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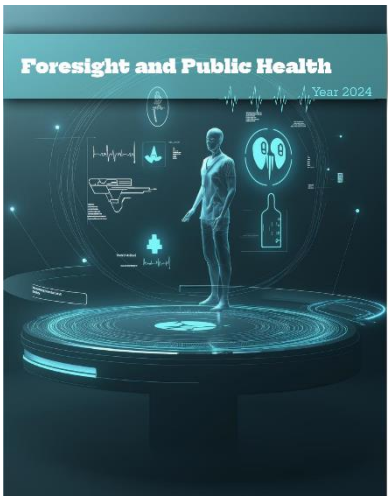

Exploring Future Scenarios of Antimicrobial Resistance: A Qualitative Study on Public Health Policy and Preparedness

Mahbobeh Hojjati[1], Zohreh Zadhasn[2*]

1 Department of Clinical Psychology, Islamic Azad University, Najaf Abad Branch, Najaf Abad, Iran
2 Department of Psychology and Counseling, KMAN Research Institute, Richmond Hill, Ontario, Canada

Corresponding author email address: zohrehzadhasan@kmanresce.ca

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ABSTRACT

This study explores future scenarios of antimicrobial resistance (AMR). This qualitative research employed semi-structured interviews with 19 participants, including experts in public health, epidemiology, healthcare policy, and AMR research. Participants were recruited through online announcements and professional platforms. Theoretical saturation was used to determine the sample size. Data were collected through virtual interviews, transcribed verbatim, and analyzed using NVivo software. A grounded theory approach was applied, with open and axial coding used to identify key themes related to AMR governance, public health preparedness, technological developments, and societal factors. The study identified four major themes influencing AMR's future trajectory: policy and governance challenges, public health preparedness gaps, technological and scientific barriers, and societal and behavioral factors. Policy inconsistencies, weak enforcement mechanisms, and inadequate surveillance systems were key governance issues. Public health preparedness remained insufficient, with limited healthcare capacity, delayed policy responses, and inadequate community engagement in AMR mitigation. Technological advancements, such as artificial intelligence and antimicrobial alternatives, were seen as promising but hindered by regulatory and financial constraints. Societal drivers of AMR included antibiotic misuse, pharmaceutical marketing influence, and public misconceptions. Participants emphasized the need for coordinated policy interventions, improved surveillance, and increased investment in research and innovation. Addressing AMR requires a globally coordinated response that integrates governance reforms, enhanced public health preparedness, technological advancements, and behavior change strategies. Strengthening regulatory frameworks, increasing funding for AMR initiatives, and promoting international collaboration are essential for mitigating future risks.

Keywords: Antimicrobial resistance, public health policy, AMR surveillance, healthcare preparedness, qualitative research, antibiotic misuse, global health governance.

Introduction

Antimicrobial resistance (AMR) is one of the most pressing global health threats, posing significant challenges to public health systems, healthcare policies, and future preparedness strategies (Sundram et al., 2024). The rapid evolution of resistant pathogens, coupled with the misuse and overuse of antimicrobials in human medicine, veterinary practice,

and agriculture, has exacerbated the crisis, leading to increased morbidity, mortality, and economic burden worldwide (Sokolović, 2024). AMR not only undermines the efficacy of existing antimicrobial therapies but also threatens the very foundation of modern medicine, making previously treatable infections life-threatening (Sama, 2024). With the dwindling pipeline of new antibiotics and the complex socio-political and economic factors influencing AMR management, it is imperative to explore potential future scenarios and develop robust public health policies to mitigate its impact (Ribeiro et al., 2024).

The global nature of AMR necessitates a multidisciplinary and coordinated response, yet governance challenges remain a key barrier to progress (Kilaru & Lim, 2024). Many countries lack comprehensive national action plans or struggle with fragmented policies, making enforcement inconsistent and ineffective (Johnson, 2024). The World Health Organization (WHO) has long advocated for the adoption of a One Health approach, which integrates human, animal, and environmental health to combat AMR, but implementation remains uneven across different regions (Izati et al., 2024). A major concern is the disparity in AMR surveillance, with some countries having advanced genomic sequencing capabilities while others lack basic reporting systems (Ekuri, 2024). This imbalance creates significant gaps in global AMR monitoring and hinders the ability to develop timely and effective countermeasures (Tikhute, 2023).

