Antimicrobial resistance in China across human, animal, and environment sectors – a review of policy documents using a governance framework

Ding Yang,[a,b] Oliver James Dyar,[c] Jia Yin,[b] Wenwen Ma,[b] Qiang Sun,[b,*] and Cecilia Stålsby Lundborg[a]

[a]Department of Global Public Health, Karolinska Institutet, 17177, Stockholm, Sweden
[b]Center for Health Management and Policy Research, School of Public Health, Cheeloo College of Medicine, Shandong University, Jinan, 250012, China
[c]Department of Public Health and Caring Sciences, Uppsala University, 75122, Uppsala, Sweden

The Lancet Regional Health - Western Pacific 2024;48: 101111

Published Online xxx
https://doi.org/10.1016/j.lanwpc.2024.101111

Summary

Antimicrobial resistance (AMR) poses a multifaceted threat to the human, animal, and environment sectors. In response, China has formulated a series of policies since the 2000s. Thus far, there has been no comprehensive assessment of these policy documents. This study aims to review the content of AMR policy documents at the national level using a governance framework covering three areas: *Policy Design*; *Implementation Tools*; and *Monitoring and Evaluation*. We identified 44 AMR documents from 2003 to 2022 sourced from government agency websites. Our findings have revealed noticeable discrepancies across the three governance areas. The *Policy Design* and *Monitoring and Evaluation* areas should be strengthened, particularly in the domains of 'Coordination', 'Accountability', 'Sustainability', and 'Effectiveness'. From a 'One Health' perspective, the environment sector has received less attention compared to the human and animal sectors. Effectively addressing these challenges requires a stronger commitment and widespread support from diverse stakeholders.

Keywords: Antimicrobial resistance; Health policy; Global health; China

Introduction

Antimicrobial resistance (AMR), particularly antibiotic resistance, has emerged as one of the greatest contemporary public health problems. In 2019, 4.95 million deaths were associated with AMR, including 1.27 million deaths considered to be attributable to AMR.[1] AMR is driven by antimicrobial use.[2] It is estimated that global antimicrobial consumption increased by 66% between 2000 and 2015.[3] However, a large portion of this consumption is considered to be irresponsible[4,5] involving practices such as unnecessary use, irrational dosing, and inappropriate treatment durations. The irresponsible use of antimicrobials is present in both human health and extends to animal agriculture, for example, as growth promotors.[6,7] Additionally, widespread access to antimicrobials leads to increased amounts of antibiotic residues entering the environment. These residues can encourage the emergence of AMR genes in environmental bacteria, potentially transferring to both commensal and pathogenic bacteria in humans and animals.[8,9]

In response to the complex threat posed by AMR, the World Health Organization (WHO) called in 2015 for governments to make political commitments, beginning with the development of individual, 'One Health' approach-based National Action Plans (NAP) on AMR, guided by the Global Action Plan (GAP). To date, 120 of 194 WHO member states, including China, have developed NAPs.[10]

In China, between 2011 and 2018, the compound annual growth rate of total antimicrobial consumption in hospitals was 4%.[11] Bacterial resistance to commonly used antibiotics is still on the rise.[12] For example, from 2005 to 2023, the rate of carbapenem-resistant *Acinetobacter baumannii* increased from 39% to 74%.[13] The Chinese government has demonstrated its determination to combat AMR, actively developing policies and steering actions to implement AMR governance since the 2000s. However, previous research shows that issuing policies alone is not indicative of robust surveillance or optimized antimicrobial use, not to mention comprehensive governance,[14] even if such efforts do reflect the political will and constitute an important step towards mitigating AMR.

The evaluation of AMR policy contents is thus a clear and pressing priority. Most existing assessments have focused exclusively on the content and implementation of NAPs, in individual countries,[15,16] specific regions,[17] or worldwide.[18,19] A number of these studies adopted

*Corresponding author.
E-mail address: qiangs@sdu.edu.cn (Q. Sun).

Anderson's governance framework[20] *on AMR*, analyzing NAPs in terms of *Policy Design*, *Implementation Tools*, and *Monitoring and Evaluation* areas.[15,17,18] Furthermore, there has been research focusing on specific topics, such as 'Transparency' and 'Accountability',[21] or solely on human health.[14] In China, some recent studies have had a narrower focus on the implementation of antimicrobial stewardship (AMS) efforts in the human sector, including surveys in hospitals and assessments of policy documents (including the NAPs) and other related materials.[22–24] While the NAP serves as a programmatic policy document guiding the national and local strategies and actions, it is also crucial to consider the role of other AMR policy documents for a more comprehensive understanding of the policy approaches taken to address AMR in a country.

To our knowledge, a comprehensive review of AMR policy documents across human, animal and environment sectors in China is still lacking. The goal of this study is, therefore, to use an AMR governance framework to assess all AMR policy documents at the national level, including but not limited to the NAPs from a 'One Health' perspective, in order to inform policymakers in identifying priorities and designing concrete strategies to tackle AMR.

Methods

We searched public-facing government agency websites for official policy documents (including laws, regulations, guidelines, announcements, etc.) from 2003 to 2022 and assessed identified documents using an AMR governance framework.[20]

Conceptual framework

AMR presents a multifaceted challenge characterized by its dynamic nature, and AMR governance is a process that constantly requires improvement and adjustment. *Anderson's framework*[20] aligns with this requirement, conceptualizing a cyclical process encompassing 18 domains in three key governance areas (*Policy Design*, *Implementation Tools*, and *Monitoring and Evaluation*). In adapting this framework to the Chinese context, our study made slight modifications by merging the domains of 'Antimicrobial stewardship' and 'Medicine regulation' into a new domain, 'Optimizing antimicrobial usage', due to partial overlap. Additionally, we introduced a new domain called 'International collaboration'. The final framework comprised three overarching areas and a total of 18 domains (Fig. 1).

Document search and selection criteria

Documents written in Mandarin Chinese were collected in parallel by two authors (DY, WM) until the end of January 2023. This was achieved by searching documents from a wide range of government agency websites (including the National Health Commission (NHC), the Ministry of Agriculture and Rural Affairs, the National Medical Products Administration, the Ministry of Ecology and Environment, the National Healthcare Security Administration, the Ministry of Education, the Ministry of Finance, the National Development and Reform Commission, and the Ministry of Science and Technology). We searched for documents containing 'antibiotics', 'antimicrobial agents', 'antimicrobials', 'antibiotic resistance', or 'AMR' in either the title or the text. Furthermore, we searched for potentially relevant additional policy documents referenced in the retrieved documents and other publications. All included policy documents were those i) officially issued by national government organizations, possessing unique document numbers, and ii) where the sole or primary focus of the policy documents was AMR. These criteria applied irrespective of whether they focused on specific domains or took an overarching approach. We, therefore, did not include policy documents that, for instance, mentioned AMR but were primarily focused on general aspects of hospital quality management or management of pharmaceuticals. No date restrictions were set in the above searches.

Data management and analysis

Data extracted from identified documents were organized into an Excel spreadsheet featuring one row per record. The extracted data consisted of the date of publication, unique document number, title, Chinese title, and lead issuer. First, we coded all documents by indicating their relevance to sectors such as human, animal, and environment or across two or three of these sectors. Second, we disaggregated the policy content of each identified document and coded it according to the 18 domains. Additionally, we assessed the extent to which each of the 18 domains was covered by either NAP or non-NAP documents to identify specific deficiencies. The process was led by two authors (DY, WM), and any queries regarding content disaggregation were discussed extensively among the co-authors until a consensus was reached.

Results

The findings are presented in two sections: 1) summary of search results and 2) assessment of policy contents.

Summary of search results

The search strategy identified 81 potentially relevant documents. Following an initial review, one document was excluded because it was not government-issued. The full texts of 80 documents were carefully examined, resulting in the exclusion of a further 36 documents due to their lack of a specific focus on AMR. This left a total of 44 documents for analysis (Fig. 2).

