

Global approaches to tackling antimicrobial resistance: a comprehensive analysis of water, sanitation and hygiene policies

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To cite: Weets CM, Katz R. Global approaches to tackling antimicrobial resistance: a comprehensive analysis of water, sanitation and hygiene policies. *BMJ Glob Health* 2024;**9**:e013855. doi:10.1136/bmjgh-2023-013855

Handling editor Seye Abimbola

► Additional supplemental material is published online only. To view, please visit the journal online (<https://doi.org/10.1136/bmjgh-2023-013855>).

Received 1 September 2023
Accepted 6 January 2024



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ABSTRACT

Background Unsafe water, sanitation and hygiene (WASH) contributes to a high burden of disease and exacerbates factors that promote the development of antimicrobial resistance (AMR). Enforceable policies are foundational to curbing inappropriate use of antimicrobials and providing safe WASH. While many countries have established National Action Plans for AMR that include provisions for WASH, few have codified these plans into legally enforceable policy. Here, we provide a comprehensive map and describe the current regulatory environment for WASH.

Methods We conducted a comprehensive analysis of the WASH-related policies in 193 countries. Policies were identified, collated, and categorised into a publicly available repository.

Results A total of 672 policies met the criteria for inclusion in the dataset. No category of WASH-related policies had been adopted by all countries included in the study. Policy categories that were potentially more difficult to enforce in light of economic and governance limitations tended to be more prevalent and diverse, whereas policies in categories that were highly resource intensive and specific were less universal. Countries with gaps in policy categories also tended to be regionally clustered. While countries in the South Asian and European WHO regions had nearly universal policy coverage across all countries, the presence of policies was inconsistent across countries in the African and Eastern Mediterranean regions.

Conclusion While decision-makers should rely on knowing which policies work best to mitigate the burden of WASH-related disease and AMR development, they must first have a comprehensive understanding of the current regulatory environment. Researchers and decision-makers need to know which policies work best and under what circumstances. The global mapping of WASH policies, which may have implications for AMR development, serves as a foundation for future policy analysis for AMR.

BACKGROUND

Antimicrobial resistance (AMR) poses an imminent and accelerating threat to human health and may exacerbate the existing burden of disease for populations without access

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ In 2019, 1.4 million preventable deaths were attributed to unsafe water, sanitation and hygiene (WASH), and 1.27 million deaths were traced to infections with antimicrobial resistance (AMR) pathogens.
- ⇒ The nexus between AMR and WASH is well established: in 2020, the World Health Organization, World Organization for Animal Health and Food and Agriculture Organization of the United Nations suggested that countries add provisions for establishing and improving safe WASH into their National Action Plans for AMR.

WHAT THIS STUDY ADDS

- ⇒ We comprehensively map the current global regulatory environment for WASH policies in place across six categories that have implications for the development of AMR. We use representative policy examples within each category to highlight policy diversity and identify political feasibility and resource intensity as factors that may contribute to challenges in creating new national level policies, laws and regulations for WASH. We find geographical clustering of countries with policy gaps, indicating WHO regions, such as the African and Eastern Mediterranean regions, in which efforts to codify WASH policy could be concentrated to mitigate the threat of AMR.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ Establishing enforceable WASH policies is foundational to both decreasing the burden of disease attributable to unsafe WASH and mitigating the threat of AMR development.
- ⇒ Researchers need to know where policies exist and how individual countries regulate WASH sectors to effectively analyse contributions to disease burden and AMR emergence. This knowledge may catalyse efforts by decision-makers to eliminate policy gaps.
- ⇒ There is a vital need for further exploration of the relationship between the existence of policies, implementation, WASH-related health outcomes and AMR development.

to safe water, sanitation and hygiene (WASH). In 2019, AMR was found to be the direct cause of death for 1.27 million people worldwide, rendering it more deadly than HIV/AIDS or malaria that year.¹ In the same year, an estimated 1.4 million preventable deaths were attributed to unsafe WASH, with the majority of deaths resulting from diarrhoea, undernutrition and respiratory infections.² Moreover, an estimated 60% reduction in the prescription of antibiotics could be achieved through universal and equitable access to safe water and sanitation.³ Inadequately managed wastewater also serves as a reservoir for microbes to engage in horizontal gene transfer and be exposed to selective pressures before being released into the surrounding environment.⁴ Implementable policies for WASH are critical for taking preventative measures towards combating the development of AMR.

In 2015, the World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), and the World Organization for Animal Health (formerly OIE) formed the Tripartite Joint Secretariat on Antimicrobial Resistance to develop a Global Action Plan on AMR. This plan suggested that the implementation of national-level legislation was integral to combating AMR. In turn, countries were invited to establish National Action Plans on AMR in accordance with the Global Action Plan.⁵ In 2020, the Tripartite Organizations published a technical brief urging countries to incorporate WASH and wastewater management into their National Action Plans.⁶ Many countries engaged in this planning process, but few have enacted policy to combat AMR through the improvement of WASH.⁷ The absence of enforceable WASH policies may allow for widespread overuse and misuse of antimicrobial substances, as diarrhoeal diseases attributable to poor WASH infrastructure are often inappropriately treated with antimicrobials. A recent analysis suggested that universal access to safe water and sanitation could result in a 60% reduction in gastrointestinal diseases treated with antimicrobials.⁸ However, the universal identification and mapping of these policies predicate analyses of their effects on AMR emergence.

Here, we describe our efforts to comprehensively map and detail the current global regulatory environment for WASH policies with implications for the development of AMR in waterborne microorganisms. We present a descriptive analysis of the policies that regulate WASH infrastructure around the world that may have implications for the development and spread of AMR. Understanding what policies exist is a critical first step towards assessing, at scale, which policies are effective, and under what circumstances, in addressing the global health threat of AMR.