The use of whole-genome sequencing (WGS) has been proposed as a valuable tool for AMR surveillance, allowing for the tracking of resistant bacterial strains and the identification of emerging threats in real time (Calero-Cáceres et al., 2023). However, the implementation of WGS-based surveillance is still in its infancy in many low- and middle-income countries due to high costs and technical barriers (Berman et al., 2023). Additionally, antimicrobial resistance in food-producing animals remains a critical issue, as antibiotic residues in livestock contribute to the transmission of resistant bacteria through the food chain (Yadav et al., 2022). Studies have shown that the bacteriome and resistome of humans and animals are interconnected, further complicating AMR management strategies (Carvalho et al., 2022). The need for stricter regulations on antibiotic use in agriculture, coupled with improved waste management systems to reduce environmental contamination, has been emphasized as a crucial aspect of AMR mitigation (Turankar et al., 2022).

Ethical and legal considerations in AMR governance also present significant challenges. Policymakers are often faced with difficult decisions regarding antibiotic stewardship, balancing public health concerns with economic and commercial interests (Pahlman et al., 2022). The over-the-counter availability of antibiotics in some regions exacerbates the problem, as patients self-medicate without proper prescriptions, leading to increased resistance rates (Moussa & Garba, 2022). Moreover, healthcare professionals frequently face pressure to prescribe antibiotics unnecessarily due to patient expectations and diagnostic uncertainty (Monachino, 2022). Addressing these issues requires comprehensive legal frameworks and ethical guidelines to support antimicrobial stewardship policies while ensuring equitable access to essential medicines (Langford et al., 2022).

Public health preparedness and response efforts remain inadequate in many parts of the world, as AMR is often perceived as a slow-moving crisis rather than an immediate threat (Yau et al., 2021). This perception has led to delays in policy interventions and insufficient investment in healthcare infrastructure to manage drug-resistant infections effectively (Rubin et al., 2021). The COVID-19 pandemic has demonstrated the vulnerabilities in global health security and highlighted the importance of proactive preparedness strategies (Kumar et al., 2021). Lessons learned from pandemic responses can be applied to AMR management, particularly in enhancing international collaboration, strengthening laboratory capacities, and improving healthcare system resilience (Iossa & White, 2021).

One of the major obstacles in AMR mitigation is the slow adaptation of preventive measures, including infection control strategies, vaccination programs, and public awareness campaigns (Jamrozik & Selgelid, 2020). While infection prevention and control (IPC) measures have been shown to reduce the spread of resistant bacteria, their implementation is often inconsistent, particularly in resource-limited settings (Bennett & Iredell, 2020). Community engagement plays a crucial role in AMR prevention, as public misconceptions about antibiotics contribute to inappropriate use and demand for unnecessary prescriptions (Sundram et al., 2024). Misinformation regarding antibiotic effectiveness and resistance mechanisms is widespread, necessitating targeted educational interventions to promote responsible antimicrobial use (Sokolović, 2024).

Technological advancements offer promising solutions for AMR detection, treatment, and containment. Artificial intelligence (AI) and big data analytics are increasingly being explored for AMR surveillance, enabling the early detection of resistance patterns and the identification of high-risk populations (Sama, 2024). AI-driven diagnostic tools have the potential to improve prescribing practices by providing rapid and accurate assessments of bacterial infections, reducing the unnecessary use of broad-spectrum antibiotics (Ribeiro et al., 2024). However, barriers to adoption remain, including high costs, data privacy concerns, and resistance from healthcare providers to integrate new technologies into clinical practice (Kilaru & Lim, 2024).

