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RESEARCH

The Spectre of Superbugs: Waste, Structural Violence and Antimicrobial Resistance in India

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At first glance there may seem to be no clear connections between two of humanity's most pressing problems: environmental waste and antimicrobial resistance (AMR). In fact, as we posit in this paper, there is an inevitable convergence across these medical and environmental domains that hinge on social and economic inequalities. Such intersections have not been given nearly enough emphasis. Here we offer a series of considerations regarding the potential nexus of environmental pollution, waste-work, poverty and the decreasing viability of antimicrobials. We suggest that AMR and environmental pollution will fundamentally shape one another over the course of the coming decades, with differential impacts across socio-economic divides. More perniciously, the coalescing of waste, environmental pollution and reduced potency of pharmaceutical infection management will in turn likely escalate cultural prejudices around hygiene, 'untouchability', exclusion and privilege. That is, this nexus of waste and bacterial risk will polarise and divide communities, disproportionately affecting poorer communities. This paper is intended to chart an agenda for the study of this increasingly critical site of bacterial-human-environmental relations. It does so by examining the cycle of infection, risk and vulnerability amongst the most disadvantaged sections of the population in India.

Keywords: labour; waste; antibiotics; risk; india; scale

Waste and Antimicrobial Resistance: The Natural and the Neutral

In this article we refer to waste as the (by)product of human practices. This broad understanding of waste allows us to speak of the biological, cultural/social and political domains of waste on different scales and origins: from human excreta to consumer behaviour, labour practices to industrial effluents. What might seem merely biological or even economic, processes generating waste are always anchored in social structures, cultural mores and political-economic imperatives. We highlight how within these interwoven domains of waste, social inequalities and economic forces at different scales affect exposure to waste, which also influence exposure to infection risk. By focusing on scale we are able to highlight previously concealed interactions between forms of knowledge and social practice, market fluctuations and transnational networks. It is this multi-scalar analysis that can help reveal the emerging threat of multi-resistance organisms (MROs): bacteria that have developed resistance to the majority of available antibiotics.[1] This paper is an attempt to trace the cycle of infection, risk and vulnerability associated with MROs as it pertains to the most disadvantaged sections of the population.

To anticipate our proposition regarding the nature/culture divide, consider human waste. Despite being a biological process, defecation has long been the subject of social and cultural taboos, as illustrated by the highly developed sanitation system uncovered in the ancient Mohenjo-Daro civilisation in the Indus valley (modern-day Pakistan). It took over 4000 years and the advent of germ theory in the mid 19th century for sanitation to come under the close scrutiny of the modern state and public health regimes. Despite such developments, in much of the Third World, and in India in particular, the poor continue to defecate outdoors: a practice known as open defecation. As such they are subjected to both social stigma and state-led projects aimed at eliminating open defecation. They are also extremely vulnerable to infective risk. Nevertheless, open defecation in India remains prevalent due to various factors we can only allude to in this paper (for details see Doron and Jeffrey 2014). Many regard toilets as objectionable and ritually polluting. Technology, even one as seemingly benign as toilets, is never morally and socially neutral, operating within human institutions, material and environmental conditions. Open defecation is as much a question of public health and geographical location as it is cultural notions of purity and pollution, as well as social inequalities rooted in the caste system. Natural biophysical processes, such as defecating outdoors, are

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enmeshed in wider cultural-pollical contexts of the self and society.

Consider another biophysical process. For billions of years, bacteria and other microorganisms have altered their structure through different mechanisms (mutations or gene transfer) to develop resistance to natural antibiotics (Von Wintersdorff et al. 2016).[2] Since the discovery of the chemotherapeutic potential of antibiotics and their diverse applications across human-animal-agricultural sectors, resistance has intensely accelerated, fuelling the spread and prevalence of MROs. Because of their capacity to emerge undamaged by even the most powerful antimicrobials, such microorganisms have been referred to as superbugs.

In this paper we use the prism of scale to examine the bacterial-human environment as a way of understanding the perpetuation of inequality mediated by the cycle of infective risk. Such infective risk, we will demonstrate, is amplified in conditions where personal practices (open defecation), labour arrangements (waste-picking) and environmental settings (industrial-scale effluents) are especially hospitable for an increased bacterial load and the emergence of MROs. These conditions disproportionately affect the poor, even if MROs make no such distinctions in terms of the bodies they colonise. To gauge the potential prevalence and spread of the superbugs, we shift our gaze from the hospital setting to the domain of waste to examine what it can reveal about emerging community vulnerabilities and infective risk.[3]

In what follows we explore emerging geographies of vulnerability: spaces that render poor people and their environment more exposed to infectious agents due to socio-cultural processes and environmental conditions. We focus on the factors that may contribute to the uneven emergence and spread of AMR amongst disadvantaged populations. In mapping out the specificities of this human-bacterial interface (however variable across locale and communities) and its relation to the ecology of waste in India, we attempt to highlight the intricate connections between waste, environmental pollution, AMR, economic necessity and cultural practice.