METHODS

Country selection

The research team analysed categories of water and sanitation policies that may have implications for the development of AMR for 192 of the United Nations Member States and the Cook Islands.⁹ While other analyses of the relationship between health outcomes and WASH policies often focus on a single country or a selected sample of countries, these 193 countries were included in order to perform a more comprehensive analysis of policies across a diversity of geopolitical contexts.

Identification of relevant policy data

The AMR LEX database (<https://amr-lex.fao.org/main/profile/en>), powered by the FAO LEX was consulted to identify relevant national legislation. Once identified from AMR LEX, policies were located and downloaded from an online repository of national legislation from the country's domain, where possible. Around half of the policies included in the final dataset were first identified in the FAO LEX database.

Where the relevant legislation was not found on AMR LEX, a standardised series of queries was used to search the internet for appropriate policies. The list of query terms (see [table 1](#)) used for each subtopic was developed by conducting a review of the legislation surfaced by various queries for 10 countries to establish which search terms returned the most relevant policies. All searches

Table 1 Standardised query terms used to identify potentially relevant policies (created by CMW)

Policy category	Query term 1	Query term 2	Query term 3
Water quality standards	"Water Quality Standards Regulations [Insert Country]"	"Water Quality Laws [Insert Country]"	"[Insert Country] Water Quality Standards"
Water quality monitoring	"Water Quality Monitoring Policy [Insert Country]"	"[Insert Country] Environmental Impact Assessment Laws"	"[Insert Country] Environmental Monitoring legislation"
Pollutant disposal in water sources	"Water Pollution Regulations [Insert Country]"	"Water Pollution Laws [Insert Country]"	"Pollutant Disposal Laws [Insert Country]"
Effluent wastewater discharge regulations	"Effluent Wastewater regulations [Insert Country]"	"Wastewater disposal regulations [Insert Country]"	"[Insert Country] Discharge Standards"
Sewerage regulations	"Sewerage Regulations [Insert Country]"	"Sewerage Laws [Insert Country]"	"[Insert Country] Sanitation Policy"
Medical waste disposal regulations	"Medical waste policy [Insert Country]"	"Medical Waste Management regulations [Insert Country]"	"[Insert Country] Hazardous Waste Laws"

were first conducted in English. For countries in which English is not used to conduct governmental affairs, if the use of queries in English failed to surface appropriate policies, Google Translate was used to translate the queries into the language used by the targeted country's government. In the case that all queries failed to produce relevant policies, the country was coded as having no relevant policies within that subtopic.

Only legally binding policies, laws, or regulations were included in the study. To capture the diversity of ways in which countries codify their rules and regulations, in this work, policy was used as a broad term to describe a legally binding document produced by a competent governing authority to control the conduct of individuals and entities within their jurisdiction (online supplemental table 2). For this work, we categorised legally binding policies as those that included specific enforcement mechanisms in the document or referred to a penal code which could be used to require parties within the jurisdiction to comply with the policy. Strategies, plans, and other documents outlining future actions of the national government or suggesting criteria for the development of legally binding policies were excluded from this research effort.

Once a potentially relevant, legally binding policy had been identified, a thorough review of the policy language was conducted by the research team. For policies written in languages other than those spoken by the research team, Google Translate was used for policy review. The policy was then assessed based on the inclusion criteria.

Creation of the database and inclusion criteria

Potentially relevant policies collected during the identification process were then categorised within a customised data taxonomy and assessed based on the following standardised set of inclusion criteria. Those policies that met these criteria were collected under the following categories:

- ▶ *Water quality standards*: legally binding policies that either directly set standards for water quality or mandated that a governmental body do so, including for drinking water quality, environmental water quality, and/or recreational water quality. Any policy that addressed one or all of these categories of water was captured and included in the database. Countries that had published national plans to set water quality standards in the future, or use WHO water quality standards but have not codified this practice, were coded as having no policy establishing water quality standards.
- ▶ *Water quality monitoring*: legally binding policies for water quality monitoring mandate that a competent environmental authority within the government has the power either to conduct or regulate the monitoring of residues in water sources. Applicable policies fell into two categories: (1) those policies that stated that, at regular intervals, an entity responsible for ensuring the quality of water was overseeing the testing of water sources to monitor for contamination

with pollutants, which could include antimicrobial substances; and (2) those policies that mandated that environmental impact assessments (EIAs) be conducted at sites that were potentially harmful to the environment, such as construction sites, industrial facilities, and/or agricultural areas.

- ▶ *Pollution disposal in water sources*: policies that establish legally binding regulations on point source pollution. The subtopic was intentionally designed to be broad, allowing for nearly any regulation on chemical discharges into freshwater to be captured. Policies exclusively regulating nitrogen pollution were excluded from the project. Regulations included in the database establish maximum residue limits, criminalise the unlawful discharge of chemicals in water sources, or outline penalties for point source polluters.
- ▶ *Effluent wastewater discharge regulations*: effluent wastewater discharge policies are legally binding regulations on the treatment and disposal of wastewater into water sources. Included regulations were those policies establishing chemical standards and approving discharge locations for wastewater from domestic and industrial locations. Specific regulations on wastewater from agricultural facilities or regulating the use of wastewater in agricultural practices were not included, as they were deemed beyond the scope of the project by the research team. In cases where all categories of wastewater were regulated by a single national policy, that policy was captured and included in the database.
- ▶ *Sewerage regulations*: policies are legally binding regulations on sewerage systems, all of which must have included requirements for sewerage infrastructure. While not used as a standard for inclusion, where available, policies that mandated that sewerage infrastructure be monitored by a competent governmental authority or established procedures for treatment and discharge of domestic sewage were also included. Plans to establish or expand sanitation infrastructure and guidelines for sanitation service provision that were not legally enforceable were not included in this database.
- ▶ *Medical waste disposal regulations*: medical waste disposal policies established legally enforceable methods for the management and final disposal of medical and pharmaceutical waste from healthcare or manufacturing facilities. Often, these regulations existed within broader regulations on hazardous waste. In these instances, the research team conducted a rigorous review of the policy language. As countries use various terms to encompass medical waste management, hazardous waste policies were included if they contained provisions for the handling and disposal of infectious, hospital, healthcare, biomedical, or medical waste. Guidelines published to inform the development of healthcare waste disposal policies at individual healthcare facilities were not included,

as these documents were not legally enforceable at the national level.