In addition to AI-based solutions, novel antimicrobial alternatives are being developed to address the growing resistance crisis. Research on bacteriophage therapy, antimicrobial peptides, and CRISPR-based gene-editing techniques has shown promising results in combating resistant infections (Johnson, 2024). However, these technologies are still in experimental stages, and significant challenges remain in terms of regulatory approval, large-scale production, and clinical integration (Izati et al., 2024). The pharmaceutical industry's reluctance to invest in antibiotic research and development further exacerbates the crisis, as the return on investment for new antibiotics is often lower compared to other therapeutic areas (Ekuri, 2024). Addressing this issue requires policy interventions to incentivize antibiotic innovation while ensuring equitable access to new treatments (Tikhute, 2023).

Societal and behavioral factors also play a crucial role in the AMR crisis. The misuse and overuse of antibiotics are often driven by cultural beliefs, socioeconomic factors, and healthcare access disparities (Calero-Cáceres et al., 2023). In some regions, antibiotics are perceived as a quick solution to minor illnesses, leading to excessive consumption and increased resistance rates (Berman et al., 2023). Additionally, pharmaceutical marketing strategies influence prescribing behaviors, with aggressive promotion of antibiotics contributing to unnecessary use (Yadav et al., 2022). Strengthening regulatory oversight and implementing stricter guidelines on antibiotic advertising are necessary steps to curb this trend (Carvalho et al., 2022).

Given the complexity of AMR and its far-reaching consequences, a forward-looking approach is needed to anticipate future challenges and develop comprehensive policy frameworks. This study aims to explore potential future scenarios of AMR through a qualitative investigation of expert perspectives on public health policy and preparedness.

Methods and Materials

This study employs a qualitative research design to explore future scenarios of antimicrobial resistance (AMR) with a focus on public health policy and preparedness. The research follows an interpretative approach, aiming to understand expert perspectives through in-depth qualitative inquiry. The study utilizes semi-structured interviews as the primary data collection method, allowing for an open yet guided exploration of participants' insights. Theoretical saturation was used as the criterion for determining the final sample size, ensuring that data collection continued until no new themes or concepts emerged. A total of 19 participants were selected, all of whom possessed relevant expertise in public health, epidemiology, antimicrobial resistance policy, and healthcare preparedness. Participants were recruited through online announcements and professional platforms, targeting individuals with substantial knowledge and experience in AMR policy and its future implications.

Data collection was conducted using semi-structured interviews, designed to elicit in-depth responses on the potential future trajectories of AMR, policy challenges, and preparedness strategies. The interview guide consisted of open-ended questions that facilitated discussions on anticipated risks, policy gaps, and possible interventions to mitigate AMR threats. The interviews were conducted virtually, allowing for a geographically diverse pool of respondents. Each interview lasted approximately 45 to 60 minutes, ensuring sufficient depth in responses while maintaining participant engagement. All interviews were recorded with participants' consent and subsequently transcribed verbatim to ensure data accuracy and integrity.

The data analysis process was conducted using NVivo software, which facilitated systematic coding and thematic extraction. The analysis followed a grounded theory approach, with initial open coding used to identify key themes and patterns within the data. Axial coding was then applied to establish connections between themes, leading to the

development of a conceptual framework outlining possible future AMR scenarios and public health responses. Data interpretation was conducted iteratively, with continuous cross-referencing between emerging themes and the raw interview transcripts to ensure analytical rigor. Reflexivity was maintained throughout the analysis process to minimize researcher bias, and credibility was enhanced through peer debriefing and discussions on thematic consistency.