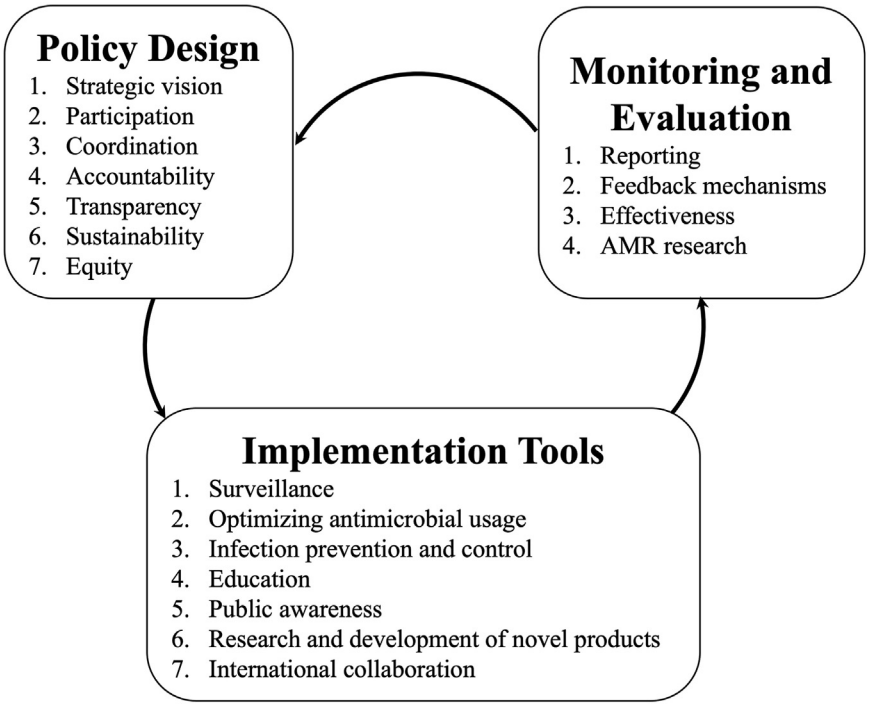

Fig. 1: **Antimicrobial resistance governance framework with 3 areas and 18 domains**. AMR = Antimicrobial resistance.

Table 1 provides an overview of the 44 documents identified spanning from 2003 to 2022 (further information is listed in the Appendix). Of these, 61% (27/44) exclusively focus on human health. Among these human health documents, 63% (18/27) relate to improve antimicrobial use, with mainly targeting secondary and tertiary hospitals and one directed at retail pharmacies. Thirty percent (13/44) of the documents are dedicated to addressing animal health concerns. Many of these documents primarily aim to improve veterinary practices and surveillance. Examples of such efforts include detailed regulations that prohibit the use of lomefloxacin, pefloxacin, ofloxacin, and norfloxacin in food animals,[25] and the ban on colistin sulfate premix as a growth promoter.[26] There is only one document related to the environment sector, specifically addressing antibiotic residues. Additionally, one document pertains to both human and animal sectors, with the objective of

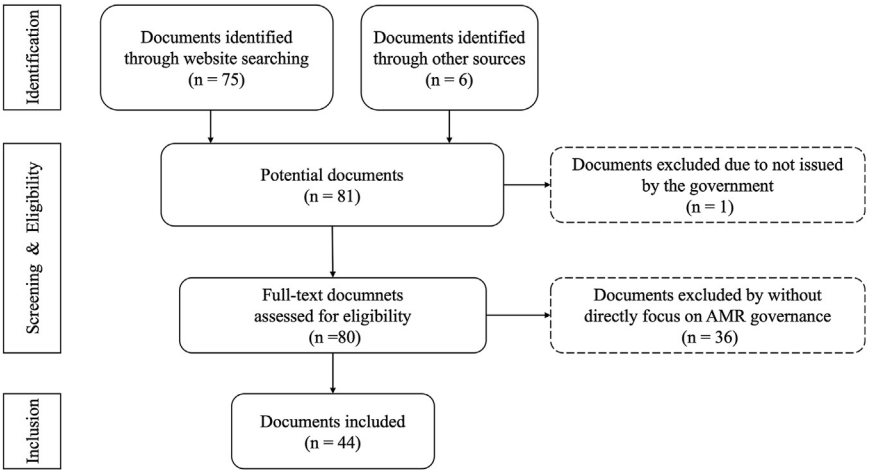

Fig. 2: **Flow diagram summary of inclusion process**.

No.	Year	Document number	Policy	Sectors
1	2003	(2003) No. 286	Carrying out Publicity Activities to Strengthen the Supervision of Antimicrobials and Promote Rational Use	Human
2	2003	(2003) No. 289	Strengthening the Supervision of Antimicrobials Sales in Retail Pharmacies and Promoting Rational Use	Human
3	2004	(2004) No. 285	Guideline on Clinical Use of Antimicrobials (2004)	Human
4	2005	(2005) No. 176	Establishing Surveillance Networks on Clinical Use of Antimicrobials and Bacterial Resistance	Human
5	2006	No. 48	Administrative Measures for Hospital-acquired Infections	Human
6	2006	(2006) No. 133	Further Improving Surveillance on Clinical Use of Antimicrobials and Bacterial Resistance	Human
7	2008	(2008) No. 48	Further Improving Clinical Use of Antimicrobials (2008)	Human
8	2008	(2008) No. 130	Strengthening Control of Nosocomial Infections by Multi-Drug Resistant Bacteria	Human
9	2008	(2008) No. 22	Surveillance Plan for Antimicrobial Resistance from Animal Origin (2008)	Animal
10	2009	(2009) No. 38	Further Improving Clinical Use of Antimicrobials (2009)	Human
11	2009	(2009) No. 10	Surveillance Plan for Antimicrobial Resistance from Animal Origin (2009)	Animal
12	2009	(2009) No. 80	Implementing Special Inspection on Generation and Disposal of Hazardous Waste such as Antibiotic Residue	Environment
13	2010	(2010) No. 111	National Joint Remediation Plan on Antimicrobial Management	Human&Animal
14	2011	(2011) No. 56	National Special Campaign on Clinical Use of Antimicrobials (2011)	Human
15	2012	(2012) No. 32	National Special Campaign on Clinical Use of Antimicrobials (2012)	Human
16	2012	No. 84	Administrative Measures for the Clinical Use of Antimicrobials	Human
17	2012	(2012) No. 72	Strengthening Surveillance on Clinical Use of Antimicrobials and Bacterial Resistance	Human
18	2012	(2012) No. 731	National Training Program on Clinical Use of Antimicrobials for Healthcare professionals	Human
19	2013	(2013) No. 37	National Special Campaign on Clinical Use of Antimicrobials (2013)	Human
20	2014	(2014) No. 300	Further Implementation of National Special Campaign on Clinical Use of Antimicrobials	Human
21	2015	(2015) No. 6	National Five-Year Action Plan on Comprehensive Management of Veterinary Drugs (Antimicrobials) (2015–2019)	Animal
22	2015	(2015) No. 42	Further Improving Clinical Use of Antimicrobials and Surveillance on Antimicrobial Resistance (2015)	Human
23	2015	(2015) No. 43	Guideline on Clinical Use of Antimicrobials (2015)	Human
24	2015	No. 2292	Ministry of Agriculture Announcement No. 2292 Prohibition of Four Antibiotics in Food Animals	Animal
25	2016	No. 2428	Ministry of Agriculture Announcement No. 2428 Prohibition of Colistin sulfate premix as a growth promoter	Animal
26	2016	(2016) No. 43	National Action Plan on Antimicrobial Resistance (2016–2020)	One Health
27	2017	(2016) No. 1281	Enhancing the diagnosis and treatment capabilities of bacterial and fungal infections in secondary and tertiary comprehensive hospitals	Human
28	2017	(2017) No. 15	Establishment of Expert Committee on Clinical Use of Antimicrobials and Evaluation of Antimicrobial Resistance	Human
29	2017	(2017) No. 10	Further Implementation of National Action Plan on Antimicrobial Resistance (2017)	Human
30	2017	(2017) No. 22	National Action Plan on Antimicrobial Resistance from Animal Origin (2017–2020)	Animal
31	2018	(2018) No. 5	Surveillance Plan for Antimicrobial Resistance from Animal Origin (2018)	Animal
32	2018	(2018) No. 13	Work Program for Reduction of Veterinary Antimicrobial use (2018–2021)	Animal
33	2018	(2018) No. 9	Further Implementation of National Action Plan on Antimicrobial Resistance (2018)	Human
34	2018	(2018) No. 822	Expert Consensus on Clinical Practice of Carbapenem Antibiotics and Tigecycline	Human
35	2019	(2019) No. 11	Surveillance Plan for Antimicrobial Resistance from Animal Origin (2019)	Animal
36	2019	(2019) No. 12	Further Implementation of National Action Plan on Antimicrobial Resistance (2019)	Human
37	2020	(2020) No. 8	Veterinary Drug Residue Monitoring Plan for Animals and Animal Products and Surveillance Plan for Antimicrobial Resistance from Animal Origin (2020)	Animal
38	2020	(2020) No. 601	Surveillance on Clinical Use of Antimicrobials and Bacterial Resistance in Children	Human
39	2020	(2020) No. 8	Further Implementation of National Action Plan on Antimicrobial Resistance (2020)	Human
40	2021	(2021) No. 7	Veterinary Drug Residue Monitoring Plan for Animals and Animal Products and Surveillance Plan for Antimicrobial Resistance from Animal Origin (2021)	Animal
41	2021	(2021) No. 73	Further Strengthening Clinical Use of Antimicrobials and Curbing Bacterial Resistance (2021)	Human
42	2021	(2021) No. 31	National Action Plan on Reduction of Veterinary Antimicrobial Use (2021–2025)	Animal
43	2022	(2022) No. 2	Veterinary Drug Residue Monitoring Plan for Livestock and Livestock Products and Surveillance Plan for Antimicrobial Resistance from Animal Origin (2022)	Animal
44	2022	(2022) No. 185	National Action Plan on Antimicrobial Resistance (2022–2025)	One Health

Table 1: **List of AMR policy documents in China.**

strengthening the management of various links such as production, distribution, and use of antimicrobials. Lastly, there are two documents that adopt a 'One Health' perspective, and these are the two versions of the NAP (2016–2020 and 2022–2025).