Any country found to regulate a research category at the subnational level was coded as having that category of regulation, and the status justification was used to note the level of government where the policy could be located. The regulation of a policy category in a country at the subnational level was verified through the identification of national-level policy devolving power over the specified sector to a subnational governing body.

Data integration into analysis and mapping of policies for emerging infectious diseases

AirTable, which provides a cloud-based platform for relational databases, was used to capture data from policies deemed appropriate for inclusion. Original source policy documents were captured as PDFs, with additional coded data entered by the research team based on a structured ontology. This customised ontology is available as online supplemental table 1. These data were then integrated and uploaded to Analysis and Mapping of Policies for Emerging Infectious Diseases (available at: ampeid.org), a digital database with repositories of policies relevant for governing infectious disease outbreaks. All documents included in this study have been collated and made publicly available on this platform.

Patient and public involvement

Given the nature of this work, no patients were involved in the research process, nor was any public involvement solicited.

FINDINGS

A total of 672 policies across the six WASH-related policy categories met inclusion criteria and were incorporated in the dataset and subsequently mapped to all applicable countries (figure 1). While legally enforceable policies in all six categories existed in a majority of countries, significant variation was identified both in the existence of policies across categories and the number of policies included in each category. Moreover, the universality of policies was found to vary greatly between WHO regions (figure 2). Many countries devolve power to subnational governments for some policy categories. This decentralisation was found to happen more often within federal governmental systems relative to unitary forms of government. Regulation of sewerage was the policy category found to be governed at the subnational level most often (figure 3).

Policy by category

Pollutant disposal in water sources was found to be the most heavily and universally regulated policy category. We identified 186 countries (96.4%) that had enforceable policies regulating the disposal of chemical pollutants in water sources. This category also had the largest number of policies, with 233 documents included in the database. The seven countries without relevant policies

were not regionally clustered, though four of the seven were low/middle-income countries with a history of instability due to conflict.

Countries varied greatly in the specificity of policies governing pollutant disposal in water bodies. For example, a 1995 regulation in Bolivia dictated which departments and levels of government were given the authority to execute actions to prevent water pollution, identify sources of pollution, declare water quality emergencies and define specific discharges that were forbidden to be disposed of in water bodies.¹⁰ Similarly, a 2019 regulation in Sri Lanka outlined the specific list of 36 pollutants and their maximum discharge limits permitted to be released in inland water bodies.¹¹ By contrast, Malaysian law from 1920 states that unless a discharge licence was issued, discharge of any polluting or poisonous matter that would pose a risk to public health, safety, or welfare was forbidden.¹²

Policies specifically regulating the discharge of effluent wastewater into water sources were found to exist in 166 countries (86.0%). 198 policies regulating this subtype of water pollution were identified. Many of these documents broadly regulated water pollution, but included specific provisions for effluent discharge, creating significant overlap between this and the previous category. Countries that lacked regulations on wastewater disposal were heavily clustered in Central, Eastern and Northern Africa, and in the Eastern Mediterranean region.

While the majority of countries had effluent wastewater policy, the ways in which governments managed effluent disposal were heterogeneous. A 1974 Indian law mandated that the central government create an advisory board with representatives of each state and industry stakeholders to provide water policy advice, conduct pollution investigations and collect evidence for legal proceedings, and assist states in setting standards for effluent disposal standards. While states must comply with minimum effluent discharge standards outlined by the central board, enforcement power for these standards is heavily devolved to subnational governments.¹³ In Finland, effluent wastewater disposal is governed both by domestic policies and by regulations from the European Union (EU). In total, four policies, two domestic and two EU directives, were identified to set specific standards for the management, treatment, monitoring, and discharge of wastewater into Finnish water bodies.^{14–17}

We identified 206 policies regulating the monitoring of water contamination. 206 policies were also found to regulate water quality. There is significant overlap in policies for these two categories; however, 171 countries (88.6%) were identified as monitoring water contamination, while only 165 countries (85.5%) were found to regulate water quality. In both categories, the Eastern Mediterranean region and Central and Northern Africa had the lowest prevalence of policies.

We identified inconsistencies in the global regulatory environment for the categories of water required to meet