Findings and Results

The study included 19 participants with diverse backgrounds in public health, epidemiology, healthcare policy, and antimicrobial resistance (AMR) research. Among them, 11 participants (57.9%) were male, and 8 participants (42.1%) were female. The participants' ages ranged from 32 to 64 years, with an average age of 45.3 years. Regarding professional experience, 6 participants (31.6%) had between 5 and 10 years of experience in AMR-related fields, 8 participants (42.1%) had between 11 and 20 years of experience, and 5 participants (26.3%) had over 20 years of experience. Geographically, participants represented different regions, including North America (n = 5, 26.3%), Europe (n = 6, 31.6%), Asia (n = 4, 21.1%), and Africa (n = 4, 21.1%), reflecting a diverse global perspective on AMR policy and preparedness. The professional roles of the participants varied, with 7 individuals (36.8%) working in governmental public health agencies, 5 participants (26.3%) affiliated with academic institutions, 4 participants (21.1%) employed in non-governmental organizations (NGOs) focusing on AMR, and 3 participants (15.8%) working in private-sector healthcare policy development. This diversity in demographics and expertise ensured a broad range of insights into the challenges and future scenarios of AMR.

Table 1. The Results of Thematic Analysis

Categories (Main Themes)	Subcategories (Subthemes)	Concepts (Open Codes)
Policy and Governance Challenges	Inconsistent global regulations	Variability in national policies, lack of international coordination, policy fragmentation, enforcement issues, political resistance
	Gaps in AMR surveillance	Insufficient data sharing, underreporting, lack of standardization, inadequate real-time monitoring
	Weak policy enforcement	Regulatory loopholes, weak accountability, limited oversight mechanisms
	Limited funding for AMR initiatives	Budget constraints, low prioritization, dependency on external funding
	Ethical and legal dilemmas	Balancing public health and economic interests, access to antibiotics, legal barriers to enforcement
Public Health Preparedness and Response	Capacity limitations in healthcare systems	Shortage of trained personnel, hospital overcrowding, inadequate infrastructure
	Slow adaptation of preventive measures	Low vaccination uptake, poor infection control policies, resistance to behavioral change
	Crisis response inefficiencies	Delayed government action, lack of emergency preparedness, absence of contingency planning
	Community engagement in AMR mitigation	Public awareness campaigns, behavioral interventions, role of media
	Integration of One Health approach	Cross-sector collaboration, addressing animal and environmental AMR sources, interdisciplinary strategies
	Challenges in rapid diagnostic implementation	High costs, technological constraints, resistance to new diagnostic tools
Technological and Scientific Developments	Advances in antimicrobial alternatives	Development of bacteriophages, synthetic biology applications, probiotics research
	Role of AI and big data in AMR monitoring	Predictive analytics, early detection algorithms, real-time epidemiological tracking
	Challenges in antibiotic discovery	High research costs, slow drug approval processes, pharmaceutical disinterest
	Personalized medicine and targeted therapies	Precision antibiotics, genomic approaches, microbiome-based interventions
	Innovations in AMR containment strategies	Smart drug delivery systems, novel vaccine technologies, CRISPR-based solutions
Societal and Behavioral Factors	Misuse and overuse of antibiotics	Self-medication, lack of prescription control, over-the-counter access
	Public misconceptions about AMR	Antibiotic myths, misunderstanding of resistance, lack of scientific literacy
	Cultural and socioeconomic barriers	Healthcare access disparities, economic pressures on prescribing, traditional medicine influences
	Pharmaceutical industry influence	Aggressive marketing, lobbying against regulations, conflicts of interest
	Trust in public health institutions	Government transparency, historical distrust, credibility of health campaigns

The findings of this study identified four major themes related to the future scenarios of antimicrobial resistance (AMR): policy and governance challenges, public health preparedness and response, technological and scientific

developments, and societal and behavioral factors. Within these themes, several subthemes emerged, each reflecting specific concerns raised by the participants.

Inconsistent global regulations were a significant challenge highlighted by participants, emphasizing the disparity in AMR policies across different countries. Several interviewees noted that the absence of a unified global strategy weakens efforts to combat AMR effectively. One respondent stated, "Each country enforces AMR regulations differently, and without a consistent global standard, we are essentially fighting separate battles rather than a collective war." This inconsistency results in fragmented enforcement mechanisms, limited international collaboration, and regulatory gaps that allow antibiotic misuse to persist.