We begin by examining the practice of open defecation (OD) and its potential contribution to the spread and prevalence of AMR in rural India. In the second section, we scale-up to examine the social or labour practices and relations, focusing mainly on those who routinely deal with waste. We draw on studies focusing on waste pickers (ragpickers) to show how, under such deprived living and working conditions, they are far more vulnerable to infective risk and a compromised immune system. Finally, we look at mounting evidence of the increasing prevalence and spread of AMR, originating from farming and effluents discharged from pharmaceutical factories. India's huge pharma industry and unregulated use of antibiotics create an ideal environment for organisms to develop resistance to antibiotics. The result is a unique set of circumstances—magnitude, frequency and availability—that provide a rich system for the rapid development of MROs.

This antibiotic-rich environment is, in part, the result of lax regulations where effluents, replete with antimicrobial agents discharged into the environment, affect marginalized communities with little medical and legal recourse. The first instance of waste (open defecation) operates at a small-scale bodily experience framed by wider cultural concerns. The other two waste-practices operate at different scales that bring to bear different power relations underpinned by market forces, transnational networks and foreign capital. What binds the three seemingly discrete waste-practices and scales—OD, waste-collection and effluents—is an environment replete with infectious agents and a potential breeding ground for MROs. Such conditions, we conclude, will disproportionately affect the health and livelihoods of those exposed: the most marginalised communities.

Ecologies of waste: The self and the world

> Open defecation is the sanitized, scholarly term for what about a billion people worldwide do with their faeces. They walk to a field, a roadside, a riverbank, an orchard, a forest or another places outdoors, squat down and relieve themselves on the ground. Then they walk away, leaving the germs to infect somebody else (Coffey and Spears 2017: 9).

There are many reasons for the continued prevalence of open defecation in India. Poor infrastructure, population density, scarcity of water and lack of education are often cited as the major causes. Yet Coffey and Spears (2017) find the core reason to be caste and concepts of pollution. Drawing on comparative data and extensive fieldwork in India, they suggest the attitudes and preferences of rural populations for defecating outdoors persist because human waste is considered ritually polluting and toilets embody such pollution (see also Vyas and Spears 2018).

In the Hindu household, purity and auspiciousness are constantly maintained by spatially restricting all potential sources of pollution: from impure materials to polluting people. Hence, many, not least the higher castes, would consider toilets in the vicinity of the household (let alone sacred places) a polluting danger and would be reluctant to build latrines in their house even if funded by the government (Doron and Raja 2015).

Religious ideas about purity and pollution inform bodily praxis, such as open defecation, but so do social relations, including marriage, rules of commensality and occupation. Even if ritual considerations do not fully determine social action, they help explain motivations and constrain and direct everyday practice. Together, religious considerations and cultural practices are also validated and visible in the architecture of village life. For instance, the lower castes and Dalits (formerly known as untouchables) are considered a threat to the ritual purity of the upper caste, especially in small-scale settings, such as in village environments. In some instances, physical contact with Dalits is restricted (if not prohibited), and they are barred from sharing water with other villagers or denied access to land, public utilities and services (Shah et al. 2006: 21, 57; Mosse 2018). The indignities and discrimination suffered by Dalits are also inscribed upon untouchable bodies. Even the places they can defecate is often appropriated, as a Dalit woman who worked as a labourer for upper caste (Jat) landlords described it:

> There is no daily wage labour here, people are forced to go outside to earn money and they come back here to defecate. And Jats even benefit when we defecate in their fields, because some time later it turns into fertiliser! Poor people can eat and drink nothing. Grain is Rs 30 for 2.5 kg and that is cooked daily, so they do not even get enough food (quoted in Jeffrey et al. 2008: 135).

It is members of the untouchable castes (especially women) who are employed (and exploited) as manual scavengers, charged with removing human faeces from the houses of upper caste and classes in the towns and villages.[4]

According to Coffey and Spears, understanding the ritual economy of caste is critical for understanding the prevalence of open defecation and exposure to human waste in rural north India: this is a world view where 'open defecation is clean and latrines are dirty' (2017: 51). The result is that OD continues in rural India regardless of one's economic and social status. For our purposes it is important to examine how such everyday practices intensify pathogenicity and whether it leads to an increasing spread of MROs or bacteria more generally.

The Rise of Superbugs

Numerous studies have shown the connections between open defecation, intestinal parasites and childhood mortality, stunting and ill health in India (for details, see Doron and Jeffrey 2018). But as concern over the spread of AMR intensifies globally, Third World sanitation problems are drawing the attention of the international community. Drug-resistant bacteria are spreading, especially in hospital settings due to the selective pressure generated through human antibiotic use. Methicillin-Resistant Staphylococcus Aureus (MRSA) is one the most well-known and deadliest types of drug-resistant bacteria and has become a lightning rod for debates about how to reign in MROs. Yet it was the discovery of the 'foreign' origin of superbugs that brought the issue into the global limelight, and India was at the centre of it.

