Dual-use research of concern landscape in Southeast Asia: prioritisation, gaps, and challenges

Caballero-Anthony, Mely; Montesclaros, Jose Ma Luis; Jeselyn; Trajano, Julius Cesar

2025

Caballero-Anthony, M., Montesclaros, J. M. L., Jeselyn & Trajano, J. C. (2025). Dual-use research of concern landscape in Southeast Asia: prioritisation, gaps, and challenges. Applied Biosafety. https://dx.doi.org/10.1089/apb.2024.0055

https://hdl.handle.net/10356/182976

https://doi.org/10.1089/apb.2024.0055

Note: This is the accepted version of the article with citation below:

- Caballero-Anthony, M., Montesclaros, J. M. L., Jeselyn and Trajano, J.C. (2025). Dual-Use Research of Concern Landscape in Southeast Asia: Prioritization, Gaps, and Challenges. *Applied Biosafety* 2024-0055. https://doi.org/10.1089/apb.2024.0055

To access the published version, please refer to the link above.

TITLE PAGE

DURC Landscape in Southeast Asia: Prioritisation, Gaps, and Challenges

Mely CABALLERO-ANTHONY, [1] Jose Ma. Luis MONTESCLAROS,[1] JESELYN[1] and Julius Cesar TRAJANO[1]

Authors' Affiliation

[1] Centre for Non-Traditional Security Studies, S Rajaratnam School of International Studies, Nanyang Technological University, Singapore

Corresponding Author

Mely Caballero-Anthony, ismcanthony@ntu.edu.sg, Block, S4, Level B3, 50 Nanyang Avenue, Singapore 639798

Keywords

Dual-Use Research of Concern; Biosecurity; Southeast Asia; Biological Risk; Biosecurity Governance

Authors' Contribution

All authors confirm responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding statement

This study is part of a grant under the Asia Centre for Health Security.

DURC Landscape in Southeast Asia: Prioritisation, Gaps, and Challenges

Mely Caballero-Anthony, Jose Ma. Luis Montesclaros, Jeselyn, and Julius Cesar Trajano

Abstract

This article examines the governance of Dual Use Research of Concern (DURC) in Southeast Asia, highlighting both progress and persistent gaps in biosafety and biosecurity. While significant developments have been made in biosafety and biosecurity, the region remains underprepared to address the complexities of DURC. This under-preparedness stems from diverse factors, including varying levels of exposure to biosecurity threats across countries, competing priorities within national biosecurity agendas, limited awareness of DURC issues, and weak institutional capacity to implement effective oversight mechanisms. These factors create inconsistencies in the implementation of DURC governance across countries, undermining efforts to establish robust safeguards against potential misuse of scientific research. The article argues that addressing these domestic issues is crucial for building more effective DURC governance frameworks. Strengthening national policies, improving institutional capabilities, and fostering awareness of DURC risks are essential steps toward mitigating biosecurity threats and ensuring the responsible conduct of research within the region.

I. Introduction

Why Southeast Asia

Asia is among the fastest growing markets for biotechnology products today given dynamics such as its rising middle class, aging populations, and growing healthcare programmes.[1] By one estimate, the global biotechnology market was valued at USD1.38 trillion in 2023, with the Asia-Pacific contributing approximately 24% of global revenues (as of August 2024).[2] Asia's biotechnology market has been projected to grow the fastest across regions globally from 2023. [3]

Southeast Asia has seen a rapid growth in its biotechnology industry, which accelerated significantly in the face of the COVID-19 pandemic.[1] The BioPharma APAC Insight Series for instance identified Singapore's growing biopharmaceuticals hub; Thailand's rapidly growing industry; Vietnam's heavy investment in healthcare infrastructure; and Indonesia's growing population of 270 million and large and growing middleclass, which make the region a significant market for biopharmaceutical companies that rely on biotechnology. Beyond these, the other promising players in the Asia-Pacific region include China's Shanghai province, Taiwan, New Zealand, and Melbourne, owing to increased R&D activity. This has led to rapid compound annual growth of 16.8% in the Asia Pacific Region from 2023 to 2028.[4]

Southeast Asia is also an important region for biotechnology from both geoeconomic and geopolitical perspectives. According to Gong Xue, the growing demand for biotech

products has resulted in a significant influx of active pharmaceutical ingredients (APIs) from China, which are essential raw materials for biotech production. She noted that China is now the largest supplier of APIs to Indonesia, Vietnam, and other Southeast Asian countries. This trend has made Asia a potential battleground for competition in biotech innovation between China and the United States.[5]

There have been concerns whether the rapid growth in biotech research and development in the region, could also pose a risk if the new knowledge developed fell into the wrong hands and were used for malicious purposes. Dual-Use Research of Concern (DURC) refers to "research that is intended to provide a clear benefit, but which could easily be misapplied to do harm,"[6] and this may be applicable to cases of laboratory accidents, as well as targeted biocrime and/or bioterrorism and the development of biological weapons. This concept has gained significant attention in global security discussions, especially in Western countries, where comprehensive policies have been developed to mitigate the risks associated with DURC.[7]

Objectives and Research Question

This article explores the DURC landscape in Southeast Asia, building on an earlier report, "Emerging Biosecurity Landscape in Southeast Asia", published by the S Rajaratnam School of International Studies in collaboration with the Asian Centre for Health Security**.**[8] The report's **coverage of biosecurity/biological threats included risks** of emerging/re-emerging infectious diseases; laboratory accidents; biotech/dual use research of concern; and deliberate/bioterrorism, which may cause harm to humans. In the said report, we considered **"biological threats" and "biosecurity threats" interchangeably**, as representing threats from biological agents that can be harmful to humans." We followed the WHO's definition of **biological agents** in its "Global Guidance Framework for the Responsible Use of the Life Sciences" (hereafter "Global Guidance Framework"), as "A microorganism, virus, biological toxin, particle or otherwise infectious material, either naturally occurring or genetically modified, which may have the potential to cause infection, allergy, toxicity or otherwise create a hazard to humans, nonhuman animals or plants."[1] The WHO's 2014 guide to EIDs and zoonoses, also considers that "different pathogen classes include viruses, bacteria, fungi and prions,"[1] and that a **pathogen**, is as "**an infectious agent (a germ) that is capable of causing disease in a human, animal or plant host**". While the report focused on the broader aspect of biosecurity, this article focuses on the DURC aspect of biosecurity and raises the following questions:

1. How big a concern is DURC to states in Southeast Asia?
2. To what extent are concerns on DURC reflected in the states' policies and commitment to international biosecurity regimes?
3. Do the regional states have the necessary protocols and practices for effective DURC governance at the national level?

In examining these questions, we argue that while Southeast Asia has made strides in biosafety and biosecurity, the region remains underprepared for addressing DURC.