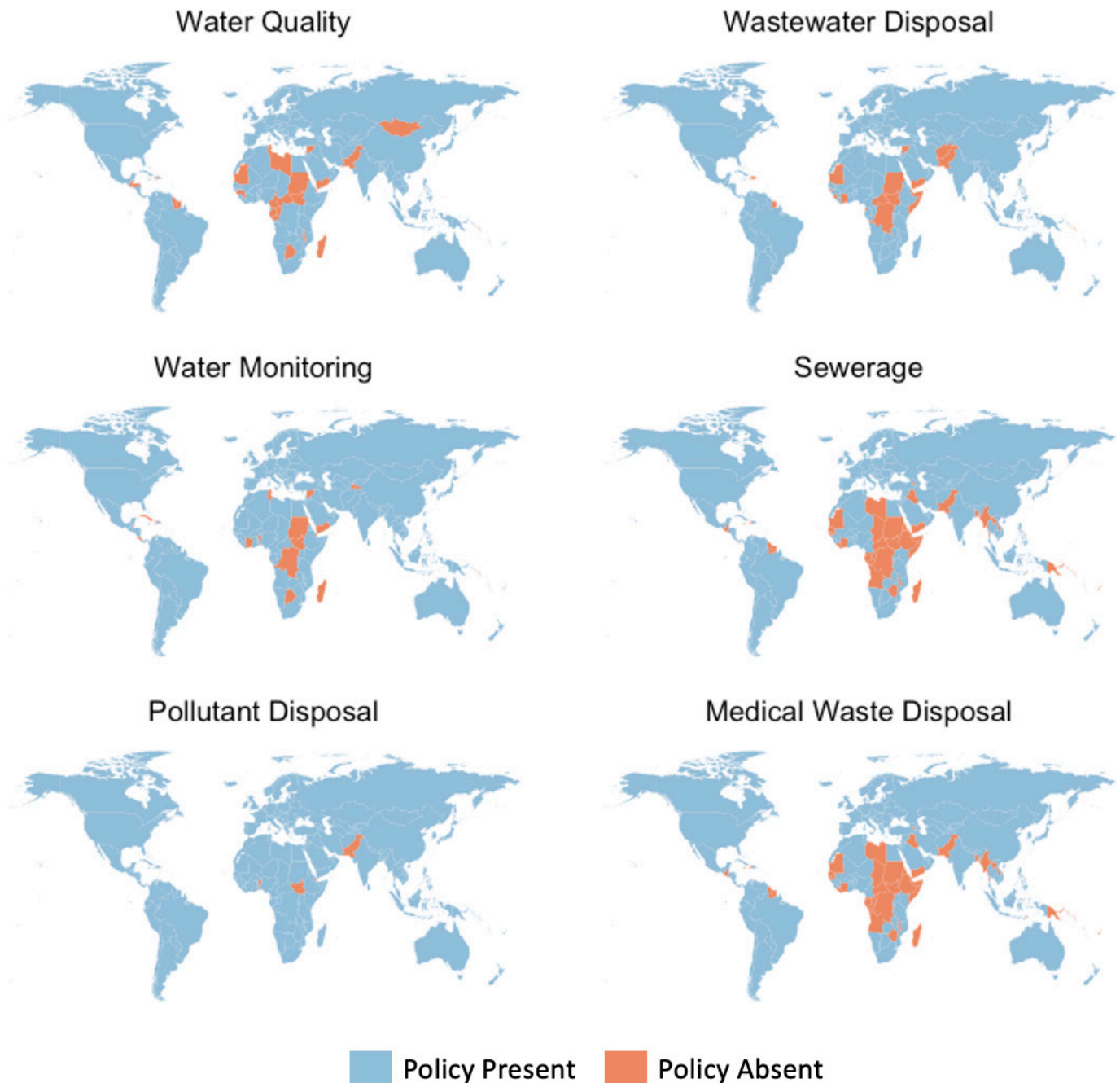


Figure 1 Map of countries with legally enforceable policies regulating WASH-related activities, by policy category. Countries identified as having applicable policy are represented in blue, while countries lacking applicable policy are denoted in orange. Created by CMW. WASH: water, sanitation and hygiene.

quality standards and the stringency of monitoring obligations. In Kazakhstan, two decrees, promulgated in 2004 and 2012, specifically stated the quality standards for potable water, outlined maximum permissible harmful impacts on environmental water bodies and mandated that Environmental Impact Assessments (EIAs) be completed on projects with potentially harmful impacts.^{18 19} Argentina's 2007 law similarly regulated the quality of environmental and drinking waters, but mandated a specific protocol for monitoring water quality at water sources.²⁰ The Dominican Republic used regulations published in 2005 to set drinking water quality standards and included

the procedure and required intervals between monitoring activities within the policy.²¹

Sewerage regulations were identified in 159 countries (82.4%). 161 documents were included in the database for this category. While we found a greater regional diversity for countries that lacked policies regulating sewerage, these countries again tended to be in Northern and Central Africa and the Eastern Mediterranean region. In addition, many countries in the Western Pacific region were not found to have applicable policies.

Great diversity was identified in the regulation of sewerage systems across countries. Some countries,

