference microbiology, virology, epidemiology, surveillance and public health research to support the government's response to communicable disease threats. It is thus viewed as a unique resource in Africa. Going forward, the NICD will be amalgamated into NAPHISA (National Public Health Institute of South Africa), which is expected to enhance health systems effectiveness. Currently, the NICD's surveillance platform consists of passive, laboratory-based surveillance: NHLS-Central Data Warehouse (CDW), enhanced laboratory-based surveillance: GERMS-SA, active, clinical-syndromic-based programs, Notifiable Medical Conditions (NMC), and outbreak responses. The Emergency Operations Centre was activated on 5 December 2017 to identify the source of the listeriosis outbreak in South Africa, through the coordinated response from a central resourced point.

Dr Kerrigan McCarthy, from the Outbreak Response Unit, Centre for Enteric Diseases, NICD, provided a detailed timeline of how the listeriosis outbreak investigation was conducted, and presented the evidence confirming the source of the outbreak. Following whole genome sequencing and 'DNA fingerprinting' of listeria isolates from patients, the NICD established that 95 per cent of isolates were sequence type 6 (ST-6), therefore it was necessary to find ST-6 in food, or in a food factory to identify the source. These findings were followed by comprehensive case-by-case analyses of the food history of patients with lab-confirmed listeriosis, which identified polony exposure as a risk. Food samples from the fridges of persons with lab-confirmed listeriosis were then tested, but none were positive for ST-6. A breakthrough occurred when a cluster of cases were reported on 13 January 2018, and food specimens (including polony) taken for culture were positive for *Listeria monocytogenes* (LM). This triggered targeted investigations/inspections of food factories (Enterprise and Rainbow), where ST-6 was isolated from the Enterprise

factory in the polony production line, and other LM strains implicated in clinical cases were identified from Rainbow. Overall, contamination of a processed meat facility, together with a systemic failure of their quality control procedures led to the largest outbreak of listeriosis ever recorded in human history. At the date of the conference, there were 984 reported cases with 180 deaths (cases were still mounting). Based on the NICD findings, on 5 March (two days prior to the Symposium), the Minister of Health, Aaron Motsoaledi, held a press release, leading to the recall of all Tiger Brands (Enterprise) products made at Polokwane and Germiston Factories, and RCL (Rainbow) polony products made at the Wolwehoek production facility.

Dr Portia Mutevedzi (Senior Public Health epidemiologist, NICD) expanded on the NMC surveillance strategies in South Africa, and fulfilling IHR real-time surveillance requirements. The NICD was tasked by the National DoH to develop an integrated, efficient and real-time NMC national surveillance system. New NMC regulations were passed in December 2017, requiring the development of new notification systems for 51 medical conditions (22 category 1 conditions reported within 24 hours). There was an assessment of the current notification processes and channels to identify limitations and learn from best practice. This resulted in the development of new notification systems and processes including: New integrated NMC case notification forms; NMC APP with web and mobile platforms to facilitate real-time electronic reporting by doctors and nurses at point of diagnosis; Case definitions; and Standard operating procedures and user manuals. The new surveillance tools and processes have been piloted and showed enhancement of laboratory and private sector-based reporting of NMCs. There has been engagement with all key stakeholders (Health Professions Council of South Africa, South Africa Nursing Council, Hospital Association of South Africa, Independent Practitioner Association and all vertical disease programmes for an integrated approach to NMC surveillance) and continued awareness campaigns at the time of the symposium. From March 2018, it is expected that there will be a move to the electronic real-time reporting and feedback platform, with real-time notification at point of diagnosis via the NMC APP (all health facilities) and laboratories, private hospitals and medical schemes data (automated real-time data inputs to the NMC database).