This lack of preparedness can be attributed to a combination of differing security priorities, limited awareness, and weak institutional capacity. Southeast Asia has traditionally focused on addressing immediate security challenges such as political instability, public health issues, and economic development. This has resulted in placing biosecurity risks such as the DURC lower on their agenda. A comparison of national policies and regional efforts will highlight where gaps exist and what steps can be taken to improve the governance of dual-use research. This analysis is timely, given the increasing role that biotechnology plays in the region's economic and scientific development, and the potential security challenges that come with it.

The paper is structured as follows. Section **II** will discuss briefly the methodology applied in this study, followed by the findings (section **III**) from our brief assessment addressing the two research questions. Section **VI** presents our discussion of potential explanations for the differences in attention to DURC within Southeast Asian countries. Section **V** concludes.

II. Methodology

This paper comprises two stages of assessment. Part I of the assessment examines the prioritisation by countries of DURC based on national statements in BWC meetings and conventions, while Part II examines how this prioritisation (based on national statements) is reflected in the policies adopted on the ground, in the five Southeast Asian countries included in this study (Indonesia, Malaysia, Thailand, the Philippines, and Singapore).

Part I methodology

A comparison of how DURC is prioritised among policymakers in Southeast Asia and the rest of the world necessitates a comparative basis for accounting for the existing levels of prioritisation to begin with. Yet, there is currently no existing explicit reference point for comparing DURC policies. The next best approach is to compare DURC-*related* policies in the present day based on the latest related literature, as was done in a paper commissioned by the United States Committee on Dual Use Research of Concern in 2017.[i] Piers Millet was tasked with assessing the gaps in international governance of DURC.[9] According to Millet, the Biological Weapons Convention (BWC) is likely "the logical international forum through which to address DURC" from a governance perspective. The BWC is a treaty that prohibits the use of biological and toxin weapons in warfare. In the 2017 report by Millet, he observed that the importance of DURC was highlighted in reports by the US, the Russian Federation, the Republic of China, and the Commonwealth of Australia, given the 'dual use potential' in some of the research conducted in these countries."[9] We examine and compare whether there is *any* mention (whether *implicit* or *explicit)* of research and/or DURC within BWC-related reports by the five Association of Southeast Asian Nations (ASEAN) member states, focusing on the latest reports available. It is important to note that despite its heightened global interest following the Severe Acute Respiratory Syndrome (SARS) outbreak, attention to DURC as a policy and security issue has

remained relatively scarce in Southeast Asia. Discussions on DURC are typically embedded within broader conversations about biosafety, biosecurity, and emerging biological risks. It was only in 2014 that Malaysia explicitly raised concerns about DURC in the context of bioterrorism.[10]

Part II methodology

The data for Part II of our assessment, on the adoption of DURC policies the ground, was collected through two primary methods: semi-structured interviews with subject matter experts and a thorough review of relevant governmental documents, policies, and draft legislation. This mixed-methods approach was chosen to ensure both qualitative insights from experienced professionals and contextual understanding from official regulatory frameworks across Southeast Asia.

The semi-structured interviews were conducted with 32 experts from five Southeast Asian countries: Indonesia, Malaysia, Thailand, the Philippines, and Singapore, spanning from March 2024 to September 2024.[ii] These experts come from diverse professional fields, including health, security, academia, laboratory management, and biology. They were selected for their specialised knowledge in biosecurity, biosafety, and biotechnology, ensuring a well-rounded perspective on the issues at hand. The interviews focused on topics such as national biosecurity policies, gaps in current governance frameworks, DURC oversight, the rapid development of biotechnology, cyberbiosecurity concerns, bioterrorism, and regional cooperation.

In addition to the interviews, a comprehensive review of government documents, policies, and draft legislation was conducted to supplement and contextualise the qualitative data. This included publicly available documents, such as national biosecurity strategies, laboratory biosafety and biosecurity guidelines, and relevant legislative drafts concerning biosecurity governance in the five countries under study. This in-depth document analysis helped to identify regulatory gaps and variations in national approaches to biosecurity and DURC, providing a crucial backdrop to the expert interviews.

III. Findings

Part I: Assessment: How do Southeast Asian countries compare in prioritising DURC, based on National Statements in BWC Reports/Commitments?

All five of the ASEAN members included in our study had ratified the BWC (Appendix table A1). Adding to this, we also examined the submission by countries of reports to the UN Security Council (UNSC) as regards UNSC Resolution (UNSCR) 1540 applying controls to prevent non-state actors (i.e., potential terrorists) from gaining access to weapons of mass destruction and found that all countries have made submissions. Therefore, while the ratification of BWC,[11] and the submission of UNSCR 1540 national implementation reports were common among the five states, this does not indicate that they will necessarily have more policies to regulate DURC.[12]

One potential caveat to using only the BWC ratification as basis for assessing the importance of DURC to countries, is that there was previously limited attention paid to this kind of research in BWC meetings, and it was only in the mid-2000s when DURC was raised during these meetings. As noted by Millet there was no mention of DURC in the outcome document of the BWC's 2002 Fifth Review Committee, although it appeared twice in the outcome document of the 2006 Sixth Review Conference.[9] According to Millet, it was the 2008 Report of the BWC Meeting of State Parties that had explicit reference of the "value of being informed about advances in bio-science and bio-technology research with the potential of use for purposes prohibited by the convention" as well as "the necessity of strengthening ties with the scientific community" was made.[9] In the same report, oversight measures were brought up although efforts were made to avoid language that would create "undue restrictions on scientific research, development, publication and biotechnology." [9] Thus, it was only in 2008 when the terms "dual-use" and "dual-use research" appeared in the report. Millet further observed that it was in the 2010s when more significant attention was given to DURC.

And so, we attempt a comparison of DURC prioritisation within Southeast Asia, following Millet's methodology. We examine and compare whether there is mention of research and/or DURC within BWC-related reports by the five ASEAN member states, focusing on the latest reports available, namely i) National Statements to 2023 Biological Weapons Convention — Meeting of States Parties;[13] ii) National Statements to Review Conference of the BWC;[14] and iii) national reports in the Biological Weapons Convention National Implementation Measures Database.[12] A summary of our findings is presented in Table 1 below, followed by further details on how we arrived at this assessment.

Table 1: Summary of Relevance of DURC in National Statements to BWC Meetings/Conferences

Country	**2023 Biological Weapons Convention — Meeting of States Parties**	**2022 9th Review Conference of BWC**	**Biological Weapons Convention National Implementation Measures Database**
Indonesia	**Yes, Explicit:**	Yes, Indirect	**Yes, Explicit**
Malaysia	Yes, Indirect	Yes, Indirect	N/A (No update)
Philippines	Yes, Indirect	Yes, Indirect	**Yes, Explicit**
Singapore	Yes, Indirect	Yes, Indirect	**Yes, Explicit**
Thailand	Yes, Indirect	**Yes, Explicit**	**Yes, Explicit**

Sources: United Nations Office for Disarmament Affairs,[11,13] United Nations 1540 Committee[12]

1. 2023 BWC Meeting of State Parties – National Statements

We find that Southeast Asia is rather late to the game as far as DURC is concerned. Based on national statements during the latest **2023 Biological Weapons Convention — Meeting of States Parties,** there is still no explicit recognition of research or "dual-use" in most countries, with the exception of Indonesia, as part of their national statements, and only implicit mention in the rest of the countries.[13] (**Table A2** in the appendix contains further details on the relevant statements in this regard).