Gaps in AMR surveillance were frequently discussed as a major concern, with participants highlighting the lack of standardized reporting systems and real-time data sharing across healthcare institutions. Many expressed frustration over the underreporting of AMR cases and the limited capacity to monitor resistance trends comprehensively. As one interviewee noted, "Without a centralized and transparent surveillance system, we are always one step behind in understanding how resistance is evolving." These surveillance deficiencies contribute to delayed policy responses and hinder the development of effective mitigation strategies.

Weak policy enforcement was another critical issue that emerged in the discussions. Several participants described regulatory loopholes and limited accountability as key barriers to effective AMR control. One expert remarked, "Even when strict policies exist, enforcement is often weak, and there's no mechanism to ensure compliance at different levels of the healthcare system." Many attributed this weakness to political resistance, economic constraints, and a lack of systematic oversight mechanisms.

Limited funding for AMR initiatives was repeatedly identified as a major constraint in developing sustainable intervention programs. Participants described how AMR research and control programs often receive insufficient government funding, relying instead on temporary external grants. One interviewee pointed out, "AMR is a slow-moving crisis, and because it doesn't create immediate public panic, governments are reluctant to allocate adequate resources." This financial limitation affects research, policy implementation, and public awareness campaigns, ultimately weakening the global response to AMR.

Ethical and legal dilemmas were raised concerning the tension between public health priorities and economic interests. Several participants discussed the challenge of balancing access to antibiotics with strict regulations to prevent misuse. As one expert explained, "We can't restrict access to life-saving antibiotics entirely, but at the same time, widespread availability contributes to resistance." Legal barriers, including difficulties in enforcing bans on over-the-counter antibiotics in some regions, were also highlighted as obstacles to AMR policy implementation.

Capacity limitations in healthcare systems emerged as a major public health preparedness challenge. Many participants emphasized the shortage of trained personnel, overcrowding in hospitals, and inadequate infrastructure as key factors that hinder an effective AMR response. One interviewee described the situation: "Healthcare workers are already stretched thin, and dealing with drug-resistant infections only adds to the burden, making it nearly impossible to provide optimal care." These systemic limitations weaken the ability to manage AMR cases efficiently.

Slow adaptation of preventive measures was also identified as a barrier to AMR mitigation. Participants pointed out that low vaccination rates, poor infection control policies, and resistance to behavioral changes contribute to the spread of resistant infections. One respondent noted, "Preventive strategies like better hygiene practices and routine vaccinations are well-known solutions, yet implementation is slow because they don't get the same attention as new antibiotics." This resistance to adopting preventive measures delays effective intervention efforts.

Crisis response inefficiencies were highlighted as a significant issue, with many participants stating that AMR-related emergencies often receive delayed government action. The absence of contingency plans and emergency preparedness frameworks leaves healthcare systems vulnerable. As one interviewee put it, "Governments react to AMR when it becomes a crisis, but by then, it's too late to contain the damage." This reactive rather than proactive approach was widely criticized.

Community engagement in AMR mitigation was considered a crucial yet underutilized strategy. Participants stressed the importance of public awareness campaigns and media involvement in educating the population about AMR risks.

One respondent suggested, “If people understood that antibiotic resistance threatens everyday treatments, they would be more cautious about demanding unnecessary prescriptions.” Increased community involvement was seen as essential for promoting responsible antibiotic use.

Integration of the One Health approach was another key discussion point, with participants advocating for a multidisciplinary response to AMR. Many emphasized that addressing resistance in humans alone is insufficient without tackling antibiotic use in agriculture and environmental contamination. One participant explained, “We need a cross-sector collaboration involving veterinarians, environmental scientists, and public health officials, not just medical professionals.” This holistic approach was widely supported as a necessary step toward effective AMR control.

Challenges in rapid diagnostic implementation were also highlighted, particularly concerning the high costs and resistance to adopting new technologies. Many participants noted that while rapid diagnostics could significantly reduce unnecessary antibiotic prescriptions, their adoption remains slow. One expert commented, “Hospitals hesitate to invest in expensive diagnostic tools, especially in resource-limited settings, even though they could prevent misuse.” This financial and technological barrier limits the effectiveness of AMR control strategies.