A global emerging threat is antimicrobial resistance (AMR). **Professor Olga Perovic**, pathologist in the Centre for HAIs, AMR and Mycosis, NICD, presented on the South African surveillance effort in the global momentum on AMR. It is estimated that by 2050, AMR will be responsible for over 10 million deaths globally, more than cancer. South Africa has taken

many steps to tackle this – South Africa is part of the Global Antibiotic Resistance Partnership (GARP) and a member of the WHO AMR-strategic and technical advisory group. All member states are actively implementing the global action plan on AMR. In 2011, South Africa conducted a situational analysis of the status of AMR in the country. This led to the SA DoH AMR National Strategy Framework (2014–2024) document, approved in October 2014. The World Health Assembly endorsed the Global Action Plan on AMR in May 2015 and the implementation plan for SA DoH AMR National Strategy Framework (2014–2024) was approved in June 2015. Additionally, in 2016 South Africa enrolled in the Global Antimicrobial Resistance Surveillance System (GLASS) to participate in a structured surveillance programme and provide reliable and complete demographic data, to support a standardised approach for the collection, analysis and sharing of data on AMR at a global level.

The talk subsequently focused on the SA national surveillance system on AMR. The NICD is the coordinating centre, in partnership with the public sector (NHLS laboratories across the country) and the private sector (Ampath, Lancet, Pathcare, Vermaak) to support GLASS. Available data on AMR surveillance was then presented. For example, looking at the *Klebsiella pneumoniae* isolates in South Africa from 2010 to 2012, the majority of the isolates (68.3 per cent) demonstrated the ESBL phenotype, with resistance to 3rd- and 4th-generation cephalosporins with multiple genes. During the same time period, 46 per cent of the *Staphylococcus aureus* isolates were Methicillin Resistant *Staphylococcus aureus*. **Professor Guy Richards**, Director of Critical Care, Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) and Wits, presented a captivating overview of Viral Haemorrhagic Diseases. He presented the 1996 Ebola Gabon outbreak, where a South African anaesthetic nurse became ill following contact with a Gabonese doctor (who had treated a patient from the disease epicentre) and had flown into South Africa. Despite >300 contacts, no further cases occurred in South Africa, primarily due to the availability of personal protective equipment (PPE), and appropriate instruction from infection control at the Johannesburg hospital. Some of the preparations were in place because of the 1976 Marburg outbreak. A detailed description of the Ebola virus disease outbreak of 2014 to 2016 followed. Ebola cases were reported in Guinea, Liberia and Sierra Leone. By 13 April 2016 after the WHO declared the West African epidemic over, there had been 28 652 cases (11 325 deaths). Alarmingly, >800 health care workers contracted the disease with nearly 500 losing their lives. Globalisation allows for the rapid spread of communicable diseases, and

during this outbreak, Ebola virus had been transmitted to seven countries including Nigeria, Senegal, the USA, the UK, Italy and Spain.

An additional Viral Haemorrhagic Disease case study was presented, where in 2008 a new arenavirus, named Lujo virus, was identified from a Zambian patient who died in South Africa, but infected several health care workers, some of whom also died.

The CDC states that Ebola virus can only be transmitted by direct contact with blood and bodily fluids. Transmission *is* primarily through this route, however, several animal studies had shown transmission without direct contact. In the 2014 outbreak, patients (and HCW using PPE) contracted Ebola virus despite no known direct contact, therefore it is conceivable that respiratory transmission may be a secondary mode of transmission as high levels of Ebola virus are found in the lung. This led Professor Richards and co-workers to challenge the WHO and CDC guidelines which recommend medical masks are used by health care workers and the CDC guideline for donning and doffing PPE. Both fail to mention protective head covering, boots or footwear. The CDC have subsequently changed their guidelines and N95 respirators are now a minimum precaution, however, the WHO have not.

The talk concluded with an overview of public and private health policies which need to be in place, isolation precautions and management, for prevention of Viral Haemorrhagic Diseases.

Professor Richards' talk was further complemented by two talks from **Professor Feroza Motara** (Head, Emergency Medicine, CMJAH and Wits) and **Ms Mande Toubkin** (Netcare), who outlined the South African public and private sector responses to public health outbreaks, respectively. They further expanded on co-ordinated health care responses to suspected Viral Haemorrhagic Diseases, major incidents and disasters. Both sectors recognise that Major Incident and Trauma System Management are an increasingly important component in overall disaster response, and have developed standardised approaches.