2. 2022 Ninth Review Conference of the BWC –National Statements

Did DURC figure in the national statements of countries during the latest 9th Review Conference of the BWC?[14] Our findings show that only Thailand explicitly mentioned it as a priority in its national BWC statements. Across four of the countries studied, there was only implicit mention of DURC. (**Table A3** in the appendix contains further details on the relevant statements in this regard).

3. Biological Weapons Convention National Implementation Measures Database

Finally, we reviewed the summaries of country practices under the "Biological Weapons Convention National Implementation Measures Database."[12] We observe explicit mention of gain-of-function research and dual use research in four of the five countries, except for Malaysia where there is no information on the UN ODA website. (**Table A4** in the appendix) contains further details on relevant statements in this regard).

4. Summary and Questions that Remain

While all countries have already ratified the BWC, this brief review value adds by assessing whether DURC is in the BWC national statements or measures reported by the five Southeast Asian countries, and whether the mention of research or DURC in these statements is explicit or implicit.

Firstly, based on the National Implementation Measures Database for the BWC, **all the countries have explicitly mentioned that there is some degree of oversight over the DURC** (this is with the exception of Malaysia where the website indicates that its webpage is still under development). The explicit reference to research/DURC is further supported by one or more laws or policies on DURC oversight, such as Articles 335 and 336 of "Health Law" in **Indonesia's case**; "Manual of Laboratory Biosafety and Biosecurity Standards" in the **Philippines' case**; Section 39 of the "Biological Agents and Toxins Act 2005" in **Singapore's case**; and Sections 6 and 28 of the "Pathogens and Animal Toxins Act B.E. 2558" (2015) and Section 4 of the Section 28 of "Announcement of the Ministry of Public Health Re: rules, procedures and conditions" require that agencies must establish a biosafety control committee (2017), in **Thailand's case**.[12]

Secondly, the review in Part I of our assessment finds that despite the existence of these laws/policies, the trend is that DURC is **often only mentioned indirectly within national statements** during BWC meetings/conventions. It was only explicitly mentioned by one of the five countries in the 2023 Biological Weapons Convention —

Meeting of States Parties (i.e., Indonesia)[13] and, and by one of the five countries in the 2022 9th Review Conference of BWC (i.e., Thailand).[14]

Therefore, there is a lack of consistent explicit mention of DURC in the latest national statement reports among most of the countries, indicating a potential lack of saliency of the issue in those countries. We now complement this with further sensing of the actual adoption of DURC policies, in the next section.

Part II. Assessment based on DURC Governance Practices in Five ASEAN Countries

To complement our analysis above, we conducted further comparisons of laws and policies on the ground. The assessment of country-level DURC governance practices focuses on four key aspects, namely, **i) Legal Measures on DURC**; **ii) List of Security Sensitive Biological Agents (SSBAs)**; **iii) establishment of an Institutional Biosafety (or Biosecurity/ Biorisk) Committee;** and **iv) the presence of Agencies to govern DURC governance practices.** Our findings are summarised in **Table 2** and **further elaborated in this section.**

Table 2: Findings on DURC Governance: i) Oversight, ii) list of control pathogens, iii) IBC, and whether and IBC is mandatory, iv) oversight agencies

Countries	**Legal Measure**	**List of Security Sensitive Biological Agents (SSBA)**	**Institutional Biosafety (or Biosecurity/ Biorisk) Committee**	**Oversight Agencies**
Indonesia	Guidelines	Draft	Voluntary	No
Malaysia	Guidelines	Draft	Voluntary	No
The Philippines	Guidelines	Draft	Voluntary	No
Thailand	Law (implicit mention only of DURC)	Yes	Mandatory	Yes
Singapore	Law (explicit mention of DURC)	Yes	Mandatory	Yes

Source: Team analysis based on interviews as described in methodology

1. Summary

There is significant diversity in DURC implementation across the 5 countries studied in this article. Of the five, only Singapore has the most robust biosecurity regime in

terms of i) Legal Measures on DURC; ii) List of Security Sensitive Biological Agents (SSBA); iii) an Institutional Biosafety (or Biosecurity/ Biorisk) Committee; and iv) the presence of Agencies to govern DURC governance practice. Following Singapore, Thailand also has ii) SSBA list and iii) IBCs, but its PATA law only indirectly addresses DURC (only implicitly mentioned in law, on Pathogens with Pandemic Potential or PPP). The rest of the countries have not yet passed comprehensive laws governing DURCs; had only draft SBA lists; had only voluntary (and not mandatory IBCs); and no dedicated body for DURC oversight.

2. DURC Governance in Southeast Asia

i. Legal Measures on DURC

DURC governance remains inconsistent across Southeast Asia, with varying degrees of legislative frameworks, policies, and implementation mechanisms among nations. Indonesia currently lacks a national framework, legislation, or dedicated agency to address DURC, leaving a significant gap in its biosecurity landscape. Although Indonesia is a signatory to the BWC, which began explicitly addressing DURC in the 2012 Meeting of Experts, the country has yet to develop a comprehensive strategy for assessing or regulating dual-use research.[9,15] A draft Biological and Toxin Weapons Bill, proposed in 2015, included provisions for mandatory licensing and registration for facilities handling controlled biological agents. However, as the bill remains unenacted, the regulatory system envisioned has not materialised, leaving areas like virology and synthetic biology potentially vulnerable to misuse.

Malaysia, while similarly lacking national legislation and a dedicated agency for DURC, has focused on awareness-building and voluntary guidelines. **The Laboratory Biosafety and Biosecurity Policy and Guidelines (2015)** encourage institutions to establish Institutional Biosafety and Biosecurity Committees (IBBCs) to oversee research activities.[16] Additionally, **the Malaysian Educational Module on Responsible Conduct of Research (RCR),** introduced in 2018, includes a chapter dedicated to dual-use risks, emphasising a culture of safety and responsible science.[17]

The Philippines addresses related DURC concerns through **the Strategic Trade Management Act,** which regulates the trade of hazardous materials, including biological agents and associated technologies.[18] The Department of Health has also issued in 2023 the Laboratory Biosafety and Biosecurity Standards Manual which serves as a reference document to update local laboratory biosafety and biosecurity guidance.[19] However, this law and guideline do not extend to the oversight of DURC or related research activities, leaving a gap in managing dual-use risks domestically.