Assessment of policy contents

Using the AMR governance framework, all included policy documents were analyzed across three governance areas and 18 domains (Fig. 3). The *Implementation Tools* area exhibited the highest frequency of

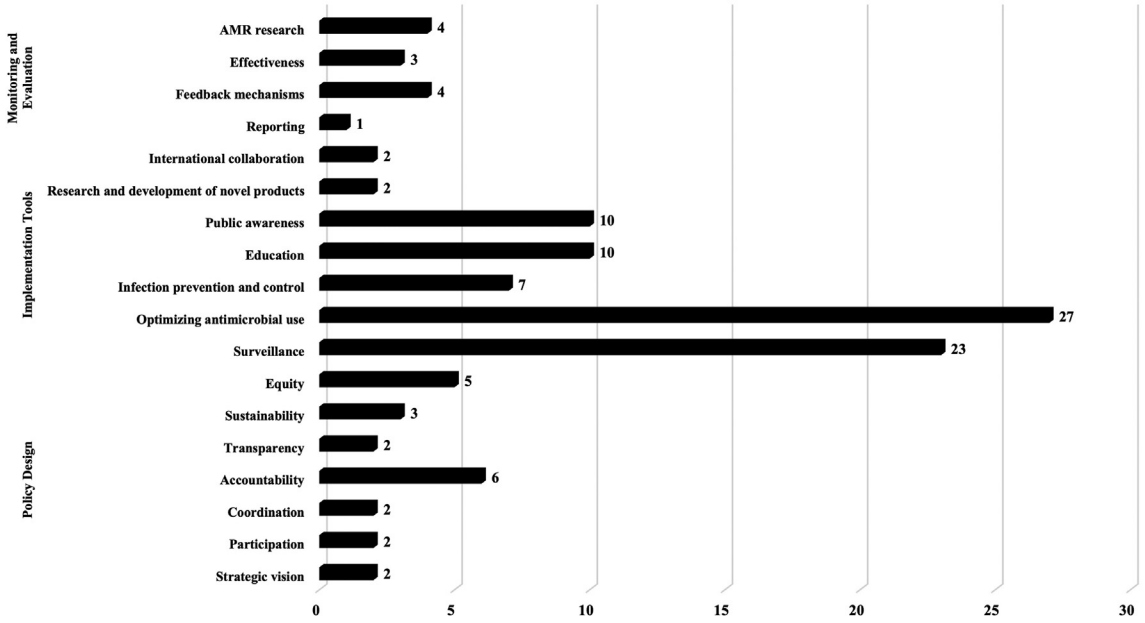

Fig. 3: **Frequency on governance domains of 44 documents**. AMR, Antimicrobial resistance.

mentions, with four domains being the most frequently discussed. Notably, 'Optimizing antimicrobial use' and 'Surveillance' stand out, referenced in 27 and 23 documents, respectively. Following closely are 'Public awareness' and 'Education'. In contrast, domains with relatively lower frequencies of mentions are found in the *Policy Design* and *Monitoring and Evaluation* areas, including 'Reporting', 'Coordination', 'Transparency', and 'International collaboration'.

Policy Design

The *Policy Design* area focuses on addressing general and procedural aspects to ensure the effective implementation of these measures. The assessment of this area comprises seven domains: 'Strategic vision', 'Coordination', 'Participation', 'Accountability', 'Transparency', 'Sustainability', and 'Equity' (Table 2).

'Strategic vision' entails the presence of well-defined goals and objectives to effectively guide interventions. The objectives in the two versions of the NAP for AMR are largely modelled on the GAP, encompassing all GAP objectives to varying degrees. The NAPs place greater emphasis on optimizing antimicrobial use, featuring three related objectives, while giving less attention to evidence-based research and sustainable investment. Compared to the first NAP, the updated NAP introduces more measurable and quantifiable objectives and outlines an overarching goal aimed at reducing the prevalence of AMR or its growth rate (Fig. 4).

'Coordination', 'Participation', and 'Accountability' are fundamental components in establishing a governance mechanism. In China, this mechanism is maintained by the NHC, the central coordinating and leading ministry, but there is no multisectoral coordinating committee in place. The development of the NAPs involves relevant competent authorities, with each ministry assigned specific subject matters, as detailed in the NAPs.[33,34] However, it remains unclear to what extent these ministries actively participate in the development process. Furthermore, uncertainty exists about the involvement of other stakeholders. The text of the NAPs does not specify any nominated responsible individuals within each ministry, nor does it outline any consequences for failing to meet the objectives set forth by the NAPs within the designated timeframe.

'Transparency' can empower various stakeholders, especially those in professional organizations, industry, and academia, by keeping them informed and encouraging them to generate knowledge and translate it into practice. Policy documents, AMR surveillance data, and progress reports for selected years are publicly available. However, there is no policy recommendation that funding allocations and antimicrobial use data should be openly and readily accessible.

Regarding 'Sustainability', three key elements are necessary: a consensus agreement among all relevant ministries, the allocation of resources and dedicated budgets for specific activities, and the establishment of a technical advisory group to provide ongoing support for AMR containment.[20] While the technical advisory group was established for human health in 2017,[29] the other two requirements have not been fulfilled.

No.	Domains	NAP (2016–2020)/NAP (2022–2025)	Non-NAP documents	Deficiencies/Missing parts
1	Strategic vision	Objectives increase from six (first NAP) to nine (second NAP) and become more specific and measurable, such as: the appropriateness rate of antibiotic prescription as an intervention target is set to 75% for the first time, and the target rate for dispensing veterinary antibiotics with a prescription is increased from 50% to 80%.	NA	No mention of situational analysis.
2	Participation	All related governmental stakeholders engage, especially the NHC, the MARA, and the MEE, across One Health.	NA	None of the documents mention the involvement of non-governmental stakeholders, such as medical and veterinary professions, universities and research institutions, food and pharmaceutical industries, wholesale and retail distributors, and the general population.
3	Coordination	The NHC is in charge. Provincial and municipal level sectors benchmark national-level authorities to carry out their work.	NA	Without an intersectoral committee.
4	Accountability	The NHC is mainly accountable to the government. All ministries have specific measures they are responsible for.	Human sector—Designating the head of local health authorities[27] and healthcare institutions[28] to be responsible for antimicrobial clinical use within a region or institution.	No mention of consequences if targets are not achieved.
5	Transparency	Progress reports to be published timely.	The CARSS is established by the NHC for information sharing regarding AMR trends, pathogen, and strain distribution of selected hospitals. (http://www.carss.cn/sys/Htmls/dist/index.html#/).	Funding plans and annual reports after 2018 are unavailable in the human sector.
6	Sustainability	The MoF are assigned for allocating funds and strengthens fund management and supervision in the old NAP (2016–2020).	A technical advisory group, the EC for Human, is set up for human health sector.[29]	Budget plans and resource allocations are missing.
7	Equity	Emphasize adhering to *the Administrative Measures for the Clinical Use of Antimicrobials*,[30] and *the Guideline on Clinical Use of Antimicrobials (2015)*[31]	Special attention to vulnerable groups such as children, the elderly, and pregnant woman.[32]	

NAP, National Action Plan. NHC, National Health Commission. MARA, Ministry of Agriculture and Rural Affairs. MEE, Ministry of Ecology and Environment. CARSS, China Antimicrobial Resistance Surveillance System. MoF, Ministry of Finance. EC for Human, Expert Committee on Clinical Use of Antimicrobials and Evaluation of Antimicrobial Resistance.

Table 2: **Analysis of governance area—Policy design.**

'Equity' requires responsible use and equal access to essential antimicrobials. Several regulations have been introduced to optimize the judicious use of antimicrobials. Each secondary and tertiary hospital is mandated to have an Antimicrobial Stewardship Working Group to ensure compliance with these regulations among health professionals. Furthermore, targeted initiatives have been launched to improve antimicrobial use among vulnerable populations, such as the elderly and children.

Implementation Tools

The *Implementation Tools* area predominantly centers around various interventions, encompassing seven domains: 'Surveillance', 'Optimizing antimicrobial usage', 'Infection prevention and control', 'Education', 'Public awareness', 'Research and development of novel products', and 'International collaboration' (Table 3).