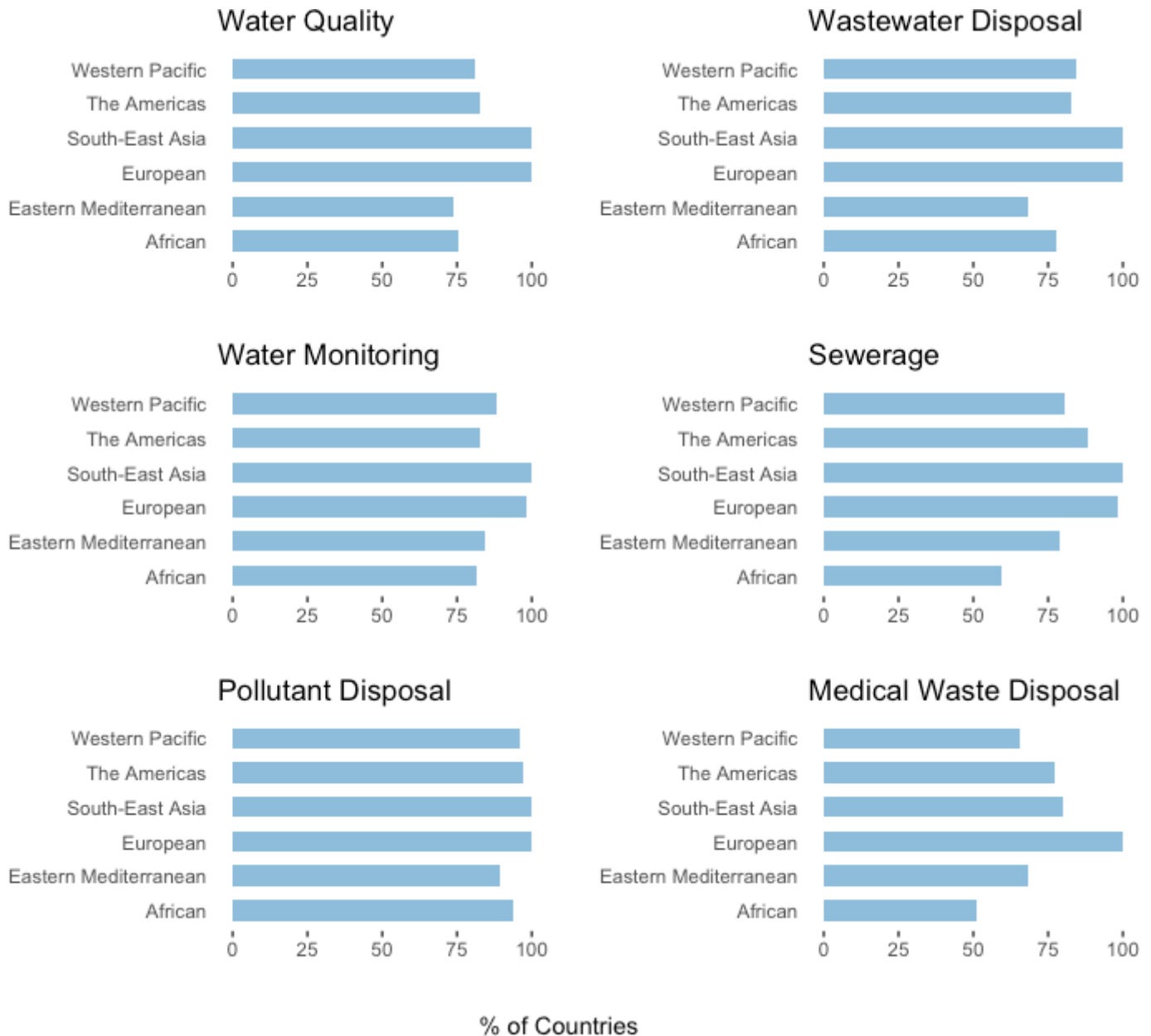


Figure 2 Percentage of countries within WHO regions with legally enforceable policies regulating WASH-related activities, by policy category. Per cent was calculated as a proportion of the countries with applicable policies out of the total number of countries within a WHO region. Created by CMW. WASH: water, sanitation and hygiene.

such as Japan and Uganda, regulate sewerage systems at the national government level. In Uganda, a 1995 act required that the central government be responsible for maintaining sewerage services and issuing sewage permits.²² In contrast, Japanese legislation published in 1972 created an agency within the central government to conduct construction, operation, monitoring, and maintenance of all sewerage systems in the country.²³ Many countries, including Indonesia, devolve regulation of sewerage to subnational governments. A 1999 Indonesian law mandated that subnational governments provide and regulate water and sanitation services.²⁴

Policies governing the disposal of medical waste were found to be the least universal and regulated by the

fewest policies of any category included in the study. Medical waste disposal was found to be regulated in 144 countries (74.6%) by 140 policies included in the dataset. The majority of the 53 countries without medical waste disposal policies were located on the African continent, though many countries in the Western Pacific and Eastern Mediterranean also lacked appropriate policies.

As seen across multiple policy categories, there was significant variation in the specificity and extensiveness of medical waste disposal regulation policies. In some countries, demonstrated by a regulation published in 2019 in Saudi Arabia, there were standalone policies solely focused on the standards for handling, treatment, and disposal of solid medical waste, medical waste effluent