In Thailand, DURC is indirectly governed under **the Pathogens and Animal Toxins Act (PATA)**, first enacted in 2015 and amended in 2020.[20] While PATA does not explicitly mention DURC, it mandates licensing and strict biosafety and biosecurity measures for individuals and organisations handling high-risk biological materials. This provides a foundational framework for mitigating dual-use risks, though without explicit DURC-specific provisions.[20]

Singapore stands out for its robust and comprehensive measures to prevent the misuse of laboratory research and address DURC. **The Biological Agents and Toxins Act (BATA)**, enacted in 2006, regulates the possession, use, transfer, and transportation of biological agents, ensuring strict control of research activities.[21] Complementing this is **the Biorisk Code of Conduct for the Life Sciences Industry and Professionals**, which aligns with international standards such as the BWC and WHO biosecurity guidelines.[22] Singapore also includes dual-use goods and research under its **Strategic Goods Control List**, further strengthening its capacity to regulate and mitigate DURC.[23]

ii. List of Security Sensitive Biological Agents (SSBA)

Several Southeast Asian countries are in varying stages of developing or revising national lists of Selective and Sensitive Biological Agents (SSBA), with some already establishing frameworks and others still working through logistical and regulatory challenges. In Indonesia, a national SSBA list has been drafted and is pending approval by the parliament. This effort, led by the Indonesian One Health University Network (INDOHUN) and the Indonesian Biorisk Association (ABI) with support from the United States. The Biosecurity Engagement Program (BEP), aims to regulate various aspects of SSBA management, including pathogen definitions, storage protocols, and research activities. However, there is a significant delay due to disputes over which ministry or agency should take responsibility for publishing the document.[24]

Malaysia has also worked on a list of sensitive biological agents, which is part of the broader Biological and Toxin Weapons Bill (BWC Implementation Bill). However, like Indonesia, the country has faced delays due to conflicting interests and political obstacles, with the bill and the SSBA list remaining stalled since 2015. Malaysian biosecurity experts are still reviewing the list, and until the bill is passed, there is limited formal oversight of these agents.[25]

Meanwhile, the Philippines has a draft SSBA list created by local biosecurity experts and government agencies, “but it has not yet been finalised and published due to ongoing delays with the related comprehensive BWC and biosecurity legislation,” according to a Filipino biosecurity expert who helped develop a draft list.[26]

This situation contrasts with Thailand, where the PATA includes a controlled list of regulated agents. The PATA categorises dangerous pathogens into four groups, based on risk factors such as prevention methods, treatment, and potential impact on humans and animals. While Thailand has already established this classification, the absence of an explicit DURC framework leaves room for improvement in the comprehensive regulation of dual-use risks.[20]

Finally, Singapore has already implemented a comprehensive and regularly updated SSBA list. This list is part of a broader regulatory effort that includes the BATA and aligns with international biosecurity standards. Singapore's advanced approach to biosecurity is exemplified by its Programme for Research in Epidemic Preparedness

and Response (PREPARE), which specifically focuses on viruses with pandemic potential.[27] This proactive research agenda demonstrates Singapore's commitment to mitigating biosecurity risks through scientific innovation and preparedness.

iii. Institutional Biosafety (or Biosecurity/Biorisk Committee)

Institutional Biosafety Committees (IBCs) play a crucial role in managing biosecurity risks, including DURC in Southeast Asia. However, just like the two previous indicators, the implementation and effectiveness of IBCs vary widely across the region. In Indonesia, IBCs are underdeveloped or absent in many research institutions. While some universities have IBCs, their scope is usually limited to basic biosafety concerns, and they often lack the training or guidelines to assess DURC potential. This gap leaves Indonesia's research institutions vulnerable to the misuse of dual-use technologies. An expert in Indonesia noted “that life scientists and researchers are not aware that their research might already have DURC elements, underlining the need for a more robust and informed IBC framework to address this issue effectively.”[24]

IBCs are also not mandatory in Malaysia, and it is estimated that only 30 percent of public universities have established one. Even where IBCs exist, they often face challenges due to a lack of specialised knowledge in DURC and lengthy approval processes. Research proposals can take months to be reviewed, which could delay the identification of potential dual-use risks.[28] Malaysia’s reliance on voluntary compliance, coupled with limited institutional capacity, hinders timely intervention in research with possible dual-use implications.

The Philippines has a similar system, where the establishment of Institutional Biosafety and Biosecurity Committees (IBBCs) is not mandatory for BSL-3 laboratories, but these committees do review and approve research involving high-risk pathogens. However, Filipino laboratory biosecurity experts claimed that “the lack of IBBCs in smaller universities creates security gaps, as these institutions are less likely to detect and address DURC risks.”[29]

On the other hand, section 28 of Thailand's PATA mandates that agencies conducting research establish biosafety control committees, providing a clearer regulatory framework for overseeing research involving sensitive biological agents.[20] Additionally, the Ministry of Public Health’s 2018 Notification (Book 135, 43 Ngor) also requires annual reporting on research activities, which contributes to more structured oversight but does not specifically address DURC.[30] Singapore has a more structured approach, with the BATA requiring facility operators to establish a biosafety committee. These committees are responsible for ensuring that no research is conducted without a risk assessment, ensuring a higher level of oversight for potential DURC activities.[21,31]

iv. Presence of Oversight Agencies to Govern DURC Governance Practices

In Southeast Asia, the oversight of DURC also remains inconsistent, with varying levels of institutional involvement and regulatory frameworks. Indonesia, for instance,

has published a Code of Conduct on Biosecurity through the Indonesian Academy of Sciences, which includes guidelines for handling dangerous pathogens, toxins, and pathogens with pandemic potential (PPP), but lacks regulatory oversight or a dedicated national agency to govern DURC.[15] Similarly, Malaysia has not enacted any specific legislation or created an agency to regulate DURC.[25] While both countries have initiated some biosecurity frameworks, they lack the formal structures and dedicated bodies required to fully address the risks associated with dual-use research.

The Philippines has a strong institutional presence through the Research Institute for Tropical Medicine (RITM), which operates high-containment laboratories for researching dangerous pathogens.[32] However, the country lacks a national-level agency dedicated solely to overseeing DURC in laboratories or the biotechnology sector, leaving gaps in governance. Filipino biosecurity experts have highlighted the risk of DURC in research, even within the state's high-security laboratories, suggesting a need for more comprehensive oversight.[33]

In comparison, Thailand has made significant strides by establishing the Department of Medical Sciences under the Ministry of Public Health to oversee research involving dangerous pathogens, especially those with pandemic potential.[30] Research institutions are encouraged to create Institutional Biosafety Committees (IBCs) to review and approve projects involving high-risk biological agents.[34] However, despite these efforts, there is still no standardised approach to evaluating DURC potential in research. The lack of a clear mandate for DURC assessment at the institutional level weakens Thailand’s biosecurity framework in this regard.

