

motivation have begun to address these societal and environmental issues in Africa. For example, Wecyclers, a recyclable collection business in Lagos (14), incentivizes neighborhoods to address improper waste management by rewarding subscribers who engage in plastic recycling. Door-to-door collection designed for informal settlements is combined with mobile applications, short message service (SMS) technology, and low-cost bicycle-powered collection vehicles. “Agents” gather recyclables directly from households, which receive points (based on weight) through SMS. Plastic waste is weighed, taken to neighborhood Wecyclers processing centers where it is sorted, baled, and then sold to recyclers. Points can be applied to the purchase of goods ranging from foodstuffs to appliances and even cash, thus improving the living standards of local households.

Other recent examples of incentive-based recycling startups in Nigeria underscore the trend toward community-based recycling adoption in Africa. Two of these companies are RecyclePoints (15) and Chanja Datti (16), both founded in 2015. In these business models, collection is facilitated by individual “subscribers” and plastic is exchanged for cash or redeemable points. Mr. Green Africa, founded in 2014 and based in Nairobi, Kenya, leverages smart technology to support an ecosystem that comprises over 2000 waste collectors and has recycled more than 2000 tons of plastic waste to date, which is returned to plastics manufacturers (17). Plastic Bank is a social enterprise deployed in Asia, with plans to expand to South Africa. It employs blockchain technology for collecting and redistributing recycled plastic materials across networks, and partners with global chemical companies to reintroduce recycled plastic to the market (18).

Also important for creating a circular plastics economy is the involvement of plastic manufacturers. Producers can create more easily recyclable plastic products and packaging, reduce plastic volumes in their designs, and replace virgin material with recycled content. Local manufacturers in Africa have begun to use plastic bottle waste for textile production, although collecting enough waste to sustain operations remains challenging. Corporations that profit from the plastic status quo must be incentivized to introduce these radical, but potentially cost-effective, changes. For example, this year the African Plastics Recycling Alliance was announced in which local consumer goods companies committed to increasing recycled plastic content in packaging, thereby stimulating the local plastics recycling economy in Africa (19). A consumer-centered approach for waste collection that works together with plastics manufacturers and other stakehold-

ers across the plastics supply chain can make it feasible for companies to have both a positive economic and environmental impact.

A NEW CULTURE

The rapid adoption of information technologies at various points along the plastic waste recycling chain can facilitate the realization of a closed-loop plastic waste ecosystem. Regional factors, such as government regulations and consumer motivation to improve African quality of life, play a critical role in the adoption of technologies to tackle plastic pollution in an environment that otherwise lacks a plastics recycling framework.

Recently, application-centered startups in African cities and surrounding areas have spurred plastic waste collection from citizens in exchange for goods ranging from household items to cash. Combined with emerging technologies, this model has been effective in low-income areas in Africa. If deployed as a global recycling model, networks that leverage consumer participation will promote the availability of high-quality recycled materials that can be reintroduced into the market and close the plastics life-cycle loop. ■

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MICROBIOLOGY

Changes in antibiotic resistance in animals

Surveys in low- and middle-income countries reveal emerging hotspots of resistance

By Catrin E. Moore

Misuse and overuse of antimicrobial agents, such as antibiotics, in humans, animals, and plants is leading to increasing antimicrobial resistance (AMR). AMR is an urgent global priority necessitating international collaboration through a “One Health” response (across humans, animals, plants, and their shared environment). Efforts have focused on AMR and antimicrobial use (AMU) in human infections; however, animals, plants, and the environment also contribute to AMR. More antibiotics are consumed by animals produced for food, to promote growth or disease prevention, than by humans. The increasing demand for animal protein, predominantly in low- and middle-income countries (LMICs), and links between AMU and AMR remains unknown, particularly in LMICs where microbiology laboratories are scarce and antimicrobial drug availability remains largely unregulated (1, 2). On page XXX of this issue, Van Boeckel *et al.* (3) map AMR in animals for food production in LMICs, with implications for One Health strategies.

AMR describes resistance to antibacterial, -viral, -parasitic, and -fungal agents. It is a complex process: In the simplest form, AMR occurs when pathogenic microorganisms change after being exposed to an antimicrobial drug, treatment becomes ineffective because of these changes, and the infections persist in the body, which can increase the spread to others. Antibacterial resistance (ABR) is probably the most important form of AMR because it likely causes the highest mortality and morbidity worldwide.

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A coordinated plan to tackle the threat of AMR was recognized by the adoption of a Global Action Plan by the World Health Assembly in 2015. This led to the development of the Interagency Coordination Group on AMR (IACG) by the United Nations (UN) General Assembly in 2016, comprising members of all health sectors: Food and Agriculture Organization of the UN (FAO), World Organization for Animal Health (OIE), and the World Health Organization (WHO). The IACG made recommendations to accelerate progress, innovation, collaboration, investing in and strengthening accountability, and global governance to combat AMR (4). Accordingly, 100 countries have developed their own National Action Plans since the launch of the Global Action Plan on AMR in 2015.