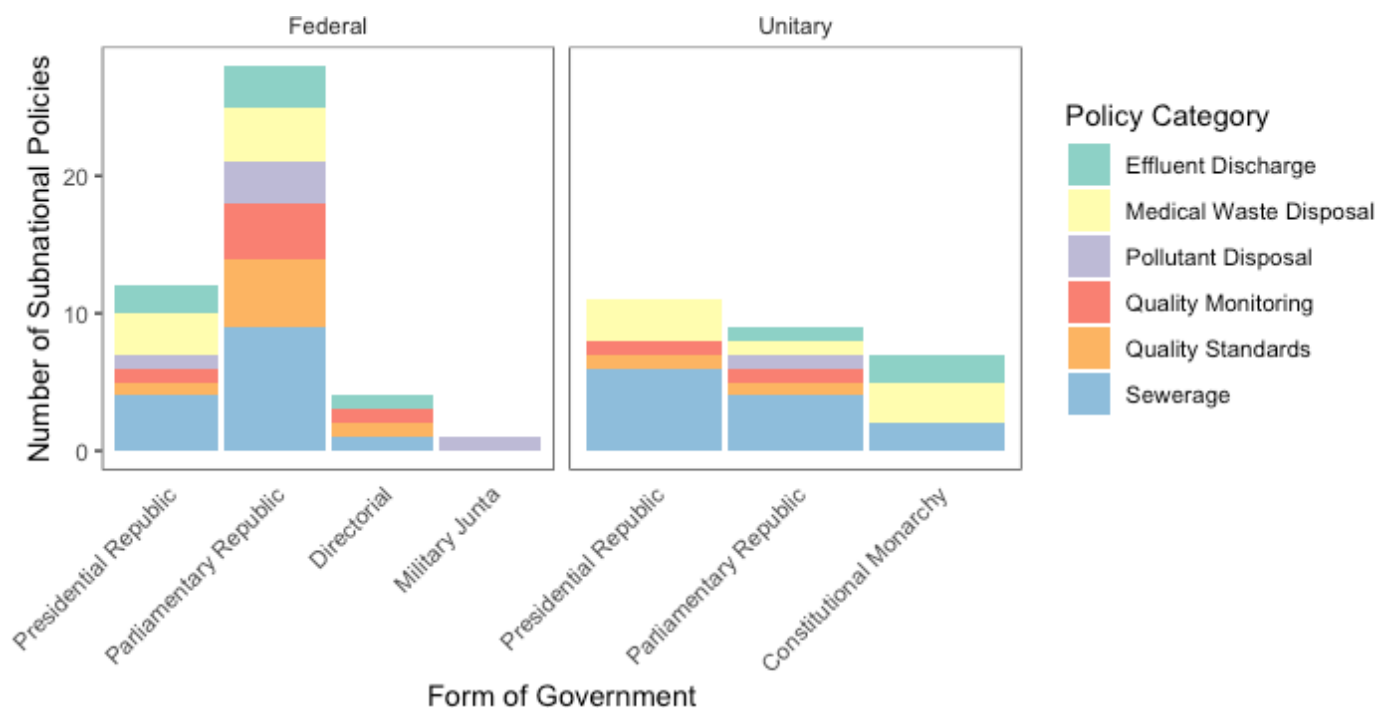


Figure 3 Devolution of power to subnational governments by form of government and policy category. Form of government was determined through a description of governance structure on an official government domain for each country with identified subnational policies. Federal presidential republic: n=5; federal parliamentary republic: n=9; federal constitutional monarchy: n=0; federal directorial: n=1; federal military junta: n=1; unitary presidential republic: n=8; unitary parliamentary republic: n=5; unitary constitutional monarchy: n=5; unitary directorial: n=0; unitary military junta: n=0. Created by CMW.

wastewater and other medical waste byproducts.²⁵ Likewise, an Angolan decree set specific procedures for the management of biological and pharmaceutical waste generated in healthcare and research facilities.²⁶ By contrast, many other countries categorised medical or infectious waste within hazardous waste policies. This was the case in Oman, in which a regulation delegated to the Ministry of Regional Municipalities and Environment the responsibility to regulate entities handling, transporting, or disposing of hazardous wastes, which explicitly include medical or potentially infectious waste.²⁷

Policies by geography

The European and South East Asian WHO regions had the highest prevalence of WASH policies in their member states across all six policy categories. Within five policy categories, both regions were found to have 100% of countries with applicable policies. Only one country in the European region was found not to have enforceable water contamination monitoring policy, while two countries in the South East Asian region lacked medical waste disposal policies.

Across all policy categories, the region of the Americas and the Western Pacific region consistently were found to have fewer countries with applicable policies than the European or Western Pacific regions. In both the Americas and the Western Pacific, a majority of countries in both regions were found to have applicable policies for all categories. However, countries in both regions performed poorly in the category of medical waste disposal, in which

77.1% of countries in the Americas and 65.3% of countries in the Western Pacific had enforceable policies.

The African and Eastern Mediterranean regions were found to consistently lack applicable policies relative to other WHO regions. In most policy categories, between 75% and 85% of countries in each region had applicable policies. However, both regions performed particularly poorly when sewerage policy was examined. In the Eastern Mediterranean, 78.9% of countries had policies regulating sewerage, while this ratio dropped to 59.2% in the African region. Likewise, while 68.4% of countries in the Eastern Mediterranean had policies on medical waste disposal, merely 51.0% of countries in the African region had applicable policies.

Devolution to subnational governments

A total of 72 policies that devolved power within a targeted policy category to a subnational government were identified across 34 countries. 18% (34 of 193) of these countries have at least one policy devolving power for a policy category to a subnational governing entity. While unitary governments constituted 53% (18 of 34) of countries with at least one category of policy delegated to a subnational government, only 37% (27 of 72) of the subnational policies were found from countries with unitary forms of government. In contrast, federal systems made up 47% (16 of 34) of countries with subnational-level regulation of at least one policy category, yet 63% of identified policies devolving power to subnational

governments were found within countries with federal forms of government.

Of the policy categories included in the study, the power to regulate sewerage and medical waste disposal was those most frequently delegated to subnational governments. 36% (26 of 72) of identified policies devolved power for the regulation of sewerage systems to subnational governments. 19% (14 of 72) of identified policies devolved oversight of medical waste disposal to subnational governments. Water quality standards and effluent waste disposal constituted 12.5% (9 of 72) each of policies empowering subnational governments, while water quality monitoring was devolved to subnational levels in 11% (8 of 72) of identified subnational policies. Pollutant disposal was the least likely to be devolved to the subnational level with just 8% (6 of 72) of identified subnational policies applicable to this policy category.

Australia and the Federated States of Micronesia were the only countries with power devolved to subnational governments across all six policy categories. Other federal systems, including the USA and India tended to regulate some policy categories, such as pollutant disposal in water sources, at the national level, while other powers, such as the regulation of sewerage, were delegated to the state level. The majority of other countries identified as devolving power to subnational governments did so for only one or two policy categories, regardless of the form of government (figure 3).

