



## *The Silent Spiral, Global Politics, Environmental Path Ways, and the Multisectoral Drivers of Anti-Microbial Resistance*

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### **Abstract**

*Antimicrobial resistance (AMR) has emerged as one of the gravest 21st-century threats to global health, economic stability, and modern medical systems. This paper investigates AMR as a complex, multisectoral phenomenon shaped by medical misuse, agricultural overdependence, pharmaceutical pollution, climate dynamics, and governance failures. Drawing on real-world outbreaks including NDM-1, MCR-1, CRE, and Candida auris the study traces how resistant organisms evolve, circulate, and entrench themselves across hospitals, livestock systems, food supply chains, and environmental reservoirs. Evidence from WHO, UNEP, FAO, CDC, ICMR, and EU surveillance networks demonstrates that antibiotic misuse in humans and animals, substandard sanitation, and unregulated pharmaceutical discharge function as mutually reinforcing accelerants of resistance. The analysis further explores how warming temperatures, PM2.5 air pollution, river contamination, and global travel amplify the emergence and spread of superbugs. The paper argues that fragmented global governance—characterized by weak enforcement, misaligned incentives, and insufficient investment in diagnostics and novel antimicrobials has allowed AMR to escalate into a silent worldwide pandemic. Emphasizing a One Health framework, the paper concludes that mitigating AMR requires coordinated political commitment, sustainable agricultural transitions, environmental regulation, and anticipatory governance capable of pre-empting microbial evolution rather than merely reacting to clinical crises.*

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## Infectious Diseases

### Jel Classification Codes

I18–Health: Government Policy; Regulation; Public Health  
 I15–Health and Economic Development  
 Q53–Air Pollution; Water Pollution; Waste Management  
 Q18–Agricultural Policy; Food Policy  
 O15–Human Development; Public Health  
 H51–Government Expenditures and Public Health  
 L65–Health Care, Pharmaceuticals, and Biotech  
 F64–Environmental Economics & Globalization

### He Silent Spiral: Global Politics, Environmental Pathways, and the Multisectoral Drivers of Antimicrobial Resistance:

Antimicrobial resistance (AMR) today stands at the center of a slow-burning global emergency, one that scientists such as Dame Sally Davies have compared to a “silent pandemic” capable of reversing a century of medical progress. While policymakers frequently reduce AMR to a technical problem one of microbes evolving faster than medicines—the deeper reality is far more complex, woven from patterns of human neglect, corporate incentives, agricultural economics, political apathy, weak global coordination, environmental deterioration, and a widening gap between countries that can afford modern infection control systems and those that cannot. The story of AMR is not simply about bacteria outsmarting drugs; it is a story of how human behavior, global trade, climate change, urbanization, pharmaceutical decline, and governance failures continuously create ecological opportunities for resistance to evolve, settle, and explode into superbugs that move rapidly across borders. Investigators who have followed AMR for decades from Ramanan Laxminarayan’s global modeling work to Tim Walsh’s early detection of NDM—Have repeatedly warned that resistance does not “emerge” in a vacuum; it is produced by policy and practice. It is produced by the way antibiotics are used, misused, overused, distributed, subsidized, and sometimes deliberately abused in both medicine and agriculture, and by the ecosystems that political systems allow to degrade until resistant organisms circulate freely through soil, air, rivers, livestock, and food chains.

The medical misuse of antibiotics remains the most visible driver, but the roots go deeper than over-prescription. Across many countries, antibiotics are routinely used not as therapeutic agents but as

psychosocial reassurance patients expect them, doctors prescribe them under pressure, and pharmacists dispense them without oversight. Countless investigations by the World Health Organization (WHO), including those led by Hanan Balkhy, have documented clinics in South Asia, Africa, and Latin America where antibiotics are prescribed for viral infections simply because patients equate antibiotic use with “proper treatment.” In India, for instance, studies conducted by AIIMS Delhi and the Indian Council of Medical Research (ICMR) have found that up to 60% of outpatient antibiotic prescriptions are unnecessary, often for self-limiting viral fevers, common colds, and mild respiratory infections that require symptomatic management rather than broad-spectrum antimicrobials [1]. Hospitals add another structural problem: incomplete treatment courses, incorrect dosage, and weak stewardship. When a patient receives a sub-therapeutic course or a drug inappropriate for the infecting organism the infection is not fully eradicated, allowing resistant mutants to survive and replicate. Investigators at the Royal Free Hospital in London have long emphasized that incorrect empiric therapy in the first 48 hours dramatically increases the risk of selecting for resistant strains, especially in ICU settings [2]. Every dose of an antibiotic exerts evolutionary pressure on microbes, and when that pressure is misapplied too short, too weak, or too broad it becomes a near-perfect recipe for driving resistance.