Advances in antimicrobial alternatives were discussed as a promising yet underdeveloped area. Participants pointed to ongoing research in bacteriophages, synthetic biology, and probiotics as potential solutions for AMR. However, as one interviewee noted, “We’re still far from mainstreaming these alternatives because pharmaceutical companies hesitate to invest in non-traditional treatments.” This lack of commercial interest slows the development and deployment of alternative therapies.

The role of AI and big data in AMR monitoring was seen as an emerging opportunity. Several participants highlighted predictive analytics and real-time surveillance as valuable tools for tracking resistance patterns. One respondent stated, “AI can process vast amounts of AMR data and identify trends faster than traditional methods, giving us a head start in prevention.” However, concerns about data privacy and integration into existing healthcare systems were also raised.

Challenges in antibiotic discovery were frequently discussed, with participants pointing to high research costs and slow approval processes. One expert remarked, “Developing new antibiotics is not profitable for pharmaceutical companies, so there’s little incentive to invest in it.” This market-driven challenge contributes to the growing scarcity of novel antibiotics.

Personalized medicine and targeted therapies were identified as potential solutions for AMR management. Participants discussed approaches such as precision antibiotics, microbiome-based treatments, and genomic strategies. One respondent suggested, “The future of AMR treatment lies in tailoring therapies to individual patients rather than using broad-spectrum antibiotics indiscriminately.” However, cost and accessibility remain concerns.

Innovations in AMR containment strategies were also explored, with participants highlighting smart drug delivery systems and CRISPR-based solutions. One interviewee noted, “We’re seeing breakthroughs in gene-editing technologies that could help us neutralize resistant bacteria, but these approaches are still in early stages.” The transition from research to clinical application was seen as a key challenge.

Misuse and overuse of antibiotics remained one of the most pressing societal issues discussed. Many participants expressed concerns about self-medication and lack of prescription control. One respondent shared, “People often take antibiotics for viral infections without realizing they don’t work, contributing to resistance.” This widespread misuse accelerates resistance development.

Public misconceptions about AMR were also highlighted, with participants noting the influence of misinformation on antibiotic use. One expert stated, “Many people still believe that stronger antibiotics work better, not understanding that unnecessary use worsens resistance.” Educational initiatives were suggested as a necessary intervention.

Cultural and socioeconomic barriers were discussed as factors influencing AMR outcomes. Participants noted disparities in healthcare access and economic pressures that affect prescribing practices. One interviewee explained, “Doctors in low-income areas often overprescribe antibiotics to satisfy patients who can’t afford follow-up visits.” These structural issues complicate AMR mitigation efforts.

Pharmaceutical industry influence was identified as a key driver of antibiotic overuse. Participants pointed to aggressive marketing tactics and lobbying efforts that hinder regulatory changes. One respondent remarked,

“Pharmaceutical companies push for higher sales, which directly contradicts efforts to reduce unnecessary antibiotic use.” These industry dynamics create conflicts of interest.

Trust in public health institutions was discussed as an important factor in AMR response effectiveness. Participants highlighted government transparency and credibility as crucial for public cooperation. One expert noted, “When people don’t trust health authorities, they are less likely to follow guidelines on antibiotic use.” Building public confidence was seen as a necessary step toward effective AMR mitigation.

Discussion and Conclusion

The findings of this study reveal that antimicrobial resistance (AMR) is a multifaceted challenge driven by policy inconsistencies, public health preparedness gaps, technological and scientific barriers, and societal behaviors. Participants emphasized that AMR governance remains fragmented, with significant variations in national policies and enforcement mechanisms. Many respondents pointed to the lack of a unified global AMR strategy, which hinders international collaboration and results in policy fragmentation. Surveillance gaps were another recurring concern, as several participants noted that many countries lack robust monitoring systems for AMR trends, making it difficult to implement effective mitigation strategies. Additionally, weak policy enforcement, limited funding, and ethical dilemmas surrounding access to antibiotics were identified as barriers to effective AMR governance.