DISCUSSION

Strong, implementable national-level WASH policies are critical for controlling the spread of AMR and supporting population health. Yet, we found that no category of WASH-related policies had been adopted by all countries included in the study. We did find, though, that broad policy categories, such as regulations related to the disposal of pollutants in water, were more universally present than those that are specific and resource intensive, such as regulations on medical waste disposal and sewerage. Moreover, we found that countries lacking policy within categories tended to be regionally clustered. In the African and Eastern Mediterranean WHO regions, between 50% and 75% of countries had applicable policies within each category, while countries in the region of the Americas and Western Pacific tended to have policy coverage ranging between 75% and 95% in each category. Nearly 100% of countries in the European and Eastern Mediterranean regions had policies in force for all six research categories. Federal governments were more likely to devolve power to subnational governments for the regulation of one or more policy categories. Sewerage regulations and regulation of medical waste disposal were the policy categories most frequently devolved to subnational governing bodies, while regulation of pollutant disposal was the policy category least likely to be decentralised.

The differential in the existence of policy by category may be explained both by political feasibility and resource intensity. Our study found that policy in categories potentially

more difficult to enforce in light of economic and governance limitations tended to be more prevalent and diverse. For example, water contamination monitoring policies were found to be widespread, though in some countries, such as Paraguay, this monitoring is only required through EIAs on work of interest, whereas in Serbia, legislation specifically outlines protocols, locations and methods for widespread water quality monitoring. The variation in specificity demonstrated by this example highlights the diverse ways that countries use policy to realise WASH-related aims. While both countries may have policy that regulates water monitoring, the diversity of that policy may beget significant variation between countries in the quality of water, and by extension, the opportunities for AMR development.

Policy categories that were resource intensive, requiring specific infrastructure or personnel with technical expertise, such as policies for medical waste and sewerage, were less prevalent and were the most likely to be devolved to subnational governments. This variation may be attributable to political feasibility and economic factors associated with the implementation of the policy. Policies that broadly address social concerns, such as water pollution, but nominally require less resource investment, may be highly politically feasible across geopolitical contexts and incentivise national governments to take ownership of these policy areas. However, policies that require intensive investments may face greater political opposition in low-resource settings, leading to either a lack of policy or a devolution of power to subnational governing entities in order to shift responsibility for politically unfavourable policy areas. In these contexts, individual entities may develop ad hoc policies or refer to guidelines produced by international organisations, though the lack of enforceable mechanisms to standardise conduct could have consequences on WASH-related health outcomes and the development of AMR.

This research expands on previous studies of discrete WASH policies within a country by assessing the current global policy environment for WASH policies that may have implications for the development of AMR. This holistic assessment elucidated regional trends, demonstrating that policy gaps are often in countries with similar geopolitical and economic factors. As an example, across nearly all research categories, multiple countries in Africa were found not to have applicable policies, while in South East Asia, policies were universally in force across nearly every category. Evidence suggests that the observed disparities in policy coverage between these two regions resulted from increased attention on national governments and recent investments from international organisations focused on the establishment and implementation of WASH policies in South East Asia.²⁸ However, within WHO regions with policy gaps, there is intraregional heterogeneity. Eastern and Southern Africa were found to have more ubiquitous policy coverage across countries in all categories relative to their counterparts in Western and Central Africa.

Our research has important limitations. While we used a standardised methodology, there may have been policies that were overlooked due to their lack of digital presence.

Low-resource countries without digitised repositories of national policy may not have been accurately captured by this study. Some countries may regulate certain WASH sectors only at the subnational level. Based on our methodology, it is possible that these countries were miscategorised if the subnational government did not have a digitised policy repository, used a language different from that used to conduct national-level governmental affairs and for which a national-level policy devolving power to the subnational governing body could not be identified. Moreover, our study considered only the presence and absence of WASH-related policies. Policy implementation and enforcement are critical to assessing the impact of a policy action. As such, without this context, there will be limitations in conducting correlational analyses on either WASH-related health indicators or AMR prevalence with these data. Further exploration of the relationship between the existence of policies, implementation, WASH-related health outcomes, and AMR development is warranted.

CONCLUSION

AMR is a major threat to global health, and the world must take actions to mitigate this threat, including identifying ways to keep water safe for human consumption and reducing opportunities for development of AMR in waterborne pathogens. In recent years, surveillance networks have identified a rise in multiple drug-resistant infections and the diversity of pathogens with antimicrobial resistance genes has increased.^{3 28} Concurrently, the lack of antimicrobial stewardship remains a major issue driving the emergence of AMR, while the development of new antimicrobial products has stalled.^{28 29} Therefore, AMR is a threat that has to be addressed through a broad continuum of action, with a critical reliance on policy, laws and regulations at the national and subnational levels. Researchers and decision-makers need to know what policies work best and under which conditions. However, before this analysis can be completed, a foundational understanding of what policies exist in the current regulatory environment is critical. This research presents the global mapping of WASH policies which may have implications for AMR development, with all data publicly available at ampeid.org.³⁰ It serves as a foundation for future policy analysis in AMR.

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Acknowledgements The authors would like to acknowledge the work of Dr Ellie Graeden in contributing to the conceptualisation of the AMP for EID project, the work of Tess Stevens in designing and managing the data structure of the project database, the work of Ryan Zimmerman in building and maintaining the AMP for EID website, and the guidance of Dr Christian Hunter and Stephanie Eaneff in the writing of the manuscript and creation of data visualisations. Finally, the authors would like to acknowledge the work of J.L. Chretien and Samantha Lau in assisting with data input.

Contributors Empirical work was conceptualised by both authors. CMW collected and managed data and completed analysis. CMW acted as the guarantor for these data. Both authors drafted, edited and approved the submitted version.

Funding This work was funded by the Rockefeller Foundation (GR425219/AWD-7775263).

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Competing interests RK is a member of the Technical Advisory Panel for the Pandemic Fund.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. [dataset] Weets CM, Katz R. Data from: AMR WASH Data. 1 September 2023. <https://github.com/cghss/AMR-WASH-AMPEID>.