Yet medicine is only half the equation. The agricultural sector uses more antibiotics globally than human healthcare does nearly two-thirds, as repeatedly emphasized in UN FAO and WHO joint reports, and in the landmark 2019 UN Interagency Coordination Group (IACG) report [3]. Investigators in the European Medicines Agency (EMA) spent almost a decade showing how Europe’s ban on growth-promoting antibiotic use, combined with surveillance mechanisms like the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC), dramatically reduced agricultural antibiotic use from 2011 onward. But in emerging economies such as India, China, Brazil, Vietnam, and parts of sub-Saharan Africa, antibiotics remain integral to livestock economics. Farmers use them not only to treat disease but to promote growth, accelerate weight gain, and compensate for poor hygiene conditions. When antimicrobials become cheaper than modernizing farm infrastructure ventilation, waste management, water sanitation—economic incen-

tives align with misuse, creating fertile ground for resistant organisms. Investigations in China's Shandong and Guangdong provinces uncovered rampant use of colistin a last-resort antibiotic as a growth promoter in pigs and poultry until the discovery of the MCR-1 resistance gene in 2015 forced regulatory bans [4]. The MCR-1 gene, found by Chinese scientist Liu Jinxin and later analyzed by Timothy Walsh and colleagues, provided a chilling demonstration of agricultural misuse feeding global AMR: a single resistance gene originating in livestock spread within months to clinical isolates in more than 30 countries.

Environmental pathways represent an even more disturbing dimension of AMR, one that historian-investigators such as Jim O'Neill, head of the 2016 AMR Review, have argued remains persistently underestimated. The UN Environment Programme (UNEP) has repeatedly reported that rivers downstream of pharmaceutical manufacturing plants particularly in India's Hyderabad region, one of the world's largest hubs for generic drug production contain antibiotic concentrations comparable to therapeutic doses [5].

Investigations by Swedish researchers from Uppsala University, who sampled Patancheru wastewater, found ciprofloxacin concentrations up to 1000 times higher than levels known to select for resistance. These contaminated waters feed into irrigation systems, enter nearby villages, and mix with municipal runoff, creating an open-air laboratory for AMR evolution. Similarly, studies in Pakistan, Bangladesh, Kenya, and Argentina have found hospital wastewater to be a central node in the emergence and dissemination of resistant organisms, with pathogens like *Klebsiella pneumoniae*, *Acinetobacter baumannii*, and *Pseudomonas aeruginosa* showing increasingly multidrug-resistant (MDR) patterns [6].

Climate change further complicates the landscape. A pivotal 2022 study published in *The Lancet Planetary Health* by Xiao Wu and colleagues showed that countries with higher levels of PM2.5 air pollution also exhibited higher levels of antibiotic resistance across major bacterial pathogens, suggesting that airborne particulate matter acts as a vehicle for both resistant organisms and resistance genes [7]. Fine particulate pollution carries microbes, DNA fragments, and antibiotic residues, enabling long-distance transmission.

As temperatures rise, bacterial replication accelerates, survival windows lengthen, and environmental niches expand. Floods, driven by climate extremes, distribute resistant organisms across wider areas; droughts concentrate contaminants in shrinking water bodies; and heatwaves amplify hospital infection loads. This multifactorial relationship means AMR is not merely a biomedical challenge but an environmental phenomenon shaped by atmospheric, hydrological and ecological currents.

The link between poor sanitation and AMR is equally critical. WHO and UNICEF estimates show that 2.2 billion people still lack safely managed drinking water systems. In these contexts, water becomes the primary vector for resistant organisms, especially in overcrowded informal settlements where human waste, animal waste, and agricultural runoff converge. Investigations of South Asian river systems particularly India's Ganges basin have repeatedly found high densities of extended-spectrum beta-lactamase (ESBL)-producing *E. coli*, NDM-1 positive bacteria, and carbapenem-resistant *Klebsiella*, especially near urban slums, hospitals, and religious bathing sites [8]. Field investigators from the Public Health Foundation of India (PHFI) documented how pilgrims who bathe in river waters during festivals acquire resistant gut flora that they later carry back to cities and villages, turning AMR into a form of microbial travel. Similar patterns appear in Africa's Lake Victoria region, where local health workers report that fishermen exposed to contaminated waters exhibit higher rates of resistant infections unrelated to antibiotic use, demonstrating that environmental exposure alone can colonize human microbiota with resistance traits [9].