In India, a new multi-resistant strain was discovered in late 2008 in a Swedish traveller infected with a common bacteria (Klebsiella pneumonia) but revealed to be carrying a drug-resistant gene that could be passed between bacteria across a range of species. It was soon named the New Delhi Metallo-beta-lactamase-1 (NDM-1). Then reports emerged in India of infants dying from bacterial infections that could not be treated by even the last resort (and often highly toxic) antibiotics.

Deaths resulting from MROs are hard to pin down, and data on health-related illnesses and disease are often unreliable. In *Superbugs: An Arms Race Against bacteria*, Hall and colleagues estimate that in India '58,000 newborns die of resistant bacteria infection every year' (2018: 38, 123). It is estimated over 100 million Indian residents carry NDM-1 bacteria as normal gut flora (Walsh and Toleman 2012), which is harmless in the gut but can be lethal if they spread to other parts of the body and cause infection. If such figures are alarming, equally worrying is that even when we know some of the key drivers behind antibiotics resistance, what remains unclear are the complex transmission 'routes of resistant bacteria, as well as resistance genes and the impact of antibiotic-selective pressures in various reservoirs (animals, humans, and the environment)' (Purohit et al. 2017). More studies are required to gain a fuller understanding of how resistant bacteria and antibiotics pass on and across different environments (e.g., soils, ponds, ground water) and are transferred between people and animals.

India poses a particular challenge for controlling AMR because it is the largest consumer of antimicrobials globally (Kakkar 2017; WHO 2015), with easy access to non-prescribed medications for both human health and livestock (Rangarathan 2017).[5] How such conditions affect infectious disease transmission dynamics and AMR evolution is a key issue stimulating recent research into the problem of open defecation in rural India.

Purohit and colleagues (2017) argue for understanding the spread of AMR from a holistic perspective: the One Health approach. Their research focused on a single Indian village, collecting stool samples from selected children and animals to determine the presence of E. coli: a bacteria considered a reliable indicator for antibiotic resistance. According to the authors, examining the intestine is especially revealing because it forms 'a "hot spots" for the transfer of resistant genes between bacteria as the exposure of frequently used antibiotics to a high density of bacteria favours evolution and dissemination of antibiotic resistance by cell-to-cell contact' (Purohit et al. 2017: 9–10). In other words, the bowels harbouring both antibiotics and the pathogens the antibiotics are supposed to eliminate provide a laboratory where resistant pathogens can develop and then be excreted and find their way into the environment and other bowels, which is perpetuated because of OD. Thus the resistant bacteria enhance their ability to survive and negate antibiotics.

Antibiotic resistance is also promoted in the gut where the presence of antibiotics can lead to the selection of highly resistant bacteria (Carlet 2012). Such bacteria are commonly excreted in faeces, which are then transferred through various routes, flies, soil-transmitted infections, and water bodies, all of which contaminate the environment, further fuelling the cycle of infection. Human waste is thus a good indicator for evaluating the physiology of infectious disease and evolution of AMR in its environment. The study by Purohit and colleagues (2017) showed high levels of resistant E. coli in human stool and village water sources. E. coli isolates were found to be resistant to most common antibiotics available in the market, including ampicillin, ciprofloxacin and tetracycline. Similar findings appear in research carried out across India (e.g., Shakya et al. 2013, Kumar Singh et al. 2018). While there is increasing evidence of MROs in human stool, and especially amongst children, the precise nature of the transmission routes requires further investigation.

We have tried to show how open defecation and exposure to fecal pathogens contributes to the spread of MROs. This is intensified when poor sanitary conditions (e.g., open drains, contaminated soil, water resources) and lack of education about hygiene practices (e.g., hand washing) leads to releasing drug-resistant bacteria into the environment. Under such conditions, soil-transmitted infections are more common, contributing to further infections and compromised immune systems, especially amongst school-aged and elderly people. In rural settings, both rich and poor practice open defecation, amplifying the spread and prevalence of MROs. Yet the poor are more vulnerable to infections due to their living and working conditions. Next, we elaborate on waste (human and material) as linked to socio-economic deprivation, and the way caste relations continue to shape infectious disease transmission and AMR.

Waste and Inequality

While not restricted to India, the handling of human waste and the practice of open defecation has particular meanings in the context of class and caste in the sub-continent (Doron and Jeffrey 2014), which in turn have important implications for the spread of infections and the dynamics of vulnerability (to MROs, for example). We noted how conceptions of ritual pollution sustain the practice of open defecation. The enduring institution of caste in India, however malleable and changing, informs processes of socialisation and everyday practice. The notion that people are hierarchically ordered according to ascribed statuses is continually reinforced by elaborate ideological, social and economic structures that can be traced back generations. Those hierarchies find expression in village architecture and property rights and are maintained in marriage relations and attitudes towards the collection and disposal of all types of waste.