Singapore’s approach to DURC oversight is more established, relying on existing regulatory frameworks and collaborative efforts between multiple government agencies. The Genetic Modification Advisory Committee (GMAC), in coordination with agencies such as the Ministry of Health and the Singapore Food Agency, provides a robust system for assessing the potential risks of DURC in research involving genetically modified organisms (GMOs), viruses, and toxins.[35] Singapore’s Biological Agents and Toxins Act (BATA) requires BSL-3 laboratories to have IBCs that assess research proposals and recommend risk mitigation strategies, ensuring that dual-use risks are thoroughly reviewed and managed. This integrated, multi-agency approach places Singapore ahead in terms of addressing DURC within the region.[31]

IV. Discussion: Potential explanations

We discuss four potential explanations why DURC in the five ASEAN countries’ practices, have been unevenly adopted, with limitations in most of these countries.

- ### Differing degrees of prior exposure to biological attacks/threats

In many Western countries, high-profile cases such as the 2001 anthrax attacks in the U.S. and the rapid development of synthetic biology have heightened the awareness of dual-use risks.[36] These events served as catalysts for the implementation of robust

DURC regulations and oversight mechanisms. In contrast, Southeast Asia has been slower to develop similar frameworks, even though the region's growing biotechnology industry and the increasing complexity of research capabilities make DURC a relevant concern. Furthermore, incidents of accidental laboratory releases or the high likelihood for bioterrorism in Southeast Asia underscore the importance of addressing these risks, yet national policies and capacities remain limited.

One of the potential reasons why Singapore has the most robust biosecurity regimes, is its previous exposure to multiple biosecurity threats. Over the past two and a half decades, Singapore has experienced and battled various biological events - 1999 Nipah outbreak, 2001 anthrax hoaxes, 2003 SARS epidemic, 2009 H1N1 pandemic and numerous influenza outbreaks as well as the recent COVID-19 pandemic and mpox cases. In this regard, the establishment of national containment BSL laboratories in recent years has been for the strengthening of Singapore's health security and pandemic preparedness. But certain research may cause harm through accident or misapplication. A Singapore biosecurity professional stated that "with this kind of research activities involving dangerous pathogens, guidelines and proper conduct standards are needed, along with effective oversight by institutions and leadership (i.e. robust risk management)." [31]

- Competing Priorities of other Biosecurity Threats

Another explanation could be the differing security priorities. For instance, the absence of effective oversight of DURC can be traced to weakness in the broader biosecurity governance in the Philippines (of which DURC governance is only one of its components). The delay in establishing nationwide SSBA list also highlights the challenges countries in the region face in developing effective biosecurity frameworks and aligning priorities. In our interview with Filipino laboratory biosecurity practitioners, they noted that:

"More attention and resources are invested in biosafety than in biosecurity. The absence of a comprehensive biosecurity legislation poses a big challenge to effective responses to bioterrorism and DURCs. Currently, it is not in the legislative priority of the Philippine Congress as it has low awareness on the importance of a comprehensive biosafety and biosecurity legal framework."[29]

To assess whether this argument in the Philippines can be generalised across the five countries, **Table 3** below shows opinions of interviewed experts, indicating the ranking of biosecurity risk perceptions in Southeast Asia. This is drawn from our earlier report, with a scale of "high" (red fill), "moderate" (yellow fill) and "low" (blue fill) levels.[8] Experts ranked i) emerging/reemerging infectious diseases (EIDs/REIDS) highest across all countries, while the risk of ii) laboratory accidents are perceived to be high in Malaysia and the Philippines, moderate in Indonesia, and low in Thailand and in Singapore.[8] Next, Indonesia places a high-risk perception on iii) DURC within the biotechnology industry/research clusters, while this risk is perceived as moderate in

the Philippines, low in Malaysia and Singapore, and less significant in Thailand. Finally, the risk perception on iv) deliberate misuse/bioterrorism is moderate in Malaysia, the Philippines and Singapore, but low in Indonesia and Thailand. It must be noted that risks, such as bioterrorism or breaches of laboratory biosafety, are perceived to be low/moderate because of established health and security systems and regulations that can mitigate or prevent the said risk, but not low in terms of how these are prioritised by the state.

Table 3: Summary Table of Southeast Asia's Biosecurity Risk Perceptions

	i) EIDs/ REIDs	ii) Laboratory Accidents	iii) Biotech / DURC	iv) Deliberate misuse/ Bioterrorism
Indonesia	High	Moderate	High	Low
Malaysia	High	High	Low	Moderate
Philippines	High	High	Moderate	Moderate
Singapore	High	Low	Low	Moderate
Thailand	High	Low		Low

Source: Team analysis. Note: Other types of risk will be further explored in later editions/versions of this report, as the research is ongoing for ASEAN countries.

Based on **Table 3**, it appears that DURC is only one among the many biosecurity threats facing the region. The lack of comprehensive DURC governance leaves these growing industries vulnerable to dual-use risks, including the potential misuse of research for malicious purposes or the unintentional release of dangerous pathogens. Accidental releases from laboratories, which have occurred globally, highlight the need for more stringent biosafety and biosecurity measures that include DURC assessments. Moreover, as the hotspot of terrorism—whether by non-state actors or other entities—it is critical for Southeast Asia to strengthen its regulatory frameworks to ensure that scientific advancements do not inadvertently contribute to security risks.

- Lack of a Comprehensive Biosecurity Policy Framework

The lack of a comprehensive biosecurity legal framework also impedes the development of effective DURC measures in some of the Southeast Asian countries. Singapore demonstrates that the adoption of a biosecurity policy framework can effectively enhance the development of DURC oversight mechanisms. DURC is a biosecurity issue as life sciences research could be misused to pose a significant threat to public health, agriculture, animals, the environment, or national security. Managing DURC is a key aspect of biosecurity and therefore necessitates a comprehensive biosecurity policy framework. Effective management of DURC requires a robust policy framework. Although all five countries—Indonesia, Malaysia, the Philippines, Singapore, and Thailand—are signatories to the BWC, the absence

of comprehensive biosecurity laws in Indonesia, Malaysia, and the Philippines to fully implement the Convention makes it difficult to establish effective policies for DURC oversight.

In mitigating potential and emerging biological risks, the development of biosafety governance at the national level is more robust and have longer history than biosecurity. Preventing the possible adverse effects of genetically modified organisms or GMOs on food safety, public health and the environment was the initial factor that pushed countries to adopt stronger biosafety frameworks that began in the 1990s. They also subsequently ratified (with the exception of Singapore) Cartagena Protocol on Biosafety, given their common concerns over GMOs.

