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Balancing Clinical and Environmental Responses to Infectious Diseases

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A child enters a village clinic in China presenting with symptoms of lead poisoning. She is treated, and the area around her house is investigated for the source of exposure, an environmental response designed to prevent re-exposure. A child enters the same clinic presenting with symptoms of acute schistosomiasis infection. He is treated and sent home only to be reinfected in his still-contaminated community. This contrasting response to chemical and infectious environmental hazards is not an isolated example; rather it is a reflection of the largely clinical orientation of many global infectious disease control efforts,¹ despite the potential for environmental interventions to sustainably and cost-effectively limit re-exposure to environmental pathogens.² We argue that the management of environmental pathogens—currently dominated by clinical intervention—could benefit from an improved balance between clinical response and environmental action. Interestingly, physicians themselves have argued for just such a balanced response to *chemical* environmental hazards—an important historical example is the chemical hazard lead (Pb).

Pediatricians argued persuasively to expand the response to lead poisoning from the clinical setting into the environment where exposures were taking place.³ In 1957, for instance, a pediatric radiologist confronted with a steady stream of childhood lead poisoning cases at the Children's Hospital of Michigan stated that "all [clinical] therapy is wasted if a child is sent back into the environment where the trouble originally started."⁴ Similarly, in 1969, the senior attending pediatrician in Children's Hospital of the District of Columbia warned of the risk that lead-poisoned children discharged from the hospital into the same environment will "return to the hospital a few months later with further damage" from re-exposure.⁵ Even as clinical care and treatment for lead poisoning was advancing, physicians were pushing for primary prevention that reduced re-exposure "thorough inspection of the house and removal of sources for new [exposure]."^{3, 4}

Like their toxic chemical analogs, environmentally-mediated pathogens—infectious agents with environmental stages in water, soil or air, or those carried by non-human hosts or vectors—are emitted into environmental media where they can persist, move between communities (e.g. in flowing water), and expose people who contact, ingest or inhale contaminated water, food, soil or air. Exposure to these environmentally-mediated

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JVR conceived the idea for the paper and both authors wrote it, had full access to all the data, and read and approved the final version. JVR was responsible for deciding to submit the paper for publication.

pathogens results in diseases of significant global importance: water, food, and soil borne agents that cause diarrhea; vector-borne agents that cause dengue or malaria; respiratory agents such as rhinovirus and influenza; and agents transmitted through contact such as *Staphylococcus aureus*.

A prime example of a class of environmental pathogens for which clinical treatment is rarely accompanied by environmental action are soil-transmitted helminths (STH). Infections are treated using antihelminthic agents, yet treated patients return to a contaminated environment and re-infection is pervasive. For many STHs such as hookworm and *Ascaris*, which persist in the environment, a cycle of deworming and reworming is accepted as a reality in current global control campaigns,^{1, 6} and some have argued that the predominance of drug therapy must give way to more comprehensive measures that include environmental and other interventions,^{1, 2, 6} particularly as repeated reinfection can itself lead to more severe clinical outcomes in some cases.⁷ The goal of a more balanced, integrative approach is to minimize the repeated re-exposure to environmental hazards that occurs when mitigation focuses solely on clinical therapy; this in turn would minimize populations being sent right back "into the environment where the trouble originally started."⁴

Of course, environmental strategies to reduce infectious diseases have a long history. John Snow identified cholera as a waterborne agent in England in the 1850s, and Edwin Chadwick launched major improvements in environmental conditions in urban areas during the same period. Biomedical advances over the following decades complimented sanitary reform. For example, hookworm elimination in the U.S. South benefitted from a balance of clinical treatment and sanitary interventions; campaign leaders attributed success to the combination of "20 per cent. thymol and epsom salts [treatment] combined with 80 per cent. sanitation [prevention]."⁸ Today, global sanitation, sewerage and clean water campaigns carry on these successes, but some efforts to control environmentally-mediated infectious diseases are in need of an improved balance of available interventions. This struggle is exemplified by polio, which is on the verge of eradication. The global eradication effort, focused almost exclusively on vaccination, has been enormously successful, yet poor sanitation infrastructure has contributed to slow progress in achieving elimination.⁹ Although polio is an enteric pathogen transmitted through the fecal-oral route, a combined strategy of vaccination and environmental intervention, which may lessen the intense vaccine coverage required for elimination, has been given only tangential attention.⁹ Another important example is environmentally-mediated antimicrobial resistance in human pathogens, which has largely been confronted through changes in clinical practice, with little attention paid to much-needed environmental interventions in industrial agriculture.¹⁰

In contrast, an increasingly effective balance of available interventions has been achieved by programs to reduce hospital-acquired infections by methicillin-resistant *Staphylococcus aureus* (MRSA), a commensal organism of the skin transmitted via hands of health care providers. Evidence for environmental transmission of *Staphylococcus* emerged in the early 1960s,¹¹ and current protocols acknowledge the key role that environmental management and hand hygiene play, in addition to active surveillance, decolonization, antibiotic stewardship and other non-environmental controls.¹² Environmental measures may prove yet more crucial for MRSA control given recent evidence that patients are at greater risk of acquisition if admitted into a hospital room previously occupied by a colonized patient—a clear call for environmental disinfection.¹³ Importantly, these environmental controls may need to extend outside the hospital to confront the growing risk of community-acquired MRSA.¹⁴ Further research is needed on the importance of the environment in directly transmitted pathogens, but one thing is clear: pathogens are present on fomites, especially during outbreaks, and targeting these environmental surfaces provides an additional barrier to infection.¹⁵

As with MRSA, there is significant progress to report in balancing clinical and environmental interventions to reduce certain parasitic diseases, especially in China.¹⁶ Particularly notable is the country's emphasis on environmental interventions to reduce schistosomiasis infections. National control policy now emphasizes specific activities to reduce environmental exposures of human and other mammalian hosts while simultaneously reducing environmental contamination.¹⁷ These activities expand on China's chemotherapy-based schistosomiasis control programs,^{17, 18} and efforts in other global settings could learn from China's success balancing antihelminthic treatment with environmental interventions.¹

It is clear that reliance on drug treatment alone for control of environmentally-mediated pathogens is unsustainable, and environmental action has an important role to play,² but research is clearly needed to provide quantitative estimates of the optimal combination of interventions for a particular pathogen in a specific location and social context. Cost-effectiveness studies for the control of infectious disease need to move beyond chemotherapy and vaccines to integrative approaches that include environmental management.¹⁹ Indeed, improved understanding of the impact—and cost-effectiveness—of controlling the source of emissions (e.g., limiting contamination with poliovirus-infected waste); reducing environmental reservoirs (e.g., targeting schistosome animal hosts); and limiting exposure (e.g., eliminating MRSA from hospital bed surfaces) is greatly needed. For many environmentally-mediated pathogens of global importance we lack the basic tools to carry out environmental interventions, such as the ability to detect the pathogen in the environment.²⁰ A recommitment to research that examines pathogen environmental biology, including rigorous estimation of fate and transport characteristics, transmission pathways, and dose-response relationships, can provide key parameters needed for gaining insight into effective environmental interventions. Such research crosses disciplinary boundaries, and funding agencies such as the US National Institute of Allergy and Infectious Diseases and National Institute of Environmental Health Sciences provide limited support for infectious disease research with an environmental emphasis.²¹ Along with public health scientists, physicians can resuscitate their historical role by insisting that funding priorities address both clinical and environmental knowledge gaps, and that a combination of clinical and environmental interventions are implemented based on the evidence gained.

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