Invariably, it is the people born into the lowest-status, Dalits, who are charged with collecting waste, including human waste (see Singh 2014). As such, these communities are disproportionately exposed to occupational and environmental risk and potentially life-threatening bacteria. In some areas of rural India, Dalits still manually remove the 'night soil' of upper castes from dry latrines (Doron and Jeffrey 2018).[6] In certain parts of Northern India in 2014, there were more than 900,000 dry latrines from which excrement continued to be removed by hand.[7] Put this in the context of how pathogenicity spreads through faeces and you begin to reveal the connection between untouchability, bacterial risk and social exclusion.

The socio-economic order underpinning village India, with its traditional occupational order is increasingly fragmented. The ritually low service castes are engaging in a range of occupations demanded by market conditions, which are no longer tied to an ascriptive system of occupational specialization. Nevertheless, untouchables are still commonly found working in waste-related jobs, whether in cleaning up village spaces or sweeping courtyards, lanes and streets. In urban India, middle-class families often employ a sweeper of low-caste origin to clean their toilets, even if these are flush toilets. Such practices reinforce the belief system that it was an untouchable's role to remove others' excrement. In a recent review of caste in India, David Mosse (2018: 428) argues that while urbanisation produced a diversification of occupations, those at the very bottom of the caste hierarchy remain tied to the most demeaning jobs:

> [I]dentity-bound work is most characteristic of stigmatized occupations, none more so than the filthy, dehumanizing and unprotected work of dealing with human excreta, known as "manual scavenging", campaigned against and prohibited by law, but still assigned to the lowest Dalit castes, including by contractors to the Indian Railways. Despite transition from manual scavenging to sewer work … modern sanitation and sewer programs have accommodated caste divisions and discrimination, while placing workers in danger, as attested by the regular and early deaths of Indian sewer workers.

Unmediated contact with waste—human or otherwise—is socially demeaning and physically risky, with implications for the spread of disease and infections.[8] However, as emphasized above in the context of rural India, upper castes also practice open defecation and are as likely to carry and spread infections. Yet, in urban settings in particular, the marginalised are far more exposed to infectious agents. Social status and infectious disease interact importantly with exposure to waste.

The Toxic Burden

Within the context of diminishing effectiveness of antibiotics, which many within poorer communities use in an ad hoc fashion through unregulated pharmacies, the problem of MROs spreading in human faeces, soil, water sources, or through flies and zoonotic transmission will become even more acute. The majority of the poor in urban slums are migrants with little recourse to sanitation facilities and clean water (see McFarlane 2008). Such living conditions mean most opt for the outdoors and public spaces for relieving themselves, so much so that the former rural development minister, Jairam Ramesh, called Indian railways the 'world's largest open toilet'.[9]

The viability, type and design of latrines remains a vexed issue in India. Even when installed, they are not necessarily used (Doron and Raja 2015). Solving public waste is not simply a matter of infrastructure, neither is reducing infective risk simply a matter of education. You can educate kids to wash their hands with soap after defecating, but if the water is contaminated, and people routinely defecate outdoors in proximity to residential dwellings, such programs will have limited efficacy. Further, there is often little appreciation by the authorities and NGOs for the rules, cultural norms and power relations in slum communities, which shape access to urban spaces (Doshi 2012; McFarlane 2008; Pranav et al. 2017). This is also the case with slum development programs that tend to overlook everyday health-seeking behavior and the geographical dispersion of livelihoods, especially when tied to waste economies in the informal sector (see Ananthakrishnan and Patil 2013). We examine the connection between waste-related work and emerging infectious disease in the following sections, highlighting the interplay between the social and physiological realms and its implication for disease transmission and the prospect of AMR.

Waste collection in the densely populated cities of India is an enormous challenge for the authorities. Most cities rely on an informal labour force to perform much waste-related work. It is one of the most widespread occupations amongst India's most disadvantaged communities. Newcomers to cities and other marginalised populations typically find waste-picking an apposite entry point for subsistence living. But this occupation renders waste pickers vulnerable on several fronts: physical, social and economic. Collecting waste is marked by long work hours scouring the streets and open dumps, and the price of recyclables is variable and fluctuating according to demand. Such uncertainty is compounded by the itinerant and informal nature of the occupation, where police harassment and arbitrary imprisonment are an enduring fear, as Kathrine Boo (2012) poignantly described in her award-winning book on waste pickers in a Mumbai slum community.

The informal economy, driven by market forces, shapes waste collection. This has implications for obtaining reliable data on how ragpickers' physiology (undernutrition, exposure to pollutants), ecology (crowded, unhygienic living conditions) and health-seeking behaviour (factors that may contribute to antibiotic overuse) affect infectious disease transmission dynamics and AMR evolution. We attempt to link these considerations, drawing on disparate studies to hypothesise how inequalities impact levels of antibiotic resistant bacteria.