Currently, existing policies reveal that biosafety governance is much stronger than biosecurity governance. In recent years, with their ratification of the Biological Weapons Convention, Southeast Asian countries have crafted various government regulations and legislative frameworks to implement the BWC. However, a majority of countries in the region have yet to produce a comprehensive biosecurity act or BWC implementation act. Singapore has put in place a robust biosafety and security regime, underpinned by the BATA legislation. Its government regularly reviews and amends its legislation, practices, and procedures to ensure they remain relevant and aligned with international best. Thailand’s PATA aligns with the current global context, including outbreaks of emerging and re-emerging diseases, as well as advances in modern biotechnology, such as the genetic modification of pathogens, which can be used for both beneficial and harmful purposes.[34]

Biosecurity regulations in most of the Southeast Asian countries remain patchy, characterised by varying degrees of stringency and enforcement across different countries. The region's diverse landscape of agricultural practices, wildlife trade, public health capacity, national security interests and economic priorities contributes to the inconsistent implementation of biosecurity measures.

One key scenario that should be considered is a DURC incident in a research lab in any of the countries in the region that would have transboundary consequences. With lack of effective DURC governance even at the national level in most of Southeast Asian countries, it would be extremely challenging for national response agencies to deal with possible cases of DURC accidents that would have severe implications on public health. Moreover, given the lack of national policies on DURC in most of the Southeast Asian countries, having a harmonised ASEAN-wide regional policy is not feasible. It follows that it would be extremely difficult to mount a regional response and provide assistance to the affected country. It would be difficult for countries to coordinate joint/regional responses in case of lab accidents, that would have regional consequences.

Another significant gap is the lack of national control list of dangerous biological agents. The oversight of DURC with especially dangerous pathogens, toxins, pathogens with pandemic potential entails a national control list of biological agents.

Singapore and Thailand have fully developed a systematically categorised list of biological agents, which can translate into effective regulatory oversight of DURC and limiting the capacity of malicious actors to access biological agents. Meanwhile, some countries in Southeast Asia have just started developing such a list through national consultations and workshops with stakeholders and agencies involved in national security, health services, life sciences and biotechnology.

- Low Awareness of DURC and Biosecurity

"Several life science researchers have conducted research without realising that it could be classified as DURC," noted one of our interviewees.[24] In fact, this sentiment is shared among several Southeast Asian countries, indicating a limited awareness of dual-use research concerns among researchers. This lack of awareness may result from the absence of comprehensive biosafety and biosecurity regulations and protocols, as well as the differing capacities and effectiveness of IBCs to detect and review DURC. Additionally, certain universities and private organisations do not have established research protocols or oversight bodies, such as IBCs, in place.

Low awareness of DURC could also come from the lack of biosecurity awareness in general. In fact, our research interviews indicated that even in Singapore and Thailand, where there are strong biosecurity legal frameworks, life science and biotechnology researchers still have limited awareness of potential indications of DURC in their respective projects and biosecurity in general. A biosecurity expert opined that "a huge awareness gap exists between biosafety and biosecurity." Scientists, medical professionals, the health security community, academics, and laboratory staff are more accustomed to biosafety practices, whereas "biosecurity remains a relatively unfamiliar concept to many of these groups."[29]

To enhance awareness and oversight of DURC, we strongly recommend the mandatory establishment of IBCs within research institutions in all Southeast Asian countries, given that Singapore is the only country in the region that has a noticeably clear and strict requirement on the establishment of IBCs in life science and health-related research facilities. Additionally, all IBC members should undergo standardised training to ensure consistent expertise in biosafety and biosecurity and that they are updated on new developments in modern biotechnology and life sciences. Furthermore, the establishment of a national-level coordinating body or committee on DURC with oversight functions is also advised to strengthen DURC governance. This body would be responsible for setting uniform standards and protocols, facilitating national trainings for all IBCs as well as promoting the adoption of best practices across institutions, thereby fostering a cohesive and robust framework for oversight.

VI. Way Forward

Southeast Asia has seen significant advancements in biotechnology, with an increasing number of research institutions and laboratories working on sensitive areas

such as synthetic biology, genetic engineering, and virology.[37] With the rapid increase in the demand for biotechnology in Southeast Asia, DURC has now become an important issue for the region due to the potential risks associated with accidental laboratory releases and bioterrorism.

Our findings show a significant variance in DURC governance in Southeast Asia, based on the perspectives reflected in the national statements and measures in Part I of our assessment, and in policies that have been adopted domestically in Part II of our assessment. We have argued that the diversity in institutional divergence is partially attributable to four factors: differing degrees of prior exposure to biosecurity threats among the five countries thus according low priority to DURC as a biosecurity concern; competing priorities given other biosecurity threats (EIDs, bioterrorism and laboratory accidents); lack of DURC oversight policies; and low levels of awareness of biosecurity threats (including among legislators). If Southeast Asia were to meet the growing market demand for biotechnology products within and beyond the region, then it behoves countries through ASEAN to promote greater awareness of DURC governance, and for the regional body to provide guidance to its member states in generating supportive policy environments.

Today, global guidelines already exist on mitigating biorisks within biosafety labs, as noted in the WHO's "Global guidance framework for the responsible use of the life sciences: Mitigating biorisks and governing dual-use research" issued in 2022.[38] The low hanging fruit for ASEAN, moving forward, would therefore be to promote a regional campaign to regionalise and localise this initiative among the ASEAN member states. This can be done by issuing guidelines to its member states on the how best to adopt the practices recommended in the WHO's guidance framework. Additionally, the region may work towards developing an agreed list of SSBAs that are relevant to the member states. This could likely differ from the prioritised list of SSBAs in more developed countries such as the United States or in European countries but is nonetheless important for biosecurity governance.

Finally, there is no one-size-fits all model, as can be seen in diversity of approaches, for instance, Thailand's approach of assigning oversight to a dedicated agency, as opposed to Singapore's approach which builds on existing structures coordinated within a whole-of-government mechanism. By sharing these best practices among the ASEAN member states, ASEAN can help lay the foundations for improved DURC oversight and governance regionally.

Acknowledgements

The authors would like to thank key biosecurity experts and practitioners who participated in our research interviews for sharing their subject matter expertise and perspectives.

Appendix

Appendix Table A1: Ratification of BWC among Key ASEAN Member States

Countries	**Biological Weapon Convention**	**UN Security Council Resolution 1540 (Reports of National Implementation)**
Indonesia	Ratified, 1992	Submitted to UN, latest 2018
Malaysia	Ratified, 1991	Submitted to UN, latest 2018
The Philippines	Ratified, 1973	Submitted to UN, latest 2020
Thailand	Ratified, 1975	Submitted to UN, latest 2019
Singapore	Ratified, 1975	Submitted to UN, latest 2020

Sources: UNODA Disarmament Treaties Database,[11] 1540 Committee[12]

Appendix Table A2: Is DURC or Research in the National Statements of the Five ASEAN Countries Involved, under **2023 Biological Weapons Convention — Meeting of States Parties**?