'Surveillance' systems were established across the human and animal sectors in 2005[35] and 2008,[38] respectively, supported by laboratory capacity. In the human sector, surveillance sites have been set up in selected secondary and tertiary sentinel hospitals across all provinces. These sites collect samples from both inpatients and outpatients to monitor resistant organisms and levels of antimicrobial use. In the animal sector, surveillance aims to monitor consumption and priority resistant organisms isolated from selected farms, as well as the presence of antimicrobial residues in chicken, cattle, sheep, pigs, and their products. However, there is no surveillance plan for the environment sector. Meanwhile, ensuring standardized and reliable laboratory practices is a crucial aspect of surveillance. Both NAPs state the establishment of national reference laboratories and biological specimen banks. They also emphasize the establishment of standardized and quality-assured systems and protocols for antimicrobial susceptibility testing to provide technical support for AMR surveillance.[33,34]

The promotion of 'Optimizing antimicrobial usage' can be achieved through AMS, which consist of a coordinated set of interventions within healthcare

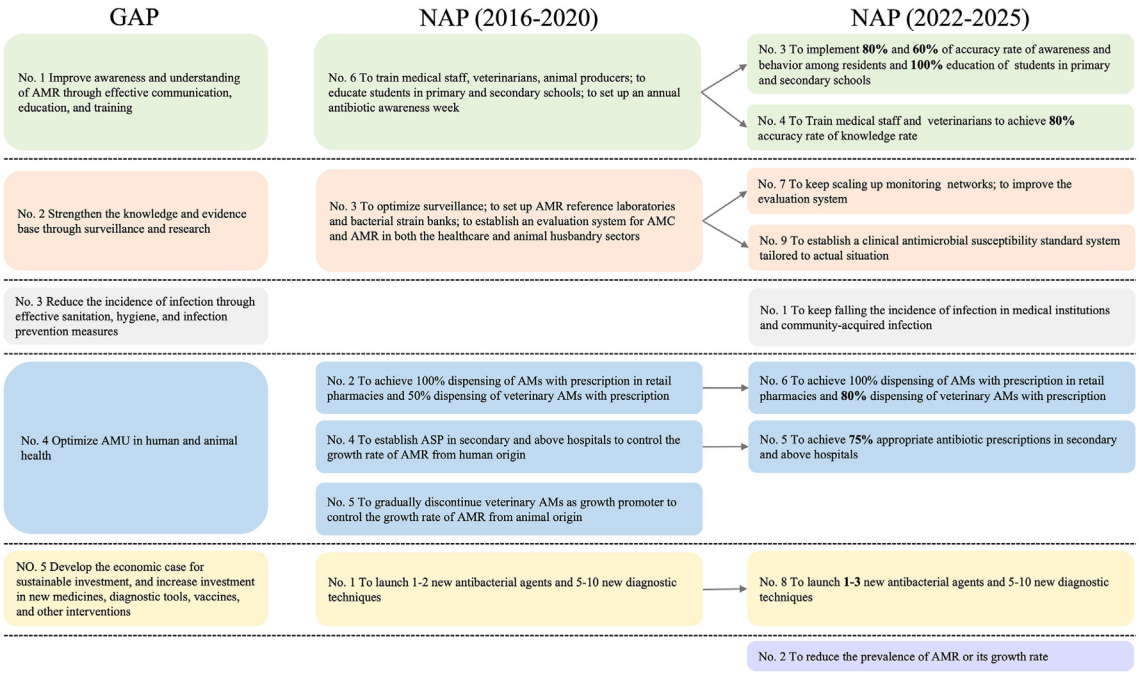

Fig. 4: **Comparison of objectives in the NAPs of China with those in the GAP**. GAP, Global Action Plan, NAP, National Action Plan, AMR, Antimicrobial resistance, AMC, Antimicrobial consumption, AMU, Antimicrobial use, AMs, Antimicrobials, ASP, Antimicrobial stewardship program.

institutions. First, *the Antimicrobial Classification List (ACL)* stipulates prescription privileges for different categories of antimicrobials based on the professional qualifications of doctors. Second, *the Post Review of Antimicrobial Prescription (PRAP)* mandates regular reviews of antibiotic prescriptions in all healthcare facilities, with the results used to determine performance incentives. Violations of regulations could lead to the revocation of a doctor's right to prescribe antimicrobials. Third, specific indicators are used to influence prescribing behaviors. Lastly, it is stipulated that antibiotic dispensing at community pharmacies must require prescriptions. In the animal sector, efforts are being made to improve the use of veterinary antimicrobials, such as reducing the use of antimicrobial combinations, gradually reducing the variety (in terms of antibiotic classes) and quantity of antimicrobials used as growth promoters, and putting in place a system to trace veterinary antimicrobial use.

'Infection prevention and control' (IPC) programs across human, animal and environment sectors are identified as a top priority in the new NAP, guided by the principle of prioritizing prevention. Notably, the government has previously introduced *the Administrative Measures for Hospital-Acquired Infections*[40] and *the Strengthening Control of Nosocomial Infections of Multi-drug Resistant Bacteria*[41] in 2006 and 2008, both targeting healthcare facilities. In 2016, a policy aimed at enhancing the diagnosis and treatment capabilities of bacterial and fungal infections was issued, targeting secondary and tertiary comprehensive hospitals.[42]

'Education' and 'Public awareness' are both essential to providing adequate information to effectively implement AMR strategies. Regular training programs have been established for professionals working in the fields of human and animal health to enhance their knowledge and address AMR. In 2012, the Ministry of Health (MoH) conducted a national program for continuing education training targeting professionals in secondary and tertiary public hospitals.[43] Additionally, various models are employed by health authorities at national, regional, and local levels, as well as universities, to enhance knowledge and awareness. For instance, the annual World AMR Awareness Week campaign held every November is widely promoted through mass media.[33,34]

'Research and development of novel products' and 'International collaboration' are domains that are only discussed in the NAPs. There have been no subsequent strategies or accompanying documents to follow up on these matters.

Monitoring and Evaluation

The *Monitoring and Evaluation* area is essential for gauging the effectiveness, efficiency, and impact of initiatives, as well as for making informed decisions

No.	Domains	NAP (2016–2020)/NAP (2022–2025)	Non-NAP documents	Deficiencies/Missing parts
1	Surveillance	Surveillance to cover tertiary, secondary public hospitals and PHCs. Surveillance data from clinical settings and livestock farming should be connected to maximize the value of monitoring results.	Human sector—Since 2005, a national surveillance system for resistant organisms and antimicrobial use has been set up in 107 hospitals.[35] In 2012, a significant expansion was made, including 1349 hospitals, and introducing new monitoring indicators.[36] In 2020, antimicrobial use surveillance systems targeting children were expanded at all secondary and tertiary hospitals with pediatric clinics. Furthermore, 67 children's hospitals were selected to report additional AMR data covering 31 provinces across the country.[37]	Surveillance on private healthcare facilities, and environmental surveillance are unavailable.
		Standardized reference laboratories and biobanks to be set up.	Animal sector—National surveillance for resistant organisms has been established since 2008[38] and was extended to antimicrobial residues monitoring in food products in 2018.[39]	No mention of laboratory capacity supported by regular external quality assessments.
2	Optimizing antimicrobial usage	Human sector- national guidelines were recommended to be followed, such as: the *Guideline on Clinical Use of Antimicrobials (2004 and 2015), the National Essential Medicines List*.	Human sector—Action 1: ACL divided antimicrobials into three categories, 1) Non-restricted antibiotics could be prescribed by physicians, 2) Restricted antibiotics should be prescribed by physicians with intermediate or senior professional titles, and 3) Special grade antibiotics should be prescribed by physicians with a senior professional title with the consent of a multidisciplinary expert consultation, are not allowed to be used in ambulatory care, and require biological samples to be taken before use; and medications such as carbapenems and tigecycline adopted a special file management, more stricter, requiring to record any information during treatment. Action 2: PRAP was performed monthly in each secondary and tertiary public hospitals. 25% of physicians with the right to prescribe antibiotics were selected randomly. Each physician had no less than 50 prescriptions to be evaluated. The hospital publicizes the review results and incorporates them into the performance evaluation. Action 3: Indicators, the number of types of antibacterial drugs equipped in the hospital, the rate of antimicrobial prescriptions in emergency, outpatient, and inpatient departments, drug utilization index (DUI), the rate of submission of microbiological test samples, the timing of antimicrobial use for prophylactic purposes of surgical patients.	No mention of rapid diagnostic tools in any settings.
		Animal sector- Administrative Regulations and guidelines of veterinary antimicrobial usage to be formulated. Withdrawal plan of antimicrobials as feed additives for growth promotion was implemented.	Animal sector—Action 1: The production, sale and use of four antibiotics (lomefloxacin, pefloxacin, ofloxacin, norfloxacin) were prohibited for food animals.[25] Action 2: Colistin sulfate premix was prohibited as a growth promoter.[26] Action 3: The *Administrative measures on veterinary antimicrobials* and *Veterinary antimicrobial classification list* have been drafted during this period, soliciting the input of stakeholders.	No mention of corresponding incentives or penalties to enforce the action plan.
				PHCs and private healthcare facilities are excluded.
3	Infection prevention and control	IPC in healthcare institutions to be strengthened. Drinking water, sanitation, and personal hygiene to be strengthened to reduce community-acquired infections.	*The Administrative Measures for Hospital-Acquired Infections* is developed to curb the spread of antimicrobial-resistant organisms in various healthcare institutions.[40]	No mention of guidelines for IPC across animal and environmental health.
		IPC of environmental pollution by antimicrobials to be strengthened.	*The Strengthening Control of Nosocomial Infection of Multi-drug Resistant Bacteria* mainly highlights prevention and control of multidrug-resistant bacteria through improvement in hand hygiene, isolation measures, aseptic technique operating procedures, and environmental sanitation.[41]	No mention of any financial and non-financial incentives or penalties for IPC policies.
		Human and animal vaccination programs to be strengthened.	*Enhancing the diagnosis and treatment capabilities of bacterial and fungal infections in secondary and tertiary comprehensive hospitals* aims to support the achievement of objectives in the NAP, including strengthening the construction of the diagnosis and treatment system, enhancing the allocation of personnel through training, and implementing a multidisciplinary diagnosis and treatment model.[42]	