Across the globe, studies show the numerous physical risks those working in waste-related jobs are routinely exposed to, from cuts and jabs to respiratory illness (Romero et al. 2010; Ray et al. 2004) and parasitic, skin and dental infections (World Bank Report 2006). Moreover, the crowded living and working conditions of slum dwellers more generally add to what is an already severely compromised immune system (Ray 2004), leaving waste workers vulnerable to lung infections and other common infections plaguing people in urban slums. Riley and colleagues (2007) point out in their comparative study of slums around the world structural considerations that underpin the prevalence of diseases in such deprived settings, even if identifying the precise transmission paths remains unclear:

> Chronic non-communicable and communicable diseases like hypertension, diabetes, intentional and unintentional injuries, tuberculosis, rheumatic heart disease, and HIV infection are recognized to exist in slums because of the late complications of these diseases that the formal health sector sees and deals with. However, in slums, little is known about the magnitude, distribution, and risk factors for these illnesses before they manifest as stroke, myocardial infarction, kidney failure, suicide, multidrug-resistant TB, heart valve disease, and AIDS.

Terms such as 'structural violence', popularised by anthropologist Paul Farmer (2004), aptly capture the types of organizational and institutional structures that inhibit marginalized populations from ready access to public goods, such as health care, water and sanitation. Structural violence operates through a variety of normative and impersonal systems of exclusion tied to gender, regimes of labour, caste relations, and political and material interests and ideologies. Structural violence mediates one's exposure to risk-laden waste in its most raw form; whereas, when waste is pushed up the chain and refined to gain more value, it becomes relatively risk-free: less infective and dangerous to handle. To understand what might be the more common infectious agents causing illness among these marginalised populations, we need to better understand *how* their risk-laden environment affects infectious disease transmission dynamics and encourages the development of AMR.

The inventory of risk that waste-pickers confront on a daily basis is daunting. Cultural stigma associated with dealing with polluting materials is exacerbated by the biophysical effects of these occupations, with cuts to hands and feet and reparatory infections common. Studies show ragpickers with lower immunity levels, toxicities, and chronic illnesses resulting from exposure to environmental waste (e.g., Chokhandre et al. 2017; Ananthakirshnan and Patil 2013; Patwary et al. 2011). Waste pickers are not a homogenous group, as a recent study amongst a diverse range of pickers also highlights. In this health profile of women ragpickers in Mumbai, Ulap and Bhate (2014: 1) argued that the levels of risk decline according to the nature of the work. They concluded that there was evidence of increased morbidity 'among ragpickers who collected rags along dumpsite than street side and door to door waste collectors'.

Such findings correspond with reports of ill health amongst ragpickers living and working near open dumpsites, for example in Deonar, the country's largest landfill located in Mumbai, which burst into flames in early 2016 and enveloped the city in toxic smoke. The prospects of the ragpickers residing near the dump in Mumbai's eastern suburbs are chilling, as reported in *The Hindu*:

> With open defecation, acute air and water pollution, and decaying garbage, M-East Ward has the lowest life expectancy rate of less than 50 years, and the highest infant mortality rate with around 20 per cent of all deaths in 2015 accounted for by infants. Every second child is underweight. Over 90 per cent of pregnant women in 2014-15 were anaemic, and there is a high instance of maternal mortality. There is a high threat of contacting diseases such as tuberculosis. Healthcare is grossly inadequate; the 'health service' providers are mostly quacks. Education is poor, and seven out of ten households have no access to piped water connection.[10]

Under such conditions, it should be no surprise that India's marginalised are prone to infectious disease and will, we posit, be most exposed to the threat of AMR. More research is required to test our hypothesis if we are to better understand the AMR cycle. It is also clear the dangers of confronting pollutants are magnified for manual labourers, like waste-pickers, who are routinely exposed to heavy metals, toxin-laden fumes and other contaminants produced in such toxic environments, for instance when dealing with E-waste (see Doron and Jeffrey 2018: 124–128). As such, occupational hazards, even minor cuts or scrapes, can quickly spiral into life-threatening infections.

In an earlier study of a dumpsite in Delhi, Ray and colleagues (2004) concluded ragpickers are far more vulnerable than the rest of the population to a range of health problems:

> After controlling for smoking as a confounder, respiratory symptoms and lung function decrement were recorded in 94% and 52% of the ragpickers, respectively, compared with 56% and 34% of controls. The ragpickers showed a higher prevalence of low hemoglobin, … unhealthy gums, frequent diarrhea, and dermatitis, when compared with controls. Their sputum showed an abundance of alveolar macrophages, siderophages and inflammatory cells, and a very high frequency of squamous metaplasia and dysplasia of bronchial epithelial cells, suggesting inflammation and cellular changes in the airways (Ray et al. 2004: 595).

In other words, ragpickers (in all their diverse occupational practices) continue to experience severe health problems, as evidenced in more recent studies evaluating the burden of morbidities amongst waste pickers in Mumbai and Chennai (Praveen et al. 2017; Ananthakrishanan and Patil 2013).