Country	Mention of DURC
Indonesia	Yes, explicit: "The importance of involving the scientific community and industry experts to identify and address the **dual-use** implications of scientific and technological advancements" (page 2, emphasis ours)
ASEAN (Malaysia one of signatories; no national statement from Malaysia)	Yes, indirect: "**peaceful uses** of biological, chemical and nuclear technology" (p.1 , emphasis ours)[iii] indirectly indicates awareness of non-peaceful uses
Philippines	Yes, indirect: only "CBRN National Action Plan" and "BWC Confidence Building Measures")
Singapore	Yes, indirect: "robust biosafety and biosecurity regime, underpinned by the Biological Agents and Toxins Act (BATA)"
Thailand	Yes, indirect: "address **various challenges** including those that are derived from the impacts of **technological developments**. We stress the importance of knowledge sharing, technological transfer and capacity building" (page 2, emphasis ours)

Source: National statements in United Nations Office for Disarmament Affairs, 2023[13]

Appendix Table A3: Is DURC or Research in the National Statements of the Five ASEAN Countries Involved, under the **9th Review Conference on the BWC?**

Country	Mention of DURC
Indonesia	Yes, Indirect: "while reviewing the operation of the Convention, the States Parties shall take into account any **new scientific and technological [SnT] developments relevant to the Convention [BWC].** We however have never assumed this mandate in the past Review Conferences. We note that the States Parties have widely recognized the need to establish a **SnT review mechanism** and various constructive proposals have also been submitted on this matter. We therefore hope that this Conference will find a landing zone to move this matter forward" (emphasis ours)
Malaysia	Yes, Indirect: "review of **developments in the field of science and technology** related to the Convention; strengthening national implementation, assistance, response and preparedness; addressing concern on compliance issues; and **strengthening the BWC institutional matters**." (emphasis ours)
Philippines	Yes, Indirect: "an advisory mechanism recognizing the need for a **proper balance between risk mitigation and promoting innovation** to maximize benefits from **peaceful uses of biotechnology**." (emphasis ours)
Singapore	Yes, Indirect: "**robust biosafety and security regime**, underpinned by the Biological Agents and Toxins Act (BATA). We constantly review our legislation and procedures to ensure they remain relevant and aligned with international best practices. By 2025, Singapore will have our first Biosafety Level (BSL) 4 lab, which will be equipped to handle highly infectious and lethal diseases such as Ebola." (emphasis ours)
Thailand	Yes, Explicit: "On Thailand's part, legislations and measures have been put in place to ensure biosafety and biosecurity and the **prevention of the misuse of pathogen which also cover all the dual-use items**. In addition, the BIOTEC also develops training courses to raise awareness on biosafety amongst researchers and students." (emphasis ours)

Source: National statements in United Nations Office for Disarmament Affairs, 2022[14]

Appendix Table A4: Is DURC or Research in the National Statements of the Five ASEAN Countries Involved, under the **Biological Weapons Convention National Implementation Measures Database**?

Country	Mention of DURC
Indonesia	Yes, Explicit: "**Oversight of life-sciences dual-use research:** Articles 335 and 336 of Health Law require research to comply with ethical and scientific principles in compliance with provisions of laws and regulations. Any research of utilization of health technology must consider potential risks and benefits to public health."
Malaysia	No update: Website entry was "under development" as of the time of access on 24 October 2024
Philippines	Yes, Explicit: "**Oversight of life-sciences dual-use research:** Institutional Biosafety and Biosecurity Committees review, approve and oversee research involving the use of recombinant or synthetic DNA/RNA and other biohazards especially for Dual Use Research of Concern. Biorisks officers have advisory functions to the management on establishing and monitoring workplace biosafety and biosecurity procedures."
Singapore	Yes, Explicit: "**Oversight of life-sciences dual-use research:** Under Section 39 of the Biological Agents and Toxins Act 2005, every operator of a facility must appoint a biosafety committee. Section 41 of the Act requires operators to ensure no research, teaching or operational activity involving biological agents or toxins at the facility is undertaken until a risk assessment of the activity is conducted by the biosafety committee. Part 5 of the Biorisk Code of Conduct for Life Sciences Industry and Professionals also addresses institutional oversight over research."
Thailand	Yes, Explicit: "**Oversight of life-sciences dual-use research:** Sections 6 and 28 of the Pathogens and Animal Toxins Act B.E. 2558 (2015) and Section 4 of the "Announcement of the Ministry of Public Health Re: rules, procedures and conditions that agencies under section 28 must comply with and establishing a biosafety control committee (2017)", provide for oversight over research for the purpose of disease control, disease prevention and therapy, which involves pathogens or animal toxins."

Source: National statements in United Nations 1540 Committee, 2024[12]

References

1. KPMG. Site Selection for Life Sciences Companies in Asia: India, China, Hong Kong SAR, Singapore and the emerging markets of Southeast Asia. 2020. Available from: https://assets.kpmg.com/content/dam/kpmg/cn/pdf/en/2020/07/site-selection-for-life-sciences-companies-in-asia.pdf.
2. Precedence Research. Biotechnology Market Size to Worth Around USD 4.25 Trillion by 2033. Precedence Research Website; 2024. https://www.precedenceresearch.com/biotechnology-market [Last accessed: 18 October 2024].
3. Biospace. Biotechnology Market Size to Reach USD 5.68 Trillion by 2033 – BioSpace. Biospace Website; 2024. https://www.biospace.com/biotechnology-market-size-to-reach-usd-5-68-trillion-by-2033 [Last accessed: 18 October 2024].
4. Omnia Ibrahim. Five Emerging Biotech Hubs in the Asia-Pacific Region. Lab Biotech; 2022. https://www.labiotech.eu/best-biotech/emerging-biotech-hubs-in-asia-pacific-apac/ [Last accessed: 18 October 2024].
5. Xue, Gong. What Is Dual-Use Research of Concern? IDSS PAPERS; 2024. https://www.rsis.edu.sg/rsis-publication/idss/ip24069-another-battlefield-in-the-great-power-technology-competition-chinas-geostrategic-approach-in-biotechnology-and-implications-for-southeast-asia/ [Last accessed: 18 October 2024].
6. WHO. What is dual-use research of concern? WHO Website; 13 December 2020. https://www.who.int/news-room/questions-and-answers/item/what-is-dual-use-research-of-concern [Last accessed: 28 October 2024].
7. Executive Office of the President of the United States. United States Government Policy for Oversight of Dual Use Research of Concern and Pathogens with Enhanced Pandemic Potential. May 2024. Available from: https://www.whitehouse.gov/wp-content/uploads/2024/05/USG-Policy-for-Oversight-of-DURC-and-PEPP.pdf.
8. Mely Caballero-Anthony, Julius Cesar Imperial Trajano, Jose Ma. Luis P. Montesclaros, and Jeselyn. Emerging Biosecurity Landscape in Southeast Asia. RSIS; 2024. https://www.rsis.edu.sg/staff-publication/emerging-biosecurity-landscape-in-southeast-asia/.
9. Piers D Millett. Gaps in the International Governance of Dual-Use Research of Concern. Commissioned paper by the United States Committee on Dual Use Research of Concern: Options for Future Management. The National Academies Press. Available from: https://nap.nationalacademies.org/resource/24761/Millett_Paper_011717.pdf.
10. United Nations. Statement By Mr. Shaharuddin Onn, Deputy Permanent Representative of Malaysia. UN Website, 2014. https://docs-library.unoda.org/Biological_Weapons_Convention_-_Meeting_of_Experts_(2014)/BWC%2BMX%2B2014%2B-%2BOpening%2Bstatements%2B-%2BMalaysia.pdf.