Public health preparedness was also found to be inadequate, with participants highlighting capacity limitations in healthcare systems and slow adaptation of preventive measures. A key issue raised was the lack of trained personnel and resources to manage drug-resistant infections effectively. Participants emphasized that while infection prevention strategies such as vaccination programs and antimicrobial stewardship initiatives are known solutions, they are not being implemented effectively. Crisis response inefficiencies were also reported, with concerns that AMR is often treated as a long-term issue rather than an immediate public health crisis, leading to delayed policy action. The role of community engagement was highlighted as a crucial factor in AMR mitigation, yet many respondents believed that public awareness campaigns remain insufficient in changing antibiotic use behaviors.

Technological and scientific developments in AMR management were discussed as both opportunities and challenges. Advances in antimicrobial alternatives, the potential of artificial intelligence (AI) in AMR monitoring, and the role of personalized medicine were seen as promising solutions. However, participants noted that high research costs, slow regulatory approval processes, and pharmaceutical industry reluctance to invest in antibiotic development remain major obstacles. Furthermore, rapid diagnostic technologies, which could play a key role in reducing unnecessary antibiotic prescriptions, have not been widely adopted due to financial and logistical barriers.

Societal and behavioral factors also emerged as significant contributors to AMR. Participants expressed concerns about the widespread misuse and overuse of antibiotics, particularly due to self-medication and over-the-counter availability in certain regions. Public misconceptions about antibiotic effectiveness and cultural influences on prescribing practices were also identified as key drivers of resistance. Additionally, pharmaceutical marketing strategies were reported to have a considerable impact on antibiotic consumption patterns, often promoting unnecessary use. Trust in public health institutions was another major concern, as participants believed that limited government transparency and inconsistent messaging have led to reduced public confidence in AMR policies.

These findings align with existing literature on AMR governance challenges. Studies have highlighted that inconsistencies in national AMR policies and weak enforcement mechanisms contribute significantly to resistance rates (Sundram et al., 2024). The One Health approach, which integrates human, animal, and environmental health perspectives, has been widely recommended as a solution; however, its implementation has been inconsistent due to policy fragmentation (Sokolović, 2024). Research has shown that global coordination in AMR surveillance remains inadequate, with some countries investing in advanced monitoring techniques such as whole-genome sequencing while others lack basic reporting systems (Sama, 2024). These disparities align with participants' concerns that limited surveillance capabilities hinder effective AMR management (Ribeiro et al., 2024).

The role of surveillance in AMR management has been widely discussed in the literature. Whole-genome sequencing (WGS) has been identified as a critical tool for tracking resistant bacterial strains, yet its adoption remains limited due to financial and technical constraints (Calero-Cáceres et al., 2023). Studies have shown that AMR surveillance in food-producing animals is particularly weak, leading to concerns about the transmission of resistant bacteria through the food chain (Berman et al., 2023). Research conducted in Brazil has demonstrated the interconnectedness of the bacteriome and resistome in humans and livestock, emphasizing the need for stricter antibiotic regulations in agriculture (Carvalho et al., 2022). These findings support participant concerns regarding the need for a stronger regulatory framework to control antibiotic use in veterinary medicine and food production (Turankar et al., 2022).

The public health preparedness gaps identified in this study are also consistent with previous research. Many scholars have argued that AMR is often treated as a secondary priority compared to more immediate health threats, leading to insufficient funding and weak policy responses (Pahlman et al., 2022). The COVID-19 pandemic has provided a case study in global health preparedness, demonstrating both the strengths and weaknesses of emergency response strategies (Moussa & Garba, 2022). Research has suggested that lessons from pandemic responses, including improved laboratory capacities and strengthened healthcare infrastructure, could be applied to AMR management (Monachino, 2022). However, as this study's participants noted, political will remains a major barrier to prioritizing AMR policies (Langford et al., 2022).