Superbugs an informal term referring to organisms resistant to multiple antimicrobials emerged as the most visible consequence of these overlapping pressures. The rise of NDM-1 (New Delhi Metallo- $\beta$ -lactamase-1) in 2008–2010 remains one of the most dramatic illustrations of resistance evolution and global spread. Discovered by Walsh, Kumarasamy, and their collaborators, NDM-1 was first identified in a Swedish patient who had received medical treatment in New Delhi [10]. The gene, carried on mobile plasmids, rendered bacteria resistant to carbapenems powerful antibiotics considered the last line of defense. Within a year, NDM-1 was detected in clinical samples in Pakistan, the United Kingdom, Canada, Australia,

Kenya, and Japan. The rapid spread demonstrated how global travel, medical tourism, and gaps in sanitation infrastructures could accelerate AMR far beyond any single country's borders. The outbreak also exposed tensions between nations: Indian officials pushed back against the naming of NDM-1, calling it "unfair," while British, Pakistani, and American researchers insisted that political sensitivities could not override scientific transparency. The controversy itself revealed a governance gap—AMR does not respect borders, but the politics of naming, acknowledging, and managing outbreaks often does.

Other superbugs followed similar trajectories. Carbapenem-resistant Enterobacteriaceae (CRE), especially KPC-producing strains, spread rapidly across Italy, Israel, and the United States from the late 2000s onward, leading to hospital shutdowns, ICU outbreaks, and mortality rates exceeding 50% in some cases [11]. The United States Centers for Disease Control and Prevention (CDC) labeled CRE "one of the most urgent public health threats" due to its ease of transmission and limited treatment options. In Brazil and Colombia, OXA-48 producing strains caused widespread outbreaks in tertiary care hospitals, while in Southeast Asia, the combination of ESBL-producing strains and high environmental contamination led to a near-constant baseline of resistant infections.

The fungal superbug *Candida auris*, first identified in 2009 in Japan but later found to have emerged independently in India, South Africa, and Venezuela, added another layer of complexity. *C. auris* thrives in warm, humid environments and resists standard disinfectants. Investigations by the CDC and the UK's Public Health England (now UKHSA) showed that *C. auris* could survive for weeks on hospital surfaces, colonizing equipment, walls, and bedding. The fungus's simultaneous emergence on multiple continents led scientists such as Arturo Casadevall to hypothesize a climate-related mechanism: rising global temperatures may have selected for fungal strains capable of surviving at human body temperature [12].

Pharmaceutical dynamics represent a quieter yet equally critical part of the AMR story. The global antibiotic pipeline has been shrinking for decades due to limited commercial incentives. Antibiotics are curative, short-course therapies; unlike drugs for

chronic illnesses, they generate little long-term profit. When a new antibiotic is developed, stewardship policies often restrict its use to prevent resistance, which paradoxically disincentivizes manufacturers. Major pharmaceutical companies such as Sanofi, Novartis, AstraZeneca, and Johnson & Johnson have significantly reduced their antibiotic R&D programs since the early 2000s, leaving small biotechnology companies to fill the gap. Some of these smaller companies, including Achaogen—developer of plazomicin, an antibiotic approved in 2018—went bankrupt shortly after launching their products, revealing the broken market structure for antibiotics [13].

Still, innovation continues in pockets, as seen in the announcement of Gan Lum, a new antimalarial developed jointly by Novartis and the Medicines for Malaria Venture (MMV). In clinical trials across 12 African countries, Gan Lum showed 97% effectiveness even in regions with established resistance to artemisinin-based therapies [14]. Scientists described the drug as "a fire extinguisher ready for the coming blaze," underscoring the urgency of developing treatments before resistance outpaces them. But malaria resistance is only one thread; bacterial and fungal resistance remain chronically underfunded areas despite being responsible for far more global deaths annually.

Global governance efforts have attempted to respond to AMR, but progress remains fragmented. The World Economic Forum (WEF), during its 2025 Annual Meeting in Davos, facilitated the release of the Davos Compact on AMR through its Global Future Council on Tackling Antimicrobial Resistance. The compact outlined strategies for public–private collaboration, emphasizing innovation funding, sustainable food systems, and multi-sectoral engagement [15]. The Unified Coalition for the AMR Response (UCARE), launched simultaneously by the WEF's Centre for Health and Healthcare, brought together governments, philanthropic entities, biotech companies, and global institutions in an effort to break existing silos in AMR governance. UCARE's focus areas—including improving access to diagnostics and vaccines, supporting antimicrobial development, raising awareness, and promoting sustainable agriculture effect the One Health vision increasingly endorsed by WHO, FAO, OIE (now WOA), and UNEP [16].

The One Health paradigm, which recognizes the inter-

connectedness of human health, animal health, plant health, and environmental systems, has become central to AMR policy. Investigators across multiple sectors highlight that resistant organisms move fluidly between humans, animals, soil, air, and water; therefore, interventions limited to hospitals or clinics will inevitably fail. For example, the discovery of the NDM-1 gene in drinking water and seepage samples from Delhi neighborhoods demonstrated that environmental contamination can maintain resistance regardless of hospital stewardship measures [17]. Similarly, Denmark's experience with eliminating growth-promoting antibiotics in pigs showed that animal health can be maintained through improved hygiene, vaccination, and biosecurity, contradicting claims that agriculture requires routine antibiotic use for economic viability [18].