Additionally, Ms Mande Toubkin described Netcare's event and mass casualty capability, e.g. they assist with the 94.7 Cycle Challenge, Comrades Marathon, Two Oceans Marathon, A1 Grand Prix, etc. They have also sent teams to help with various disasters such as the Maputo Mozambique floods, Puket Thailand tsunami, Japan earthquake, Nigeria UN bomb blast, etc.

Along a similar theme **Dr Jacqueline Weyer**, Centre for Emerging Zoonotic and Parasitic Diseases, NICD, presented on 'Laboratory biorisk

management: the challenge for Africa'. Statistics from the USA show that five of 1 000 laboratory workers develop laboratory-acquired infections annually. No statistics for Africa exist. Of the laboratories in Africa that are accredited to international standards, more than 90 per cent are in South Africa. Additionally, of the BSL4 laboratories worldwide, there are only two BSL4 laboratories in Africa – in Gabon and South Africa. The outcome of the WHO joint external evaluation tool showed that of the African countries included in the evaluation, only two (South Africa and Uganda) had a 'whole-of-government biosafety and biosecurity system in place for human, animal and agriculture facilities' and three countries (South Africa, Tanzania and Uganda) had 'biosafety and biosecurity training and practices'.

Overall laboratory biosafety/biorisk guidelines for Africa are not available, and practice is based mostly on international guidelines, not taking into consideration resource constraints or informed risk assessment within the African context. There is a glaring lack of capacity for facility (equipment) construction/commissioning, and the biosafety profession is not well recognised in Africa. In summary, there is a need for contextualised guidelines and standards, resource allocation to ensure the development of a safe and secure laboratory infrastructure and competent workforce, and a compelling need to stimulate leadership in biorisk management in Africa.

The critical role of laboratories for Global Health Security was strongly emphasised by **Professor Wendy Stevens**, who presented on 'Innovations in Laboratory Systems: Key to addressing Global Health Security'. Surveillance is built on a backbone of high quality diagnostics. The detect arm of the GHSA action packages focuses on laboratories, and to be effective requires national connected networks, quality and monitoring, appropriate technology and a trained workforce, and ongoing research and development. However, many laboratories in Africa are hampered by lack of funding, skilled resources, good quality management systems, logistics and solid data collection and storage strategy.

Describing the laboratory landscape in South Africa, there is a nationwide connection of all laboratories. For example, the NHLS has networked 266 laboratories for all tests into one Central Data Warehouse (CDW). They perform >88 million tests annually, with an >780 routine assay repertoire. These numbers are increasing annually, and the increased demand for assays has already resulted in improved technology, with access to the information from anywhere in the country, and continuous R&D. Connectivity and data collection requirements are stringent. Data collection and analytics is critical to improve patient linkage to care. Hospital information systems interface to the data centre, and all patient laboratory

results are made available to health care workers via an internet service provider. The CDW can be used to create data dashboards for programme monitoring (e.g. ARV rollout), mapping service coverage (e.g. daily HIV viral load test volumes in districts, municipalities), etc.

Overall, 80 per cent of the South African population is service by the large NHLS laboratory footprint. Looking at integrated innovation (beyond the laboratory) to the clinic-laboratory interface, critical focus areas are the patient, the specimen, the transport of the specimen, the central laboratory, and system-wide connectivity. Professor Stevens introduced the iLEAD programme that aims to expand an African innovation laboratory network to accelerate the development of tools and products that will have measurable patient impact by improving laboratory services throughout Africa. This will be achieved by using a hub and network approach by leveraging existing regional skill and infrastructure, and begin the 'Inclusive Innovation Conversation' for lab systems in Africa.

Moving from infectious agents that threaten health security to other determinants – themes of politics and poverty also emerged. Dramatic inequalities dominate global health, and a social gradient in health exists in all countries and within cities.

Professor Jo Veary from the African Centre for Migration & Society at Wits presented 'Securing the border? Responding to migration, mobility and health in Southern Africa'. This is a highly politicised, ongoing issue, with many competing security agendas: politics and power; border management; sovereignty of nation states; securitisation of migration; justice; trauma; protracted crisis; fear of the other; public health and health security, etc.