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REFERENCES

- Murray CJL, Ikuta KS, Sharara F. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *Lancet* 2022;399:629–55.
- Wolf J, Johnston RB, Ambelu A, *et al*. Burden of disease attributable to unsafe drinking water, sanitation, and hygiene in domestic settings: a global analysis for selected adverse health outcomes. *Lancet* 2023;401:2060–71.
- The Review on Antimicrobial Resistance. Tackling drug-resistant infections globally: final report and recommendations [Internet]. 2016. Available: https://amr-review.org/sites/default/files/160518_Final%20paper_with%20cover.pdf
- Nguyen AQ, Vu HP, Nguyen LN, *et al*. Monitoring antibiotic resistance genes in wastewater treatment: current strategies and future challenges. *Sci Total Environ* 2021;783:146964.
- World Health Organization. Global action plan on antimicrobial resistance. 2015. Available: https://www.amcra.be/swfiles/files/WHO%20actieplan_90.pdf
- Food and Agriculture Organization of the United Nations, World Organization for Animal Health, and World Health Organization. Technical brief on water, sanitation, hygiene and wastewater management to prevent infections and reduce the spread of antimicrobial resistance. 2020. Available: <https://www.who.int/publications/i/item/9789240006416>
- Essack S. Water, sanitation and hygiene in national action plans for antimicrobial resistance. *Bull World Health Organ* 2021;99:606–8.
- O'Neill J. Tackling drug-resistant infections globally: final report and recommendations. Government of the United Kingdom. 2016. Available: <https://apo.org.au/node/63983>
- The Democratic people's Republic of Korea was the one UN member state excluded from this study due to a lack of available data. 2023.
- Plurinational State of Bolivia. Decreto Supremo N 24176 de 8 de Diciembre de 1995 [Internet]. 1995. Available: <https://mineria.gob.bo/juridica/19950815-17-26-5.pdf>
- National environmental (ambient water quality) regulations, No.01 of 2019. Sri Lanka. 2019. Available: <https://www.cea.lk/web/images/pdf/acts/act47-80.pdf>

- 12 Waters act 1920. Malaysia. 1989. Available: <https://ampeid.org/documents/malaysia/waters-act-1920/>
- 13 Water (prevention and control of pollution) act 1974 (water act). India. 1974. Available: [https://cpcb.nic.in/water-pollution/#:-:text=The%20Water%20\(Prevention%20and%20Control,of%20water%20in%20the%20country](https://cpcb.nic.in/water-pollution/#:-:text=The%20Water%20(Prevention%20and%20Control,of%20water%20in%20the%20country)
- 14 European Union. Directive 2008/105/EC of the European Parliament and of the Council on environmental quality standards in the field of water policy. 2008. Available: <https://eur-lex.europa.eu/eli/dir/2008/105/oj>
- 15 European Union. Council directive 91/271/EEC concerning urban waste water treatment. 1991. Available: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A31991L0271>
- 16 Water act (No.587 of 2011) [Internet]. Finland. n.d. Available: <https://www.finlex.fi/sv/laki/ajantasa/2011/20110587>
- 17 Government decree on urban waste water treatment (No.888 of 2006). Finland. 2006. Available: <https://www.finlex.fi/sv/laki/smur/2006/20060888>
- 18 Ministerial decree No.104 validating Sanitary regulation. Kazakhstan. 2012. Available: <https://adilet.zan.kz/rus/docs/V1500010774>
- 19 Ministerial decree No.50 validating the regulation on maximum permissible harmful impacts on water bodies. Kazakhstan. 2004. Available: https://online.zakon.kz/Document/?doc_id=1045994
- 20 Law No.26,221 - provision of drinking water supply service and sewage collection. Argentina. 2007. Available: <https://www.argentina.gob.ar/normativa/nacional/ley-26221-125875/texto>
- 21 Decree No.42-05 that establishes the regulation of water for human consumption. Dominican Republic. 2005. Available: <https://repositorio.msp.gob.do/bitstream/handle/123456789/1187/DecNo.42-05.pdf?sequence=1&isAllowed=y>
- 22 Water act 1995 (cap 152) [Internet]. Uganda. 1995. Available: <https://www.mwe.go.ug/sites/default/files/library/Uganda%20Water%20Act.pdf>
- 23 Japan Sewerage works agency act. Japan. 1972. Available: <https://www.japaneselawtranslation.go.jp/en/laws/view/2810/en>
- 24 Law (UU) number 22 of 1999 concerning regional government. Indonesia. 1999. Available: <https://peraturan.bpk.go.id/Home/Details/45329/uu-no-22-tahun-1999>
- 25 Implementing regulations of uniform law for medical waste management. Saudi Arabia. 2019. Available: <https://www.moh.gov.sa/en/Ministry/Rules/Documents/Uniform-Law-for-Medical-Waste-Management.pdf>
- 26 Presidential decree No.160/14 approving the regulation on the management of waste originated from hospital and health services. Angola. 2014. Available: <https://gazettes.africa/archive/ao/2014/ao-government-gazette-dated-2014-06-18-no-115.pdf>
- 27 Regulation for the management of hazardous waste. Oman. 1993. Available: https://www.ilo.org/dyn/natlex/natlex4.detail?p_lang=en&p_isn=83516
- 28 Tang KWK, Millar BC, Moore JE. Antimicrobial resistance (AMR). *Br J Biomed Sci* 2023;80:11387.
- 29 World Health Organization. 2021 Antibacterial agents in clinical and preclinical development: an overview and analysis. 2021. Available: <https://www.who.int/publications/item/9789240047655>
- 30 Weets CM. AMR-WASH-Ampeidv1. *Zenodo* 2024.