However, the risks associated with AMR extend beyond clinical settings and agriculture. Global food systems have increasingly become vectors for resistant organisms. Investigations by the European Food Safety Authority (EFSA) repeatedly found ESBL-producing *E. coli* in retail chicken meat, while US FDA surveillance detected rising rates of multidrug-resistant *Salmonella* and *Campylobacter* in supermarket poultry. International trade, especially in seafood, further complicates the picture; shrimp farms in Southeast Asia, which often use antibiotics in aquaculture, export products worldwide, creating transboundary pathways for resistance. When consumers handle contaminated raw meat, resistant organisms can colonize their gut without causing symptoms, silently spreading through populations until a clinical infection reveals the underlying resistance burden.

The global health implications of AMR are profound. A landmark 2022 analysis published in *The Lancet* estimated that AMR was directly responsible for 1.27 million deaths in 2019 and associated with nearly 5 million deaths figures comparable to, or exceeding, the annual toll of HIV/AIDS and malaria combined [19]. These deaths disproportionately occur in low- and middle-income countries where laboratory capacity is limited, infection control resources are thin, and access to effective antibiotics is inconsistent. Investigators in Nigeria, Tanzania, Indonesia, and Nepal frequently report cases where clinicians must treat severe infections blind without

diagnostic support resulting in broad-spectrum empirical therapy that fuels further resistance. In contrast, hospitals in the United States or Germany can perform rapid molecular diagnostics, identify resistance mechanisms, and implement targeted therapy. This inequality between countries with advanced diagnostic ecosystems and those without creates global pockets where resistance can emerge unchecked.

The economic consequences are equally devastating. The World Bank's 2017 and 2022 AMR economic modeling studies warned that, without intervention, AMR could push up to 28 million people into extreme poverty by 2050 and reduce global GDP by 1% to 3.8%, depending on severity [20]. The agricultural sector would suffer disproportionately due to reduced productivity, livestock mortality, and loss of trade. Health systems would face soaring costs associated with prolonged hospital stays, expensive last-line drugs, and increasing ICU burdens. For example, treatment of carbapenem-resistant infections in US hospitals can cost more than \$60,000 per patient, compared to \$10,000 for susceptible infections [21].

Yet these statistics do not capture the lived reality of AMR: surgeries that become too dangerous to perform, cancer chemotherapy rendered ineffective due to infection risk, organ transplants postponed indefinitely, and neonates dying from infections once considered easily treatable. Investigators in Malawi's Queen Elizabeth Central Hospital have documented neonates dying from sepsis caused by ESBL-producing organisms, while oncologists in the United Kingdom report cases where patients cannot receive chemotherapy because the risk of AMR infections outweighs the benefits of cancer treatment [22]. The ripple effects extend into every branch of modern medicine.

Improving water, sanitation, and hygiene (WASH) infrastructure remains one of the most powerful tools for mitigating AMR, yet political investment remains insufficient. WHO estimates that more than half of health facilities in sub-Saharan Africa lack basic handwashing stations at points of care. In these settings, resistant organisms spread easily between patients, staff, and surfaces. Hand hygiene, sterilization, and waste management simple measures often taken for granted in wealthy countries become life-or-death determinants. Investigative reports by Médecins Sans Frontières (MSF) found that war zones like Yemen and

Syria exhibit extraordinarily high rates of AMR due to destroyed sanitation infrastructure, overcrowded hospitals, and repeated interruptions in antibiotic supply chains [23].

The solutions are well known but under-implemented: strengthening stewardship, regulating pharmaceutical waste, reducing agricultural misuse, increasing vaccine coverage, investing in diagnostics, improving sanitation, funding antibiotic innovation, and enhancing global surveillance. The challenge lies not in identifying interventions but in coordinating them across sectors, nations, and political interests. AMR demands a truly global response one that fuses science, economics, politics, and environmental management under a unified strategy.

As the world continues to grapple with environmental degradation, expanding agriculture, pharmaceutical pollution, and warming climates, the conditions for AMR evolution intensify. The superbug explosion is not a distant future scenario it is happening now, in hospital wards, riverbeds, poultry farms, and urban air. Unless coordinated global action accelerates dramatically, the 21st century may become the era in which humanity loses its antimicrobial shield. As investigators across the scientific and medical communities continue to warn, the cost of inaction will not be measured only in deaths but in the collapse of modern medical certainty itself.

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