(Table 3 continues on next page)

No.	Domains	NAP (2016–2020)/NAP (2022–2025)	Non-NAP documents	Deficiencies/Missing parts
(Continued from previous page)				
4	Education	AMR and antimicrobial use are incorporated in syllabuses of students in medical fields, including physicians, dentists, nurses, pharmacists, and veterinarians. Healthcare and veterinary professionals from diverse institutions are required to engage in continuous education programs, which include on-the-job training updates, workshops, and examinations. This is essential to broaden knowledge and maintain efforts to effectively implement guidelines.	A two-year educational program[43] was conducted nationwide, concerning clinical use of antimicrobials in healthcare institutions. The training was performed in 31 provinces after compilation of training materials and organization of national teacher training. Targeted audiences are physicians, pharmacists, nurses, administrator of infection department from secondary and tertiary public hospitals, with a total of 20,000 professionals. Subsequently, daily small-scale training is carried out in various healthcare institutions.	No mention of educational activity on veterinary practitioners.
5	Public awareness	Combination of online and offline ways to raise awareness, including distribution of posters, billboards, public transport signs in print media, and dissemination of information in press conference, websites and social media platforms through videos and pictures, particularly in World AMR Awareness Week every November. Public communication program targets various audiences, such as residents in urban/rural area, school children, farmers, and livestock keepers.	The measures in non-NAP policy are similar with those in NAPs, which aims to promote the importance of responsible use of antibiotic to the public, and to enhance societal awareness and involvement in addressing the challenges posed by antibiotic misuse and inappropriate usage.	No mention of sustainable executive plan, and whether the design conception of public awareness campaigns considers behavioral sciences, social science, and psychology.
6	Research and development of novel products	The research and development of novel antimicrobials, diagnostics, vaccines, and alternative treatments based on the study of molecular epidemiology and bacterial resistance mechanism across human, animal and environment sectors are to be supported.	NA	Dedicated budget for innovation was unavailable.
7	International collaboration	Participation in development of international standards and guideline, prevention strategies, personnel training. Partnership with other countries for surveillance, sharing relevant resistance surveillance results with the international community Providing support to other countries and regions in need to carry out AMR governance activities.	NA	No data shared with GLASS.

PHCs, primary healthcare centers. ACL, Antimicrobial Classification List. RAP, Review of Antimicrobial Prescription. IPC, Infection prevention and control. GLASS, WHO Global Antimicrobial Resistance Surveillance system. AMR, Antimicrobial resistance.

Table 3: **Analysis of governance area—Implementation tools.**

regarding policy refinement. This area comprises four domains: 'Reporting', 'Feedback mechanisms', 'Effectiveness', and 'AMR research' (Table 4).

'Reporting' is conducted annually in both human and animal sectors. Progress reports in the human sector present surveillance findings on antimicrobial use and the incidence of resistant organisms. In contrast, reports in the animal sector only mention the use of veterinary antimicrobials and use sales volume to represent usage quantity. The updated NAP mentions the timely publication of progress reports but lacks specifics regarding frequency and relevant content.

'Feedback mechanisms' involves collecting information to guide future actions. For instance, an alert mechanism for antimicrobial practice in healthcare facilities has been set up since 2008.[46] This could guide prescribing behaviors by selecting antimicrobial regimens based on the surveillance findings of the bacterial resistance prevalence within a region.

'Effectiveness' requires the government to measure the impact of various AMR interventions and specific policies. A document issued in 2018[32] called for an evaluation of the administration of clinical antimicrobial use in hospitals, but no document or report informing the assessment results is available. The updated NAP suggests conducting process monitoring and outcome evaluation annually.

'AMR research' is instrumental in generating information to support AMR governance. The government has established separate human and animal AMR expert committees to provide evidence for policy formulation, implementation, and improvement.

Discussion

In this study, we have comprehensively assessed the content of 44 AMR policy documents issued by the Chinese government from 2003 to 2022, using a governance framework with a 'One Health' perspective. The aim is to gain insights into the various policy contents to inform policymakers in identifying priorities and designing concrete strategies to tackle AMR. Our study has revealed noticeable discrepancies across the

No.	Domains	NAP (2016–2020)/NAP (2022–2025)	Non-NAP documents	Deficiencies/Missing parts
1	Reporting	Progress is to be published.	[a]Human sector—Reports from 2016 to 2018[44] were released, presenting situational analyses of antimicrobial use and the incidence of resistant organisms, expenditure, challenges, and next steps.	Human sector-Reports (2019–2022) published as books, not freely available.
			[a]Animal sector—Reports from 2018 to 2020[45] were published, presenting the classification, amount and trend of usage, enabling public access in a transparent fashion.	Animal sector—no timely update since 2020.
2	Feedback mechanisms	System to be developed for risk monitoring, assessment, and early warning of microbial resistance.	An alert mechanism was developed in 2008.[46] For antimicrobials with a resistance rate of more than 30% to the main target bacteria, early warning information should be notified to medical staff in a timely manner. If over 40%, empirical medication should be cautious. If over 50%, it should be prescribed based on drug susceptibility tests. If over 75%, it should be suspended.	Animal sector-no mention of related feedback mechanisms.
3	Effectiveness	Annual process monitoring and outcome evaluation to be developed at a national level with an indicator system.	Human sector—*The Further Implementation of National Action Plan on Antimicrobial Resistance (2018)*[32] clarified secondary and tertiary public hospitals were evaluated with various indicators from *the Administrative Measures for the Clinical Use of Antimicrobials.*	Human sector-no mention of cost-effectiveness evaluations.
				Animal sector-no mention of effectiveness related evaluations.
4	AMR research	The Ministry of Science and Technology oversaw allocating dedicated budgets to support AMR research by bidding on projects.	Human sector—The EC for Human[29] set up to study the correlation between antimicrobial use and AMR, the pattern of AMR, infectious disease spectrum, the economic burden of AMR. All relevant information and update is presented on its website (http://www.kangnaiyaopingjiawei.com).	Dedicated budgets were not available in either human or animal sectors.
			Animal sector—The EC for Animal[47] is to set up to provide evidence-base for the monitoring of AMR of animal origin, the spread mechanism of AMR, and the evaluation of veterinary AMR.	

ASP, Antimicrobial Stewardship Program. EC for Human, Expert Committee on Clinical Use of Antimicrobials and Evaluation of Antimicrobial Resistance. EC for animal, Expert Committee on Veterinary Drug Residue and Antimicrobial Resistance Containment. [a]NB, reports are not policy documents, but they were mentioned here to inform the progress and deficiencies.

Table 4: **Analysis of governance area—monitoring and evaluation.**

three governance areas within the governance framework. The measures in the *Implementation Tools* area are well-established, with repeated inclusions in policy documents and subsequent developments over the past two decades, as seen in 'Surveillance' and 'Optimizing antimicrobial usage'. However, the *Policy Design* and *Monitoring and Evaluation* areas are still at a rudimentary stage, particularly in the domains of 'Coordination', 'Accountability', 'Sustainability', 'Research and development of novel products', and 'Effectiveness'. From a 'One Health' perspective, efforts have been invested in the human and animal sectors, but the environment sector is largely missing from the policies reviewed, as is the importance of cross-sectoral collaboration.

