

## Review Paper

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Antibiotic resistance is one of the greatest contemporary public health concerns. The unregulated and improper use of these compounds in anthropocentric practices, such as livestock farming, has rapidly increased the number of antibiotic-resistant microbes worldwide. As more antibiotics are introduced to human and animal populations, as well as our environments, selective pressures act to increase resistant communities of organisms. These growing populations of resistant microbes are of particular concern in Southeast Asia. The World Health Organization (2023) describes this region as a hotspot of antibiotic resistance due to sociocultural practices that promote widespread misuse. To better understand the current state of antibiotic resistance in Southeast Asia, the drivers, consequences, and mitigation efforts will be explored.

A multitude of factors influence the prevalence of antibiotic resistance in Southeast Asia. The first of such factors is the low cost of these medications (WHO, 2023). When compared to hospital visits, the price of antibiotics is minuscule in this region. This is significant in low to middle-income countries because individuals are more likely to buy inexpensive antibiotics as an alternative to visiting a hospital to receive a medical diagnosis (Table 5, Saito et al., 2018). With limited financial resources, it becomes more realistic for individuals to self-diagnose and avoid professional medical treatment. Not only are antibiotics less costly, but they are also easily accessible (Zellweger et al., 2017; WHO, 2023). Most of these treatments can be bought over the counter at drug stores. This, too, enables self-diagnosis and avoidance of seeing a medical practitioner, thus amplifying the abuse of these medications (Saito et al., 2018). Moreover, like many other regions, agricultural practices are a leading contributor to antibiotic resistance in Southeast Asia (Lambraki et al., 2023). As human populations increase in this region, the use of antibiotics to promote growth in livestock becomes essential to meet food demands (Table 1, Lambraki et al., 2023).

The factors of misuse described lead to many negative consequences. One major repercussion of antibiotic misuse is extended hospital stays (Fox-Lewis et al., 2018). Sicknesses caused by antibiotic-resistant microbes are difficult to treat. If antibiotics are ineffective against the disease-causing organisms, the best that hospital staff can do is treat individual symptoms until the patient's immune system recovers. Moreover, this misuse of antibiotics leads to poor monitoring of resistance (Zellweger et al., 2017). As discussed, most antibiotic treatments are bought over the counter, and official diagnoses are almost never achieved. Even if an individual seeks out a medical professional, it is likely that proper diagnostics will not be pursued due to limited microbiology labs for such testing (Zellweger et al., 2017). As a result, it becomes nearly impossible to identify resistant strains, effective treatment plans, and high-risk areas (Fox-Lewis et al., 2018). For example, Vilaichone et al. (2018) point out that resistant *Helicobacter pylori* is common in Southeast Asia, yet the standard treatment regimen has not adapted to using a more effective antibiotic and monitoring potential areas of resistance (Tables 1 and 2). Finally, individuals who contract an antibiotic-resistant infectious disease are at an increased risk of comorbidity and mortality (Vilaichone et al., 2018). This is especially true for persons who avoid seeking medical diagnosis and treatment. However, even those who do make it to a hospital may parish depending on how aggressive the resistant organism is.

Many Southeast Asian countries are pursuing strategies to mitigate rising antibiotic resistance. One approach to such mitigation in this region is improved monitoring programs (WHO, 2023). Currently, monitoring is primarily done in hospital settings (Table 1, Zellweger et al., 2017). Community settings do not have sufficient monitoring procedures (Zellweger et al., 2017). This is especially concerning as community settings can

promote the undetected introduction and spread of resistant microbes, especially in areas with poor infrastructure (such as a lack of sanitation services). The surveillance of antibiotic-resistant organisms is essential in identifying areas of high risk and pursuing strategies that minimize potential spread. Furthermore, countries within Southeast Asia are actively working with WHO to enact preventative measures that minimize antibiotic resistance. Current policies include the regulation of over-the-counter antibiotics, as well as lowering the cost of medical care so it does not become a barrier for sick individuals (WHO, 2023). Another way that many countries in this region are attempting to mitigate the negative effects of antibiotics is through education (Zellweger et al., 2017). Awareness programs are being promoted for both medical staff and community members, but more thorough programming is highly encouraged (Zellweger et al., 2017).

The recent COVID-19 pandemic has demonstrated significant implications for antibiotic resistance. Namely, the pandemic has limited essential resources required for monitoring, minimizing, and researching resistance patterns (Tomczyk et al., 2021). As COVID-19 cases increased, funding, laboratories, hospitals, and medical professionals were dispatched to fight the spread of the disease. That is, resources that were once being funneled into antimicrobial resistance initiatives were reallocated to support COVID-19 responses (Tomczyk et al., 2021). Moreover, collaborations (existing or prospective) to combat antibiotic resistance were also disbanded due to the turmoil of the pandemic (Tomczyk et al., 2021). Tomczyk et al. (2021) note that low to middle-income countries have been disproportionately impacted by such events (Table 1). This is likely the case because their resources are far more limited than higher income countries, and thus, they do not have enough resources to split between COVID-19 response and antibiotic resistance projects.

Overall, it is clear that rising antibiotic resistance in the region of Southeast Asia is a major threat to world health. Important drivers of the growing resistance in this region include low cost, ease of accessibility, and overuse in agriculture. The consequences associated with such misuse range from minimal diagnostic testing to long-term hospital care. The most severe of all consequences is increased mortality. As a region of high-risk, many Southeast Asian countries have united with the World Health Organization to address the concerning rates of antibiotic resistance. These approaches include the regulation of over-the-counter antibiotics and healthcare costs. Other mitigation strategies focus on increased surveillance and awareness. Moreover, as infectious diseases like COVID-19 persist alongside increasing resistance, it is likely that lower to middle-income countries will struggle disproportionately to support the health and well-being of their citizens. Further research is required to determine how Southeast Asia can confront severe public health crises and antimicrobial resistance simultaneously. Areas of weakness will have to be identified within this region in conjunction with support from health organizations and other collaborators. Such measures will ensure that the established healthcare infrastructure is capable of withstanding various threats to public health.

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