Consuming antibiotics and absorbing waste

In seeking treatment for such infections and other faecal-oral and respiratory illnesses, people often resort to antimicrobials. In India these antimicrobials (antibacterial, antiviral and antifungal) are easily obtained over the counter, often with little understanding of the type and dosage required to treat infections (Pranav et al. 2017; Orzech and Nichter 2008). The potential overuse and certain misuse without expert guidance inevitably results in heightened overall antimicrobial load and selective pressure, which accelerates the local and global problem of resistance (see Hall et al. 2018). A polluted environment, widespread diarrheal and respiratory infections, combined with an overexposed population to antibiotics, is a breeding ground for MROs.

Amongst urban slum dwellers, the practice of self-medication is informed by various motivations, as detailed in a recent study of an urban slum in Karnataka:

> The issues such as lack of awareness about nearby healthcare providers and facilities, affordability, scarcity of time to avail treatment, urge for faster cure of illness, poverty, loss of work/wage upon availing treatment from crowded health facilities, and possible absence of physicians in public health facilities has emerged as contributing factors for self-medication practices among urban poor living in slums (Pranav et al. 2017: 21).

The study concludes with the observations that such an environment is conducive to the 'development of drug resistance, pathogenic resistance, drug-drug interactions and complications due to adverse drug reactions, polypharmacy and prolonged illness' (Pranav et al. 2017: 19). Drug-resistant bacteria are thus induced through self-medication, a practice underpinned by socio-economic inequalities (see also Orzech and Nichter 2008). At the same time, the prevalence of antibiotics in the system is also said to be a product of changing consumer habits and market forces. As we shall see below, although on a different scale and with different effects, the cost is borne by marginalized communities living and working in contaminated environments.[11]

An article in India's leading English-language newspaper, the *Times of India* recently reported:

> Tonnes of antibiotics, painkillers and other medicines are flowing down the [river] Yamuna, and scientists at AIIMS [All India Institute of Medical Sciences] say our habit of throwing away leftover medicines in household garbage is partly to blame for this (29 Aug 2018).[12]

The article points to findings that suggest the highest levels of drug contamination were found in leachate draining off Delhi's major landfills, Ghazipur and Okhla. Such drug-laden effluents contaminate water and soil in the nearby neighbourhoods, leading to the creation of selective pressure in bacteria, which fuels the growth of MROs. Ragpickers living and working in such contaminated environments are most exposed. They rely on such polluted water for drinking, cooking and bathing, as Doron learned in repeated visits to these sites. These are the people who are forced to carry the toxic burden of economic growth, urbanization and consumerism—manifest in ever-growing and uncontrollable waste piling up in the capital's landfills. Thus, in addition to the dangers of everyday life—physical injuries and infectious diseases, unsanitary dwellings, the need to seek quick-fixes, counterproductive cures for ill health—a drug-contaminated environment further contributes to ragpickers' exposure to AMR.

Different scales are conducive to the evolution of AMR and find their expression in waste-related practices (open defecation, ragpicking), territorial organisations (slums, dumps, landfills) and consumer capitalism. There are different sources of natural selection, all strongly favoring AMR traits in microorganisms, originating from different scales of human organization. In addition, there is a temporal scale that connects the wasted bodies of ragpickers to their health-seeking behaviour. Individual sickness is a small-scale, experience-based embodied knowledge, which is mediated by what we argued are the more impersonal large-scale forms of violence across age, gender, caste and class in a political economy marked by neoliberal policies. Drawing on the notion of 'structural violence', literary studies scholar Rob Nixon (2011) has suggested a complementary concept: slow violence. For Nixon, this concept captures the more inconspicuous and incremental types of violence that afflict the poor and marginalised and that, in terms of scale and temporality, extends beyond established structural inequalities outlined so far. Slow violence is especially pertinent to our next section, focusing on waste and the human and environmental costs generated by consumer capitalism and the pharmaceutical industry.

The Perfect Storm

In the past few years, the scientific community and the media have been reporting a perfect storm scenario for the global spread of superbugs emanating from India. Poor sanitation, open defecation, waste-work, self-medication and revelations of excessive use of antibiotics in agriculture and livestock industries are all viewed as key contributors (Laxminarayan and Chaudhury 2016; Hall et al. 2018). This is compounded by India's unregulated pharmaceutical industry, another chief driver fuelling the AMR crisis, which several studies have shown discharges antibiotic-laden waste into the environment (Fick et al. 2009; Lubbert et al. 2017).