The Chinese government started introducing policies exclusively targeting AMR and/or antimicrobial use in the 2000s, which was relatively late in global terms. For example, Sweden has formulated such policies since the 1980s, along with a 'One Health' perspective since 2000.[48] Similarly, the U.S. and certain European states established national AMR surveillance systems in the 1990s.[49] Furthermore, most policies are at a strategic level, with few considering operational plans and monitoring and evaluation plans. Strategic, operational, and monitoring and evaluation plans are considered pivotal components of a NAP, as outlined in the *WHO's A Manual for Developing National Action Plans*, produced in 2016.[50] Policies identified are primarily strategic plans outlining goals, priorities, and interventions. However, they lack implementation and evaluation arrangements such as timetables, budgets, performance indicators, and data collection methods. One potential reason for this absence is the disparities among provinces in China in terms of economic conditions, health resources, and AMR prevalence. These disparities collectively contribute to the challenge of establishing a unified national-level implementation and monitoring plan. Although policies are formulated nationally, refinement, implementation and oversight fall to health authorities from the 31 provinces (autonomous regions and municipalities). Another possible reason could be restricted access to internal documents, revealing transparency issues in AMR governance.[21]

Greater efforts are needed in the environment sector. While the 'One Health' approach has been integrated in the first NAP since 2016, our review revealed a significant gap in environment governance compared to the human and animal sectors. This observation aligns with previous studies in other countries.[51–54] There is a tendency to overlook the role of the environment in the development and spread of AMR,[55] possibly because the environment is the most dynamic and complicated sector of the 'One Health' triad with widespread coexistence of resistant bacteria and antibiotic resistance genes.[56] The literature shows no countries have systematically implemented national environmental surveillance systems beyond research settings.[57] China has the capacity to establish sentinel surveillance and sampling systems, beginning with high-risk environmental settings such as sewage and soil near livestock farms, fish farms, and hospitals.

Inadequate interagency coordination and accountability impede AMR governance progress.[58] The absence of a multisectoral coordinating committee exacerbates the challenge in China. The NHC theoretically coordinates efforts, but it lacks the authority to enforce assignments across other ministries that are at the same 'governance level'. Additionally, the documents do not specify any consequences for unmet objectives within each ministry, whilst failure to meet key performance indicators is common in other contexts in China. Ministries still work in silos, indicating a lack of robust inter-sectoral collaboration and accountability. This is corroborated by findings from an earlier qualitative interview study with individuals who have expertise in the field and also influence on AMR policies.[59] There is a need for a collective political will to simultaneously harness the surveillance data of AMR and antimicrobial use and foster greater accountability. Practices from other countries could serve as valuable role models for China. In the USA, the government established an overarching multisectoral group, the Interagency Task Force for Combating Antibiotic-Resistant Bacteria, in 2014. This task force adopts a 'One Health' strategy involving U.S. Government agencies responsible for human, animal, and environmental health. It actively encourages collaboration and communication to tackle antibiotic resistance across all pertinent sectors.[60] In Sweden, a national working group, the Swedish Strategic Programme Against Antibiotic Resistance (Strama), was initiated in 1994 to support national efforts of the entities responsible for healthcare. Similar working groups also exist in the veterinary and food sectors.[61] Strama has contributed to the sustained reduction of antibiotic use and low bacterial resistance levels in Sweden.[62] In addition, the Swedish government also developed the NAP (2023–2025) and the intersectoral coordinating mechanism against AMR to coordinate multisectoral work at the national level.[48]

Turning plans into actions, a dedicated budget is a critical first step in ensuring practical and sustainable implementation efforts. It is, therefore, imperative to understand how much the actions included will cost, which actions should be prioritized, and how to allocate resources to maximize cost-effectiveness before making funding decisions. Despite this, funding and resource allocations were seldom alluded to in the identified policy documents. Considering the conflicting priorities of the government, it is difficult to earmark funding to support each initiative at the national and sub-national levels in such a large country.[63] Possibly, surrogate approaches could be used instead. The *WHO Costing and Budgeting Tool for NAPs on AMR* was developed in 2021.[64] This pragmatic and adaptable tool describes step-

by-step processes to generate detailed costs for the activities as well as to cost priority activities that still need to be funded. Using the tool may help the Chinese government to improve the appropriateness and extent of financial support.

Innovation seems to be neglected, as evidenced by its absence or only cursory mention in policy documents. This is despite the inclusion of research and development of novel products, such as new antibiotics, diagnostic techniques, and vaccines, in the list of objectives in both the NAPs. Given the challenges in developing new antibiotics, vaccination has gained recognition as an effective approach to reducing AMR.[65,66] While vaccination is frequently discussed in various NAPs, it is often absent from strategic objectives or lacks detailed operational, monitoring and evaluation plans.[67] Furthermore, expanding access to and use of point-of-care tests (such as C-reactive protein and procalcitonin), especially in outpatient settings,[58] could help to reduce unnecessary antimicrobial use. There are significant gaps in initiatives related to these aspects in China, primarily due to cost increases, as well as labor and competency requirements.[68] Even without issues of funding and manpower, the deployment of these rapid diagnostic tools also faces obstacles rooted in established healthcare practices and habits, which demand significant changes to the workflows of both clinical and microbiology departments.[69]

AMR policies rooted in 'Optimizing antimicrobial use' and 'Surveillance' have reduced antimicrobial use in hospitals and antibiotic prescriptions in ambulatory care.[44] Likewise, the policy of colistin withdrawal in the animal sector also decreased colistin resistance.[70] However, some refinement is still needed. First, primary healthcare facilities and private pharmacies have been overlooked. In 2021, it was estimated that 52% of healthcare visits in China took place in primary healthcare facilities,[71] while the majority of interventions were predominantly conducted within secondary and tertiary public hospitals. Twenty years since the regulation against dispensing antibiotics without a prescription came into effect, the practice persists in community pharmacies, notably in rural areas and the central and western provinces.[72] Second, a similar situation exists with surveillance, where current systems are largely focused on secondary and tertiary care settings rather than community-based settings. In addition, existing programs do not include private healthcare facilities. In 2021, the proportion of private healthcare facilities was 48%, accounting for 36% of all outpatient visits.[71] Third, the underuse of antimicrobials should be given the same weight as overuse and misuse. Delayed diagnosis, ineffective treatment, or suboptimal antibiotic treatment can also contribute to AMR,[73] associated with an increased burden of morbidity, mortality, and increased financial costs. A previous study in China found that 66% of patients with a diagnosis of pneumonia received antibiotic prescriptions,[74] lower than the target 'acceptable range' (90%–100%) according to European antibiotic prescribing quality indicators.[75] Conversely, universal access to antibiotics has been estimated to reduce 75% of pneumonia deaths among children under five across 101 countries.[73]

Assessment of the *Monitoring and Evaluation* area showed limited capacity for enhancing the iterative process of policy design and implementation, particularly in systematically evaluating effectiveness. Our findings regarding this area are similar to a systematic AMR governance analysis of 114 countries, which found that China's score in the *Monitoring and Evaluation* area ranked 75th, although its overall score ranked 22nd in the three areas.[18] This underscores the challenge, as the slow progress in AMR containment is partly because of an inadequate or poor evidence base for the effectiveness of the myriad policies.[57]

This is the first study to analyze and assess the contents of all AMR policies issued by the Chinese government in the past two decades, using a 'One Health' perspective. While the NAPs provide outlined, general policies, they are insufficient to reflect all efforts to combat AMR in a country, especially one as large as China. This study concentrates on the NAPs as well as all national policy documents focused on AMR. We used an AMR structured governance framework to examine to what extent the key elements of identified documents fulfil the thematical requirement at two layers of granularity (three areas and 18 domains). The findings provide an overview of progress and remaining gaps at a policy level to contain AMR in China, which not only helps policymakers identify priorities and make further policy iterations but also informs scholars of potential directions for future research.

However, several limitations need to be acknowledged. First, all policy documents were retrieved from public resources. It is difficult to access to non-public internal policies and grey literature, which might underestimate the scientific nature of AMR policy design. Second, we excluded policy documents that did not have AMR as their primary focus; it is possible that excluded documents addressed some of the otherwise weaker-covered domains, although our initial review of these excluded documents does not support this hypothesis. Third, we only assessed policy documents issued at a national level; it is possible that additional regional-level policy documents have addressed some of the deficiencies identified here. An important next phase of research would be evaluating the translation of AMR policies into practical implementation on the ground, for instance, within a single province or region.

Conclusion

This study employed a governance framework to analyze and assess the content of all national AMR policy documents issued in China from 2003 to 2022, covering the human, animal, and environment sectors. The

findings indicate that the development of the *Implementation Tools* area is stronger than the *Policy Design* and *Monitoring and Evaluation* areas. To enhance subsequent iterations and ensure effective implementation, there should be a broader emphasis on integrating the environment sector guided by the 'One Health' approach; creating binding accountability mechanisms for coordination; formulating operational, monitoring and evaluation plans; including the allocation of fiscal budgets; and promoting innovation and research. Addressing these gaps necessitates stronger commitments to combating AMR and the support of diverse stakeholders.