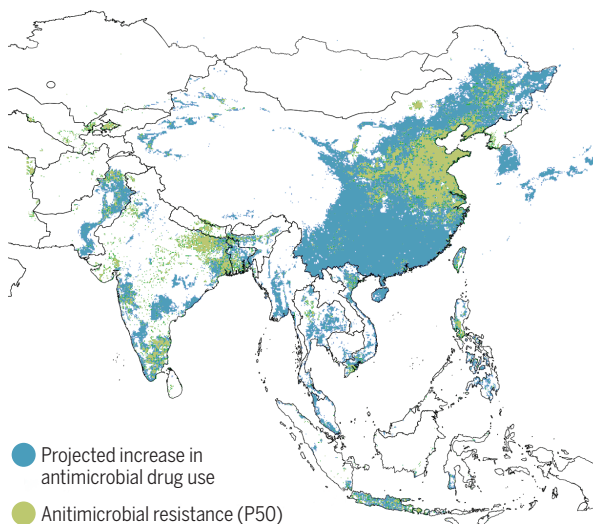
However, adoption of these plans remains difficult, particularly in LMICs because of the lack of political and local awareness together with economic poverty and inability to strengthen systems such as basic sanitation and hygiene, which could threaten progress toward the Sustainable Development Goals. These goals were adopted by the UN member states in 2015 to be attained by 2030. The goals relate to poverty, inequality, climate, environmental degradation, prosperity, peace, and justice toward Universal Health Coverage (5).

Although progress has been made, the true burden of drug-resistant infections in humans is unknown; recent initiatives suggest mortality figures in the region of 33,000 in the European Union, 23,000 in the United States, and 700,000 globally, based on resistance in selected microorganisms in the past few years (6–8). More robust and detailed information is needed to address the problem of AMR in humans and animals globally.

The only way to understand the changes in AMR over time and space is through surveillance. The surveillance methods must be robust, of a high quality, and reproducible. Microbiology data historically is heterogeneous, with numerous guidelines and data from different laboratories making data difficult to compare. For this reason, point prevalence surveys (PPS) have been used to understand both the prevalence of resistance and AMU as a snapshot taken at one point in time in the hospital sampled (for humans) (9). A number of PPS studies in humans assess antimicrobial prescriptions according to clinical syndromes at repeated intervals for very sick patients in hospital (10). Animal PPS differ because animals are sampled when they are fit and healthy before being sent for

Antimicrobial use and resistance in Asia

From 2000 to 2018, the proportion of antimicrobial drugs with resistance higher than 50% in four indicator species (P50) from farmed animals in Asia identified hotspots of antimicrobial resistance (AMR), which corresponded to areas with projected increase in antimicrobial drug use (AMU).



slaughter; unwell animals are often excluded. Therefore, comparing human and animal PPS to ascertain any connections in AMR is challenging because the microbes and amount of resistance will differ considerably in healthy animals compared with sick patients.

The WHO set up a surveillance system to collect and share human microbiology data globally [global antimicrobial resistance surveillance system (GLASS)] based on self-reporting from laboratories in all member countries (11, 12). Working with a WHO Advisory Group on Integrated Surveillance of Antimicrobial Resistance (AGISAR), GLASS will integrate animal surveillance into the system. Resistance in *Escherichia coli*, one of the eight human pathogens that causes risk to health and on the WHO critical list, is responsible for severe morbidity and mortality in humans; the resistance differs across continents and occurs in both humans and animals. The WHO and Fleming Funded Tricycle project is collecting data from humans, the food chain, and the environment to provide a full One Health picture of AMR in *E. coli* (13). The data from this project will provide initial information on the complex interactions between AMR in animals and humans.

Van Boeckel *et al.* have taken the first step to examine resistance in animals by linking AMU and AMR data on farmed animals. In the absence of surveillance data, they collected published information on animal PPS (in a systematic review of 901 surveys carried out over 18 years; between 2000 and mid-2018), and theirs is the first global estimate of AMR in food animals. The authors analyzed

data from previous studies on AMU together with evidence of AMR from animals in the same countries, which revealed an overlap between the two (14) (see the figure). Four indicator bacteria were examined, chosen on the basis of the links between human and animal infection and resistance to antibiotics that are used both for animals and humans (such as quinolones used to treat *Campylobacter* species and nontyphoidal *Salmonella* together with *E. coli* and *Staphylococcus aureus* (15)). They found an increase in the proportion of strains in which 50% were resistant to antibiotics in chicken and pigs, with hotspots of AMR in both China and India. They also identified hotspots emerging in Brazil and Kenya. A correlation between the global burden of AMR in humans and the hotspots of AMR in farmed animals and true burden of disease in humans together with appropriate interventions based on the National Action Plans could be the next step

toward linking the burden of disease in a truly One Health approach. ■

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