Globally, there is a renewed focus on migration and health. Committing to the Sustainable Development Goals: leaving no-one behind, it is well-recognised that the dignity of the individual is fundamental. However, when looking at vulnerable populations, few of the current indicators are able to shed light on the particular situations of migrants and refugees. Health of migrants has been on the World Health Assembly Agenda since 2008. For the first time in 2016, Heads of State and Government came together to discuss, at the global level within the UN General Assembly, issues related to migration and refugees. This led to a process of intergovernmental consultations and negotiations culminating in 'The Global Compact for Safe, Orderly and Regular Migration', prepared under the auspices of the United Nations, which aims to cover all dimensions of international migration in a holistic and comprehensive manner, and is expected to be adopted in December 2018.

Southern Africa is associated with mixed migration flows. These are internal: cross-border and livelihood seeking; and forced migration: with urban refugees; marginalised and hidden migrant groups; spaces of vulnerability; where negative assumptions persist. The current public health responses do not engage with migration and mobility. This has implications for communicable disease control (TB and HIV, malaria), chronic treatment continuity as well as challenges in accessing the public system for non-nationals. Moreover, the public health and social welfare systems are overburdened and struggling, and challenges are raised in a context of high inequality where nationals are also struggling to access their basic rights. There is also structural violence, with increasing anti-foreigner sentiments and xenophobic attitudes. Migration management is associated with increased securitisation, a lack of regional responses, a restrictive immigration act, limited understanding of migration dynamics, violence, fear and the securitisation of health. What is needed is a public health approach to manage migration, mobility and health, a renewed regional conversation for developing a coordinated response to migration, mobility and health, and scaling up of good practice examples to develop migration-aware and mobility-competent health responses. Health passports, roadmaps for treatment access, referral letters, treatment packs for planned movements and patient held records were suggested. The talk ended with highlighting some key concerns, where nations co-opt a health security agenda to support the securitisation of migration and the potential for regression of rights for people on the move.

Professor Hettie Schonfeldt, from the Centre of Excellence in Food Security, University of Pretoria, discussed the impact of food and nutrition security on health outcomes. South Africa is facing a double burden of malnutrition. Those who are undernourished and food-insecure lack access to affordable and healthy foods, which has adverse effects on health and development. In most cases of under-nutrition, vitamin and mineral supplementation are essential, including critical nutrients, vitamin A, iron, zinc and iodine. However, maintaining a healthy diet becomes a subsidiary concern when there are multiple unmet social needs to address. On the other hand, over-nutrition and obesity are increasing the risk of non-communicable diseases such as diabetes and cardiovascular disease. Eight of the 17 leading risk factors for death are related to excess energy intake. The issue in South Africa is whether individuals have enough food and energy versus enough nutrients, and there are numerous instances where in the same households an adult is obese but a child is undernourished. It is evident that food insecurity is strongly linked to adverse health outcomes and healthcare costs.

Emeritus Professor David Sanders, School of Public Health, University of the Western Cape, who talked about implementing the IHR: Health security for whom? The International Health Regulations (IHR) are an international legal instrument that require member countries to report certain disease outbreaks and public health events to the WHO, to help the international community prevent and respond to acute public health risks that have the potential to cross borders and threaten people worldwide. The IHR define the rights and obligations of countries to report public health events, and establish a number of procedures that the WHO must follow in its work to uphold global public health security.

Four months after the WHO reported a major Ebola outbreak in Guinea, and it had already spread and become established in neighbouring Liberia and Sierra Leone, the WHO D-G drew on provisions made in the IHR to declare the outbreak a 'public health emergency of international concern' on 8 August 2014. Twenty days later the WHO launched its Ebola Response Roadmap. However, the response has been criticised as 'too little, too late' because the epidemic had spiralled out of control to become the biggest in history.