The importance of community engagement in AMR mitigation has been widely emphasized in the literature. Studies have shown that public misconceptions about antibiotics significantly contribute to inappropriate use, making educational interventions a crucial aspect of AMR control (Yau et al., 2021). However, many public health campaigns have struggled to change behaviors due to deeply rooted cultural and socioeconomic factors (Rubin et al., 2021). Research has also highlighted the role of healthcare professionals in influencing antibiotic use, noting that prescribing habits are often shaped by patient expectations and diagnostic uncertainty (Kumar et al., 2021). These findings support participant concerns that increased awareness and behavioral interventions are necessary to change antibiotic consumption patterns (Iossa & White, 2021).

The technological and scientific challenges identified in this study are also supported by previous research. The role of artificial intelligence and big data in AMR surveillance has been widely discussed, with studies demonstrating the potential of AI-driven diagnostics in predicting resistance patterns and improving antimicrobial stewardship (Jamrozik & Selgelid, 2020). However, high implementation costs and resistance to technological change have been identified as barriers to adoption (Bennett & Iredell, 2020). Similarly, research on antimicrobial alternatives such as bacteriophage therapy and CRISPR-based gene-editing techniques has shown promising results, but regulatory and commercial challenges have slowed their integration into clinical practice (Sundram et al., 2024). Participants' concerns about the lack of pharmaceutical investment in new antibiotic development are also reflected in the literature, as studies have shown that financial disincentives have led many pharmaceutical companies to abandon antibiotic research (Sokolović, 2024).

The societal and behavioral factors influencing AMR identified in this study align with broader research findings. Misuse and overuse of antibiotics have been consistently linked to self-medication, lack of prescription control, and healthcare access disparities (Sama, 2024). Public misconceptions about antibiotic effectiveness and the cultural acceptance of antibiotic use for minor illnesses further contribute to resistance rates (Ribeiro et al., 2024). The influence of pharmaceutical marketing on antibiotic consumption has also been documented, with studies showing that aggressive promotion strategies have led to increased sales and overprescription (Kilaru & Lim, 2024). Additionally, research has highlighted the importance of trust in public health institutions in shaping compliance with AMR policies (Johnson, 2024). Participants' concerns about government transparency and credibility align with findings that inconsistent messaging and lack of public engagement reduce the effectiveness of AMR interventions (Izati et al., 2024).

This study has several limitations. First, the sample size was relatively small, with only 19 participants, which may limit the generalizability of the findings. Although theoretical saturation was achieved, a larger and more diverse sample could provide additional perspectives. Second, all data were collected through semi-structured interviews, which rely on self-reported insights that may be influenced by personal biases and professional experiences. Additionally, as

interviews were conducted online, some participants may have been less forthcoming about sensitive policy-related issues due to concerns about confidentiality. Finally, while this study provides a qualitative exploration of AMR future scenarios, it does not include quantitative data that could provide additional empirical validation of the identified themes.

Future research should explore AMR governance and public health preparedness using larger and more diverse samples, including policymakers, healthcare professionals, and industry stakeholders. Quantitative studies analyzing AMR trends across different regions could complement qualitative insights and provide more concrete evidence for policy recommendations. Additionally, comparative studies between high-income and low-income countries could identify context-specific challenges and inform targeted interventions. Further research on the role of artificial intelligence, rapid diagnostics, and novel antimicrobial alternatives in AMR management is also needed, with an emphasis on overcoming barriers to implementation.

To improve AMR policy and preparedness, governments should strengthen regulatory frameworks and ensure consistent enforcement of antimicrobial stewardship policies. Investment in AMR surveillance infrastructure, including genomic sequencing and AI-based monitoring systems, should be prioritized. Public health campaigns should focus on addressing antibiotic misconceptions and promoting responsible use through targeted educational initiatives. Additionally, pharmaceutical companies should be incentivized to invest in antibiotic research and development through financial support and regulatory incentives. Finally, greater international collaboration is needed to ensure a coordinated and effective response to the AMR crisis.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. Written consent was obtained from all participants in the study.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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