India's rapidly growing pharma industry received a boost from India's economic reforms and subsequent efforts to position the country as an attractive destination for foreign investment. This led to Special Economic Zones and Industrial Parks offering tax exemptions, with favourable labour regulations. The recent flagship campaign 'Make in India', launched by the central government, is aimed precisely at encouraging such transnational investments and foreign trade. Yet, the country's schemes to attract foreign capital may come at a cost as revelations emerge about inadequate waste management practices in the pharmaceutical manufacturing plants supplying international companies.[13]

Hall and colleagues reviewed recent studies focusing on India's pharma industry and the testing of effluents in and around drug manufacturing plants in Hyderabad. The results were 'truly shocking' (Hall et al. 2018: 189), revealing extreme levels of antibiotic concentration contaminating the environment, leading to the emergence of multi-drug-resistant bacteria. They conducted an interview with Joakim Larsson, a leading researcher on this issue, who said high '"concentrations led to the selection of highly multi-drug resistant bacteria that can also share their multi-resistance plasmids easily with other pathogens"' (Larsson, quoted in Hall et al. 2018: 189–90). These claims are reinforced by a number of studies that specifically investigated the pharma industries in Hyderabad, where samples from the untreated waste flowing into the surrounding environment unequivocally showed 'contamination of rivers and lakes' (Lubbert et al. 2017: 1; Fick et al. 2009). The long-term implications are hard to evaluate, but they are typical of what Nixon describes as 'slow violence that occurs gradually and out of sight, a violence of delayed destruction that is dispersed across time and space, an attritional violence that is typically not viewed as violence at all' (2011: 2). Already there are signs of this creeping violence, with locals describing the toxic effects of the adjacent pharma industry on the environment and their own bodies.

On his visits to the antibiotic manufacturing plants and their surrounding, Doron spoke to local villagers who repeatedly complained of skin infection, polluted waters and foul odours.[14] They also pointed to the effluents which are generally discharged under the cover of night into the water bodies, killing fish in the lakes and contaminating their crops. This daily, practical experience, however, cannot stand up to the powerful expert voices that pharma companies can bring to bear and their claims to abide by environmental regulations.[15]

One of the problems is the ambiguity as to how AMR evolves in the environment. Despite scientific evidence of high concentrations of active pharmaceutical ingredients in wastewater from pharma companies, it is difficult to connect antibiotics in the environment with a particular disease-causing AMR organism (e.g., to a legal standard, rather than a scientific one, which relies on probabilities and population-level patterns to assess causation). It is logical to speculate 'as the types and abundance of antibiotic resistant genes in the environment increases, so does the risk' of MROs developing.[16]

Another problem is the absence of strict government regulation and enforcement over pharma wastewater. The lack of certainty and data about the precise nature of the problem has meant that local villagers have been left in limbo. It is therefore up to international networks, such as REACT, media and national and local NGOs to raise the issue and focus on the detrimental effects that such contamination has on villagers and their environmental surroundings.[17]

Concerns over such environs serving as a breeding ground for MROs are now increasing, and the authorities have been called upon to tighten regulations.[18] International organisations, such as WHO and better-resourced OECD countries that are worried about the spread of AMR are also putting pressure on the Indian government to act.[19] Yet lax waste management practices, pollution and direct dumping of antibiotics in the environment continue. Some have argued that it is the standards set in place by the Central Pollution Control Board, which are inadequate.[20] Others point to the utter disregard that big pharma has towards any such standards at all. A leading South Indian daily paper, the *Deccan Herald* reported:

> The Central Pollution Control Board once again exposed the lack of respect for environmental laws by pharmaceutical companies in Telangana [TS] state and Andhra Pradesh [AP]. It has sent closure notices to 26 pharma companies in TS and five in AP. The number of pharma companies that have been sent closure notices in Telangana is second only to Maharashtra (28) in the country. Most of these companies produce drugs for export to developed countries like the United States, Canada and European nations.[21]

It is clear that the sources of drug-resistant bacteria are produced at different scales. Here we find at the higher end of the scale global capital flows compel international companies to offshore their antibiotics-producing factories to India. This leads to an interweaving of pollution, industrial waste and the potential evolution of AMR.

There are many other variables to this complex problem, which we have sought to highlight in this paper. Recall how exposure, risk and the (strategies of) amelioration are fast shifting vulnerabilities of communities. What appears as an affliction inscribed upon the 'wasted bodies' of the poor is a product of the large-scale political economy of globalisation and the insidious form of slow violence suffered by 'disposable people'. The power imbalance is vividly apparent. The numerous super-modern pharma manufacturing plants, fortified behind high walls, tower over villagers and parched fields at the outskirts of Hyderabad. These are the effects of dependency, jurisdictional arbitrage and opportunity structures. Situating environmental pollution within the wider structures of global capital, local government and industry is illustrative of the opportunity structures (and fallout) provided by countries seeking to attract foreign capital.

Conclusion

The crisis in antimicrobial viability interplays with the viability of everyday practices (open defecation), particular forms of labour (risky occupations), geographies of vulnerability (urban slums), India as a pharmaceutical global producer and the salve of unfettered access to drugs (in the absence of state-provided healthcare and regulations). Put differently, behaviour in one realm—around production, consumption and discarding of goods—can actually be tracked to another, seemingly discrete, problem of AMR and diminishing antimicrobial viability.

MROs have become an entrenched global health and security issue, and India represents a hotbed for MROs. The stage has been set for political and cultural contestations around issues of responsibility and bacterial relations. Many of these dynamics require far more research. We need more studies to clearly establish how such environmental contamination intersects with infectious disease epidemiology among humans and farm animals. Studies are required to identify which infectious agents persist in the environment and when and how they come into contact with pharma waste. We also need to know more about what makes it likely for AMR to evolve in an environment contaminated by active pharmaceutical ingredients, which is not necessarily analogous to the human (or mammalian) body, where much of AMR evolution occurs.