Following the release of the WHO report on the outbreak, Professor Sanders argued that the social determinants of the recent Ebola epidemic were missed. The recent Ebola epidemic affected three of the poorest countries in the world. Liberia, Guinea, and Sierra Leone are number 175, 179, and 183, respectively, out of 187 countries on the United Nations' Human Development Index. Many people in the affected region face chronic food shortages and extreme poverty. They may be forced by scarcity, to look for food in the forests, where they come into contact with animals harbouring the virus. Their health systems are ineffective and almost non-existent in many regions. Thus, the recent Ebola epidemic is one brought about by poverty and ruthless exploitation of the region's natural resources. The stark irony was pointed out that the lack of medical gloves in Liberia during the epidemic resulted in doctors and nurses either fleeing the hospitals, or becoming infected and dying – yet the country houses the 'largest single natural rubber operation in the world', the Firestone Natural Rubber Company. The evacuation of doctors infected with Ebola to Germany to receive treatment was rejected by the WHO during this time (foreign lives appear to be valued more highly than local lives).

Professor Sanders summarised that there is an urgent need to strengthen health systems in the region. In particular, there is a serious deficit of health workers, especially in rural areas, requiring major and sustained investment in health systems development and human resources. He

concluded by asking for the adoption of the 'One Health Concept' – to protect public health through policies aimed at preventing and controlling pathogens within animal populations, at the interface between humans, animals and the environment.

Continuing on the theme of impact of environmental factors on health, **Professor Barend Erasmus** from the Global Change Institute, Wits, presented a talk on 'Land use change and climate change: amplified consequences for health'. Data showing the increases in daily arctic temperatures in 2018 as compared to the average from 1958 to 2002 was presented. A global map showing temperature anomalies over time showed a shift in observed variance and means of northern hemisphere summer temperatures. Additionally, looking at African land temperature anomalies, there has been a 0.11°C/decade warming, relative to the 1910–2000 baseline. A dangerous climate change is considered 2°C, and in some land temperatures, some places have recorded up to a 1.5 per cent °C increase. Interestingly, South Africa is warming at double the global rate (predicted and observed). Looking at land use, there has been intensification (same use, but more intense), as well as change (different use, e.g. grazing lands changed into settlements). Land use change has resulted in forest loss, land degradation, wetland and biodiversity loss, freshwater depletion and contamination and urbanisation. Anthropocene is an epoch dating from the commencement of significant human impact on the Earth's geology and ecosystems, including, but not limited to, anthropogenic climate change. Overlaying climate change and land use change, the following health effects are obvious: 1). Direct (floods, heat, water shortage, exposure to pollutants); 2). Ecosystem mediated (changes in infectious disease risk, reduced food yields, mental health, cultural impoverishment); and 3). Indirect (consequences of livelihood loss, population displacement, conflict and maladaptation). The impact of weather on human health is a matter of increasing concern, especially in light of climate change. Studies in European cities have shown a direct effect, where a 1°C increase in maximum apparent temperature above the city-specific threshold resulted in a 3.12 per cent estimated overall change in all-natural mortality in the Mediterranean region and 1.84 per cent in the north-continental region. Additionally, stronger associations were found between heat and mortality from respiratory diseases, and with mortality in the elderly. For the African continent, the number of days with apparent temperatures >32°C has increased considerably, with implications for communities with pre-existing vulnerabilities (informal settlements, manual labourers, subsistence farmers, rain-fed agriculture, etc). Overall, climate variability and change may change density and increase the environmental conditions

which are conducive to vectors and pathogens. Climate changes disrupt exposure systems and social systems which favour disease distribution and epidemics, e.g. drought, urbanisation. In summary, studying the impact of climate and land use change on health may help mitigate risks and enhance health and security, however, there are limitations. Much of the existing literature has a narrow focus on a single health outcome. Thus, research methods and analyses that can deal with multiple causes and complex interactions are needed.