11. United Nations Office for Disarmament Affairs. Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction. United Nations Treaties Database; 2024. https://treaties.unoda.org/t/bwc. [Last accessed: 28 October 2024].
12. United Nations 1540 Committee. National Reports. United Nations Website; 2024. https://www.un.org/en/sc/1540/national-implementation/national-reports.shtml [Last accessed: 28 October 2024].
13. United Nations Office for Disarmament Affairs. National Statements to 2023 Biological Weapons Convention — Meeting of States Parties. UNODA Website, 2023. https://meetings.unoda.org/bwc-msp/biological-weapons-convention-meeting-of-states-parties-2023. [Last accessed: 28 October 2024].
14. United Nations Office for Disarmament Affairs. National Statements to Review Conference of the BWC – Ninth Review Conference. UNODA Website, 2022.
15. GHS Index. Country Score Justifications and References: Indonesia. 2021. Available from: https://ghsindex.org/wp-content/uploads/2021/12/Indonesia.pdf.
16. WHO and WOAH. A virtual dialogue between animal health and public health experts on dual-use research. 14 March 2023. Available from: https://iris.who.int/bitstream/handle/10665/372842/9789240076273-eng.pdf.
17. Academy of Sciences Malaysia. Malaysian Educational Module on Responsible Conduct of Research (De-Ming Chau, Lay Ching Chai, and Abhi Veerakumarasivam, eds.) 2018. Available from: https://issuu.com/asmpub/docs/rcr_module_readonly.
18. Republic of the Philippines. Republic Act No. 10697, Strategic Trade Management Act. Manila: Congress of the Philippines; 2015.
19. Department of Health of the Philippines. Laboratory Biosafety and Biosecurity Standards. Manila, The Philippines; 2023.
20. Kingdom of Thailand. Pathogens and Animal Toxins Act. 2015. Available from: https://kris.kmitl.ac.th/wp-content/uploads/2019/12/2.-PATHOGENS-AND-ANIMAL-TOXINS-ACT-B.E.25582015.pdf.
21. Republic of Singapore. Biological Agents and Toxins Act 2005. Singapore: Parliament of Singapore.
22. European Union. Singapore releases Biorisk Code of Conduct for Life Sciences Industry and Professionals with EU support. 5 September 2022. https://cbrn-risk-mitigation.network.europa.eu/news-1/singapore-advances-responsible-use-life-sciences-new-biorisk-code-conduct-2022-09-05_en#:~:text=online%20launch%20event%20.-,Singapore's%20Biorisk%20Code%20of%20Conduct%20for%20Life%20Sciences%20Industry%20and,as%20well%20as%20compliance%20with.
23. Singapore Customs. Strategic Goods Control List. https://www.customs.gov.sg/businesses/strategic-goods-control/strategic-goods-control-list/. [Last accessed: 8 December2024].

24. Personal Communication with an Indonesian biosecurity expert, Bogor, Indonesia, 14 March 2024.
25. Personal Communication with a Malaysian biosecurity expert, Kuala Lumpur, Malaysia, 19 May 2024.
26. Personal communication with a Filipino biosecurity expert, Manila, the Philippines, 13 June 2024.
27. Khalik, Salma. $100m plan to prepare S'pore for future pandemics. The Straits Times; 22 Nov 2018. Available from: https://www.ncid.sg/News-Events/News/Pages/$100m-plan-to-prepare-Spore-for-future-pandemics.aspx [Last accessed: 15 oct 2024].
28. Personal Communication with a Malaysian biosecurity expert, Kuala Lumpur, 21 May 2024.
29. Personal communication with Filipino biosecurity experts, Paranaque City, Metro Manila, the Philippines, 13 June 2024.
30. GHS Index. Country Score Justifications and References: Thailand. 2021. Available from: https://ghsindex.org/wp-content/uploads/2021/12/Thailand.pdf.
31. Personal communication with a Singaporean biosecurity expert, Singapore, 15 July 2024.
32. Enciso, A. RITM receives new Biological Safety Laboratory Level 3. Research Institute for Tropical Medicine; 2018. Available from: https://ritm.gov.ph/ritm-receives-new-biological-safety-laboratory-level-3/ [Last accessed 21 Oct 2024].
33. Personal communication with a Filipino biosecurity expert, Taguig City, Metro Manila, the Philippines 11 June 2024.
34. Patravee Soisangwan. Biosafety and biosecurity law in Thailand: From Legislation to practice. Journal of Biosafety and Biosecurity 2021; 3(2): 91-98; https://doi.org/10.1016/j.jobb.2021.08.006.
35. Genetic Modification Advisory Committee. Notice to Adopt the Revised Singapore Biosafety Guidelines on the Research on GMOs 2020. Singapore; 2020. Available from: https://www.gmac.sg/wp-content/uploads/2022/03/Notice-to-Adopt-Revised-Guidelines-2020.pdf [Last accessed: 17 oct 2024]
36. James M Hughes and Julie L Gerberding. Anthrax Bioterrorism: Lessons Learned and Future Directions. Emerging Infectious Diseases 2002; 8(1): 1013-1014; doi: 10.3201/eid0810.020466.
37. EDB Singapore. Why Asia is key to synthetic biology's future. 4 August 2023. Available from: https://www.edb.gov.sg/en/business-insights/insights/why-asia-is-key-to-synthetic-biologys-future.html [Last accessed: 10/17/2024]
38. World Health Organization (WHO). Global Guidance Framework for the Responsible Use of the Life Sciences: Mitigating Biorisks and Governing Dual-Use Research. Geneva: WHO; 2022.

[i] The committee is co-chaired by Co-chaired by **Richard A. Meserve (NAE)**, Senior Of Counsel, Covington & Burling LLP and **Harold E. Varmus (NAS/NAM)**, Lewis Thomas University Professor, Weill Cornell Medicine.

[ii] Conducting interviews with our research participants has been approved by the Institutional Review Board of the Nanyang Technological University with Protocol Reference Number IRB-2023-1047.