Contributors

CSL, QS, and DY designed the study. DY and WM undertook data collection, extraction, and analysis. DY drafted the manuscript. All authors interpreted data. QS, CSL, OJD, and JY critically revised the manuscript. All authors approved the final version for publication and agreed to be accountable for all aspects of the work. They had full access to all the data in the study and held the final responsibility for submission for publication.

Declaration of interests

All authors declare no competing interests.

Acknowledgements

This study is funded by the National Natural Science Foundation of China (grant number: 72174109).

The funders of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the paper.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2024.101111.

References

1 Murray CJL, Ikuta KS, Sharara F, et al. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *Lancet*. 2022;399(10325):629–655.
2 Holmes AH, Moore LS, Sundsfjord A, et al. Understanding the mechanisms and drivers of antimicrobial resistance. *Lancet*. 2016;387(10014):176–187.
3 Klein EY, Van Boeckel TP, Martinez EM, et al. Global increase and geographic convergence in antibiotic consumption between 2000 and 2015. *Proc Natl Acad Sci U S A*. 2018;115(15):E3463–E3470.
4 Garg AK, Agrawal N, Tewari RK, Kumar A, Chandra A. Antibiotic prescription pattern among Indian oral healthcare providers: a cross-sectional survey. *J Antimicrob Chemother*. 2014;69(2):526–528.
5 Li Y, Xu J, Wang F, et al. Overprescribing in China, driven by financial incentives, results in very high use of antibiotics, injections, and corticosteroids. *Health Aff*. 2012;31(5):1075–1082.
6 Martin MJ, Thottathil SE, Newman TB. Antibiotics overuse in animal agriculture: a call to action for health care providers. *Am J Public Health*. 2015;105(12):2409–2410.
7 World Health Organization. *Global action plan on antimicrobial resistance*; 2015. https://www.who.int/publications/i/item/9789241509763. Accessed July 31, 2022.
8 Economou V, Gousia P. Agriculture and food animals as a source of antimicrobial-resistant bacteria. *Infect Drug Resist*. 2015;8:49–61.
9 Hanna N, Sun P, Sun Q, et al. Presence of antibiotic residues in various environmental compartments of Shandong province in eastern China: its potential for resistance development and ecological and human risk. *Environ Int*. 2018;114:131–142.
10 World Health Organization. *Monitoring global progress on antimicrobial resistance: tripartite AMR country self-assessment survey (TRACSS) 2019-2020*; 2021. https://apps.who.int/iris/handle/10665/340236?search-result=true&query=Monitoring+global+progress+on+addressing+antimicrobial+resistance&scope=&rpp=10&sort_by=score&order=desc. Accessed January 20, 2023.
11 Wushouer H, Zhou Y, Zhang X, et al. Secular trend analysis of antibiotic utilisation in China's hospitals 2011-2018, a retrospective analysis of procurement data. *Antimicrob Resist Infect Control*. 2020;9(1):53.
12 Hu F, Guo Y, Zhu D, et al. CHINET surveillance of antimicrobial resistance among the bacterial isolates in 2021. *Chin J Infect Chemother*. 2022;22:521–530.
13 CHINET Cloud. *CHINET surveillance of bacterial resistance: results of 2023*; 2024. http://www.chinets.com/Document/Index?pageIndex=0#. Accessed March 28, 2024.
14 Charani E, Mendelson M, Pallett SJC, et al. An analysis of existing national action plans for antimicrobial resistance-gaps and opportunities in strategies optimising antibiotic use in human populations. *Lancet Glob Health*. 2023;11(3):e466–e474.
15 Ahmed SM, Naher N, Tune S, Islam BZ. The implementation of national action plan (NAP) on antimicrobial resistance (AMR) in Bangladesh: challenges and lessons learned from a cross-sectional qualitative study. *Antibiotics (Basel)*. 2022;11(5).
16 Frumence G, Mboera LEG, Sindato C, et al. The governance and implementation of the national action plan on antimicrobial resistance in Tanzania: a qualitative study. *Antibiotics (Basel)*. 2021;10(3).
17 Chua AQ, Verma M, Hsu LY, Legido-Quigley H. An analysis of national action plans on antimicrobial resistance in Southeast Asia using a governance framework approach. *Lancet Reg Health West Pac*. 2021;7:100084.
18 Patel J, Harant A, Fernandes G, et al. Measuring the global response to antimicrobial resistance, 2020-21: a systematic governance analysis of 114 countries. *Lancet Infect Dis*. 2023;23:706.
19 Willemsen A, Reid S, Assefa Y. A review of national action plans on antimicrobial resistance: strengths and weaknesses. *Antimicrob Resist Infect Control*. 2022;11(1):90.
20 Anderson M, Schulze K, Cassini A, Plachouras D, Mossialos E. A governance framework for development and assessment of national action plans on antimicrobial resistance. *Lancet Infect Dis*. 2019;19(11):e371–e384.
21 Harant A. Assessing transparency and accountability of national action plans on antimicrobial resistance in 15 African countries. *Antimicrob Resist Infect Control*. 2022;11(1):15.
22 Zhou J, Ma X. A survey on antimicrobial stewardship in 116 tertiary hospitals in China. *Clin Microbiol Infect*. 2019;25(6):759 e9–e14.
23 Xiao Y, Shen P, Zheng B, Zhou K, Luo Q, Li L. Change in antibiotic use in secondary and tertiary hospitals nationwide after a national antimicrobial stewardship campaign was launched in China, 2011-2016: an observational study. *J Infect Dis*. 2020;221(Suppl 2):S148–S155.
24 Xiao Y, Yu W, Xiao T, Shen P. Evaluating the integrated antimicrobial stewardship system of China by the assessment tool of WHO. *Health Care Science*. 2022;1(2):69–85.
25 Ministry of Agriculture. *Ministry of agriculture announcement No. 2292 prohibition of four antibiotics in food animals*; 2015. http://www.moa.gov.cn/nybgb/2015/jiuqi/201712/t20171219_6103873.htm. Accessed August 3, 2023.
26 Ministry of Agriculture. *Ministry of agriculture announcement No. 2428 prohibition of colistin sulfate premix as A growth promoter*; 2016. http://www.moa.gov.cn/govpublic/SYJ/201608/t20160801_5224428.htm. Accessed August 3, 2023.
27 National Health and Family Planning Commission. *Further implementation of national action plan on antimicrobial resistance (2017)*; 2017. http://www.nhc.gov.cn/yzygj/s7659/201703/d2f580480cef4ab1b976542b550f36cf.shtml. Accessed May 7, 2023.
28 Ministry of Health. *National special campaign on clinical use of antimicrobials*; 2011:2011. http://www.nhc.gov.cn/zwgkzt/wsbysj/201104/51376.shtml. Accessed May 29, 2023.
29 National Health and Family Planning Commission. *Establishment of expert committee on clinical use of antimicrobials and evaluation of antimicrobial resistance*; 2017. http://www.nhc.gov.cn/yzygj/s3593/201701/56fef91783644070abfab5356b0fa4a7.shtml. Accessed April 27, 2023.
30 Ministry of Health. *Administrative measures for clinical use of antimicrobials*; 2012. https://www.gov.cn/flfg/2012-05/08/content_2132174.htm. Accessed May 29, 2023.
31 National Health and Family Planning Commission. *Guideline on clinical use of antimicrobials*; 2015. http://www.nhc.gov.cn/yzygj/