Public Health Emergencies of International Concern (PHEIC) and the Role of Vaccines were discussed by **Professor Helen Rees**, Executive Director of Wits Reproductive Health and HIV Institute. We cannot predict if pathogens will move from animal to human populations, but climate change, migration and war can disrupt fragile ecosystems that ordinarily contain threats. Factors such as climate change are an important driver of vector-borne diseases including those such as Zika and yellow fever transmitted primarily by *Aedes* mosquitoes. Additionally, increased urbanisation has contributed to yellow fever outbreaks. Preventative vaccines thus play a critical role in preventing outbreaks and public health emergencies. Professor Rees described the IHR process of how events (toxic, infectious, hazardous material, etc) detected by a national surveillance system are reported to the WHO, and the subsequent responses. The Director General can establish an Emergency Committee to provide views on whether an event constitutes a PHEIC, the termination of a public health emergency of international concern, and/or the proposed issuance, modification or termination of temporary recommendations.

There have been six IHR emergency committees since 2007, including responses to the pandemic influenza A (H1N1; status: closed), MERS-CoV (status: closed), poliovirus (status: ongoing), Ebola virus (status: closed), Zika virus and neurological disorders (status: closed) and yellow fever (status: dormant). Pandemic influenza recommendations included universal flu vaccine research prioritised in the Global Vaccine Action Plan. MERS-CoV recommendations included prioritising MERS vaccine development by the Coalition for Epidemic Preparedness innovation. Numerous candidate vaccines are in the pipeline. Recommendations for Zika included prioritisation of new technology: diagnostics, vaccines and therapeutics. Currently, there are 45 Zika vaccines in development, with six currently in human clinical trials. Polio recommendations for affected countries include ensuring that all residents and long-term visitors (i.e. > four weeks) of all ages receive a dose of bivalent oral poliovirus vaccine (bOPV) or inactivated poliovirus vaccine (IPV) between four weeks and 12 months prior to international travel. bOPV is offered at borders. Recommendations of the

Emergency Committee for yellow fever included establishing stockpiles, and mass vaccination, including fractional dosing due to limited vaccine supply.

With regards to the Ebola outbreak, several companies had completed non-clinical evaluation of vaccines, but none in humans. The recent outbreak in West Africa provided an opportunity to conduct Phase III trials with rVSV-ZEBOV and rVSV/ChAd3. None of nearly 7 000 participants who had been vaccinated developed EVD after nine days or more after vaccination, thus the rVSV-ZEBOV vaccine is capable of protecting vaccinated people. The WHO Strategic Advisory Group of Experts on Immunization (SAGE) issued recommendations on potential scenarios for use of Ebola vaccines. Currently, rVSV-ZEBOV is awaiting licensure (and was not used in the 2017 DRC outbreak).

The WHO developed an R&D blueprint for action to prevent epidemics, and listed priority pathogens against which medical countermeasures are urgently needed. The Coalition for Epidemic Preparedness Innovations (CEPI), launched in 2017, has chosen to target development of vaccines for MERS-CoV, Lassa and Nipah viruses.

In summary, although outbreaks have been curtailed using public health measures other than vaccination, vaccination should be part of an integrated strategy and complement other public health measures in order to effectively interrupt transmission.

Closing remarks

There were lively discussions throughout the day, which have helped identify some gaps in the South African landscape. The importance of starting the 'One Health Approach' conversation was strongly emphasised. This would require co-operation of relevant government departments, research institutions, researchers, NGOs and industry. Regulatory Science was identified as an element that requires further attention – it came to the fore with the Ebola epidemic, where there were no policies in place to import/export clinical samples timeously.

The comment was made that it is clear from the presentations that South Africa has 21st century institutions, but 19th century implementation. A stronger commitment from government is necessary to strengthen all health systems.

Endnotes

Executive overview

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1 – Nuclear and radiological: changing risks from apartheid to democracy

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Vital Signs: Health Security in South Africa builds on the assessment metrics provided by the WHO/JEE and the GHSIndex by presenting chapters commissioned from experts and practitioners with first-hand knowledge and/or direct experience in the following risk domains: nuclear, environmental, chemical, infectious disease, biological and climate-related threats. We touch on radiological, cyber-related and bio-engineering health risks and pay attention also to the financing barriers and opportunities for health security. The chapters provide narrative descriptions and analyses of the context, strengths, weaknesses and developments in each of the risk domains and end with a set of recommendations for upscaling prevention, detection and response to catastrophic events.

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