In establishing the extent of MROs in India's healthcare facilities, rural and urban environments, or even within different populations, political will and tightened regulations are urgently required. Density of population, poor sanitation, the magnitude of waste and scarcity of clean water mean that bacterial risk, and accompanying use of microbials, will grow. This provides an ideal laboratory in which MROs will flourish. To understand the development and potential of MROs, the study of Indian conditions should be a priority.

Notes

1. MROs are most accurately defined as bacteria that are resistant to antibiotics that would normally kill them or inhibit their growth.
2. Soil bacteria naturally produce antibiotics as a competitive mechanism, with a concomitant evolution and exchange by horizontal gene transfer, of a range of antibiotic resistance mechanisms.
3. For a recent account of the social dynamic of AMR amongst clinicians and pharmacists in India, see Broom et al. 2018.
4. This is despite the fact that the practice of manual scavenging was made illegal in 1993 and again in 2013 (see https://ncsk.nic.in/sites/default/files/manualsca-act1991363573851638244 4610.pdf).
5. The prophylactic use of antibiotics in animal breeding is problematic because the regular administration of low doses of drugs wipes out weaker bacteria and leaves the field open for stronger strains. When the manure is sold on as fertiliser or washed downstream into rivers and groundwater, the resistant genes are spread to the wider bacterial community' (Changing Markets 2015: 14).
6. For a recent overview, see 'Lower Castes in India Are Still Clearing Human Waste With Their Bare Hands, Despite Laws Against It', *Global Voices*, 14 May 2016 (https://globalvoices.org/2016/05/14/lower-castes-in-india-are-still-clearing-human-waste-with-their-bare-hands-despite-laws-against-it/).
7. See 'Supreme Court orders States to abolish manual scavenging', *The Hindu*, 27 March 2014 (https://www.thehindu.com/news/national/supreme-court-orders-states-to-abolish-manual-scavenging/article5840086.ece).
8. See 'Death by Sewage: clean-ups, caste and contracts in India', New Mandala, 15 Nov 2018.
9. 'Indian rail is world's largest 'open toilet': Jairam Ramesh', *NDTV*, 27 July 2012.
10. S. Parasuraman, 'On the margins in a city of dreams', *The Hindu*, 31 March 2016 (https://www.thehindu.com/opinion/op-ed/on-the-margins-in-a-city-of-dreams/article8414442.ece).
11. India is currently the largest consumer (by DDD per anum) of antimicrobials globally, in part due to its large population and in part due to the widespread availability of antimicrobials (Laxminarayan and Chaudhury 2016).
12. 'Antibiotics you throw away may be breeding superbugs', *Times of India*, 29 Aug 2018 (https://timesofindia.indiatimes.com/india/antibiotics-you-throw-away-may-be-breeding-superbugs/articleshow/65585501.cms).
13. For a recent report on the industry, see 'Pharma Industry in Hyderabad Region: a brief report' (https://www.hitex.co.in/images/img189.pdf).
14. Doron visited the area in Nov 2018.
15. See Eriksen (2018) for an illuminating account of the multiscalar modes of knowing and interpreting the environmental effects of industrialism.
16. 'Antibiotics in the wastewater from pharmaceutical companies: Where are we at?', REACT, (https://www.reactgroup.org/news-and-views/news-and-opinions/year-2018/antibiotics-in-wastewater-from-pharmaceutical-companies-where-are-we-at/).
17. For a powerful account, see 'Hyderabad pharma industry dumping antibiotic waste in water, unwittingly creating super bug, claims Vice Video report', *New Crunch*,

27 Feb. 2016 (https://www.newscrunch.in/2016/02/hyderabad-pharma-industry-dumping.html).

[18] See 'Hyderabad pharma industry dumping antibiotic waste in water, unwittingly creating super bug, claims Vice Video report.' (https://www.newscrunch.in/2016/02/hyderabad-pharma-industry-dumping.html).

[19] The Government of India has recently come out with a *National Action Plan* (2017), and in certain States that matter is given increased consideration, for example, 'Andhra Pradesh intends to curb shrimp farming antibiotic use' in *Fish Information and Services*, 11 Oct 2017. (https://www.fis.com/fis/worldnews/worldnews.asp?monthyear=&day=11&id=94165&l=e&special=&ndb=1%20target=).

[20] Ibid, minute, 7.44.

[21] 'Telangana, Andhra Pradesh pharma firms throw pollution laws to the wind', *Deccan Herald*, 9 May 2016, (https://www.deccanchronicle.com/nation/current-affairs/090516/telangana-andhra-pradesh-pharma-firms-throw-pollution-laws-to-the-wind.html).

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Competing Interests
The authors have no competing interests to declare.

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