s3593/201508/c18e1014de6c45ed9f6f9d592b43db42.shtml. Accessed February 8, 2023.
32 National Health Commission. *Further implementation of national action plan on antimicrobial resistance (2018)*; 2018. http://www.nhc.gov.cn/yzygj/s7659/201805/c79c998bdf8f4744858051cdfd1e6818.shtml. Accessed April 8, 2023.
33 National Health and Family Planning Commission. *National action plan on antimicrobial resistance (2016-2020)*; 2016. http://www.nhc.gov.cn/yzygj/s3593/201608/f1ed26a0c8774e1c8fc89dd481ec84d7.shtml. Accessed February 7, 2022.
34 National Health Commission. *National action plan on antimicrobial resistance (2022-2025)*; 2022. http://www.nhc.gov.cn/yzygj/s7659/202210/2875ad7e2b2e46a2a672240ed9ee750f.shtml. Accessed August 2, 2023.
35 Ministry of Health. *Establishing surveillance networks on clinical use of antimicrobials and bacterial resistance*; 2005. http://www.nhc.gov.cn/cms-search/xxgk/getManuscriptXxgk.htm?id=18487. Accessed May 26, 2023.
36 Ministry of Health. *Strengthening surveillance on clinical use of antimicrobials and bacterial resistance*; 2012. http://www.nhc.gov.cn/zwgkzt/pyzgl1/201206/55062.shtml. Accessed May 29, 2023.
37 National Health Commission. *Surveillance on clinical use of antimicrobials and bacterial resistance in children*; 2020. http://www.nhc.gov.cn/yzygj/s3593/202007/ecb66ee3e5694f1a8f6d29f86163034e.shtml. Accessed May 27, 2023.
38 Ministry of Agriculture. *Surveillance plan for antimicrobial resistance from animal origin*; 2008:2008. http://www.moa.gov.cn/gk/zcfg/nybgz/200901/t20090123_1214893.htm. Accessed February 7, 2023.
39 Ministry of Agriculture. *Veterinary drug residue monitoring plan for animals and animal products (2018)*; 2018. http://www.moa.gov.cn/xw/bmdt/201801/t20180129_6135855.htm. Accessed June 26, 2023.
40 Ministry of Health. *Administrative measures for hospital-acquired infections*; 2006. https://www.gov.cn/flfg/2006-07/25/content_344886.htm. Accessed June 12, 2023.
41 Ministry of Health. *Strengthening control of nosocomial infections by multi-drug resistant bacteria.*; 2008. http://www.nhc.gov.cn/wjw/gfxwj/201304/caa37dae8bde44bc9a42dd10aeb9ff43.shtml. Accessed May 29, 2023.
42 National Health and Family Planning Commission. *Enhancing the diagnosis and treatment capabilities of bacterial and fungal infections in secondary and tertiary comprehensive hospitals*; 2016. http://www.nhc.gov.cn/cms-search/xxgk/getManuscriptXxgk.htm?id=d32dbf81d94841d1a988ef3c59f13975. Accessed March 3, 2024.
43 Ministry of Health. *National training program on clinical use of antimicrobials for healthcare professionals*; 2012. http://www.nhc.gov.cn/zwgkzt/pyzgl1/201208/55710.shtml. Accessed May 29, 2023.
44 National Health Commission. *Status report on antimicrobial administration and antimicrobial resistance in China (2016-2018)*; 2019. http://www.nhc.gov.cn/yzygj/s3594/201904/1b5a42f0e326487295b260c813da9b0e.shtml. Accessed March 24, 2023.
45 Ministry of Agriculture and Rural Affairs. Report on the use of veterinary antibiotics of China. 2018-2020. http://www.moa.gov.cn/gk/sygb/. Accessed September 7, 2023.
46 Ministry of Health. *Further improving clinical use of antimicrobials*; 2008:2008. http://www.nhc.gov.cn/yzygj/s3585u/200804/1d5c91da4dfb481b80d361a4d00fdc1c.shtml. Accessed June 30, 2023.
47 Ministry of Agriculture. *National action plan on antimicrobial resistance from animal origin (2017-2020)*; 2017. http://www.moa.gov.cn/nybgb/2017/dqq/201801/t20180103_6133925.htm. Accessed June 2, 2023.
48 Eriksen J, Bjorkman I, Roing M, Essack SY, Stalsby Lundborg C. Exploring the one health perspective in Sweden's policies for containing antibiotic resistance. *Antibiotics (Basel)*. 2021;10(5).
49 Yin J, Wang Y, Xu X, Liu Y, Yao L, Sun Q. The progress of global antimicrobial resistance governance and its implication to China: a review. *Antibiotics (Basel)*. 2021;10(11).
50 World Health Organization. *A manual for developing national action plans*; 2016. https://apps.who.int/iris/handle/10665/204470?locale-attribute=en&. Accessed September 15, 2023.
51 Munkholm L, Rubin O, Baekkeskov E, Humboldt-Dachroeden S. Attention to the Tripartite's one health measures in national action plans on antimicrobial resistance. *J Public Health Policy*. 2021;42(2):236–248.
52 Lebov J, Grieger K, Womack D, et al. A framework for One Health research. *One Health*. 2017;3:44–50.
53 Khan MS, Rothman-Ostrow P, Spencer J, et al. The growth and strategic functioning of One Health networks: a systematic analysis. *Lancet Planet Health*. 2018;2(6):e264–e273.
54 Destoumieux-Garzon D, Mavingui P, Boetsch G, et al. The one health concept: 10 Years old and a long road ahead. *Front Vet Sci*. 2018;5:14.
55 Singer AC, Shaw H, Rhodes V, Hart A. Review of antimicrobial resistance in the environment and its relevance to environmental regulators. *Front Microbiol*. 2016;7:1728.
56 Essack SY. Environment: the neglected component of the One Health triad. *Lancet Planet Health*. 2018;2(6):e238–e239.
57 Dar OA, Hasan R, Schlundt J, et al. Exploring the evidence base for national and regional policy interventions to combat resistance. *Lancet*. 2016;387(10015):285–295.
58 Nair M, Zeegers MP, Varghese GM, Burza S. India's national action plan on antimicrobial resistance: a critical perspective. *J Glob Antimicrob Resist*. 2021;27:236–238.
59 Chan OSK, Lam WWT, Fukuda K, et al. Antimicrobial resistance policy protagonists and processes-A qualitative study of policy advocacy and implementation. *Antibiotics (Basel)*. 2022;11(10).
60 The White House. *National action plan for combating antibiotic-resistant bacteria*; 2015. https://www.cdc.gov/drugresistance/us-activities/national-action-plan.html. Accessed June 13, 2023.
61 Government Offices of Sweden. *Swedish strategy to combat antibiotic resistance 2020-2023*; 2020. https://www.government.se/globalassets/government/dokument/socialdepartementet/amr_strategi_eng_web_ny.pdf. Accessed April 5, 2023.
62 Molstad S, Erntell M, Hanberger H, et al. Sustained reduction of antibiotic use and low bacterial resistance: 10-year follow-up of the Swedish Strama programme. *Lancet Infect Dis*. 2008;8(2):125–132.
63 Ranjalkar J, Chandy SJ. India's National Action Plan for antimicrobial resistance - an overview of the context, status, and way ahead. *J Family Med Prim Care*. 2019;8(6):1828–1834.
64 World Health Organization. WHO costing and budgeting tool for national action plans on antimicrobial resistance. https://www.who.int/teams/surveillance-prevention-control-AMR/who-amr-costing-and-budgeting-tool; 2021. Accessed September 22, 2023.
65 Vekemans J, Hasso-Agopsowicz M, Kang G, et al. Leveraging vaccines to reduce antibiotic use and prevent antimicrobial resistance: a World health organization action framework. *Clin Infect Dis*. 2021;73(4):e1011–e1017.
66 Jansen KU, Knirsch C, Anderson AS. The role of vaccines in preventing bacterial antimicrobial resistance. *Nat Med*. 2018;24(1):10–19.
67 van Heuvel L, Caini S, Duckers MLA, Paget J. Assessment of the inclusion of vaccination as an intervention to reduce antimicrobial resistance in AMR national action plans: a global review. *Global Health*. 2022;18(1):85.
68 Vicentini C, Vola L, Previti C, et al. Antimicrobial stewardship strategies including point-of-care testing (poct) for pediatric patients with upper-respiratory-tract infections in primary care: a systematic review of economic evaluations. *Antibiotics (Basel)*. 2022;11(8).
69 Dhesi Z, Enne VI, O'Grady J, Gant V, Livermore DM. Rapid and point-of-care testing in respiratory tract infections: an antibiotic guardian? *ACS Pharmacol Transl Sci*. 2020;3(3):401–417.
70 Wang Y, Xu C, Zhang R, et al. Changes in colistin resistance and mcr-1 abundance in Escherichia coli of animal and human origins following the ban of colistin-positive additives in China: an epidemiological comparative study. *Lancet Infect Dis*. 2020;20(10):1161–1171.
71 National Health Commission. *Year book of health in China (2022)*; 2023. http://www.nhc.gov.cn/mohwsbwstjxxzx/tjtjnj/202305/6ef68aac6bd14c1eb9375e01a0faa1fb.shtml. Accessed October 20, 2023.
72 Chang J, Xu S, Zhu S, et al. Assessment of non-prescription antibiotic dispensing at community pharmacies in China with simulated clients: a mixed cross-sectional and longitudinal study. *Lancet Infect Dis*. 2019;19(12):1345–1354.
73 Laxminarayan R, Matsoso P, Pant S, et al. Access to effective antimicrobials: a worldwide challenge. *Lancet*. 2016;387(10014):168–175.
74 Zhao H, Wei L, Li H, et al. Appropriateness of antibiotic prescriptions in ambulatory care in China: a nationwide descriptive database study. *Lancet Infect Dis*. 2021;21(6):847–857.
75 Adriaenssens N, Coenen S, Tonkin-Crine S, et al. European Surveillance of Antimicrobial Consumption (ESAC): disease-specific quality indicators for outpatient antibiotic prescribing. *BMJ Qual Saf*. 2011;20(9):764–772.