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Public Health Ecology: Challenges for Clinical Practice in Rural Bangladesh

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ABSTRACT

To improve health in populations addressing the United Nations Sustainable Development (SD) target goal 3.4 of reducing premature mortality from noncommunicable diseases by one third by 2030, discussions have centered on accessibility and quality of care. However, the increasingly commercial missions and centralized organization of health systems are not well aligned with public health goals for universal access. Additionally, quality-of-care conversations are focused on efficacy, often of modest levels, to the exclusion of major attention to efficiency, patient-centeredness, and equity. The promises of synthetic biology and precision medicine ignore the cost challenges of population applications.

In these broad contexts, there is an emerging paradigm for health that inflammation is a common biological pathway for multiple and interacting health conditions. This insight commands attention to the identification of the breadth of causes and stressors producing chronic inflammation and suggests that public health ecological activities may be significantly health-creating for populations. The ubiquitous causes of concern range from chemical, psychosocial, environmental, nutritional, and viral, to poor oral health. To illustrate the significant relevance of this long-overdue broader framework and new model for population health activities worldwide, this communication will consider, for one general rural Bangladeshi population, the depth of data implicating several factors in its health, and measures to decrease these adverse stressors.

Public health ecological deep medicine offers a potentially impactful and contrasting approach to population health from current business-dominated models which focus on isolated medical conditions.

Keywords

Sustainable development goals, Ecology, Inflammation, Stressors, Causes, Deep phenotyping.

Introduction

Persistent inflammation is associated with many chronic human conditions and diseases, including allergy, atherosclerosis, cancer, arthritis, and autoimmune diseases" [1]. "How you define the problem determines whether you solve it" [2].

Ecology is the branch of biology that deals with the relations of organisms to one another and to their physical surroundings. Historically, the scope of public health activities has been limited to communicable diseases-acute processes of limited duration, with assumed complete recovery in most cases, but with long-term treatment in some diseases, such as tuberculosis. In most public health discussions, instead of talking about public health ecology, we have talked about communicable diseases. However, in recent years, other categories of ecological exposures have been demonstrated to play major roles in the development of some acute, but mostly chronic noncommunicable diseases (NCDs). In particular, the emerging paradigm for health that inflammation is a common biological pathway for multiple and interacting noncommunicable disease-health conditions, has focused

greater attention on ubiquitous ecological stressors that are not communicable disease vectors [1,3,4]. Further, particularly with SARS-CoV-2 infections, the development of long-term adverse health conditions and critically, excess population mortality following acute illnesses, has blurred distinctions between specific communicable and non-communicable diseases, and focused attention on causative co-factors important in these immune, metabolic, and hormonal system disturbances [5-9].

In these changing circumstances, promoting the term public health ecology is appropriate, and then, within this broader framework, reconsidering how we can better create health for populations. I suggest the following working definition of public health ecology: clinical practices addressing the broad and powerful ecological exposures and stressors which cause chronic inflammation and multiple interacting diseases.

In addressing the United Nations Sustainable Development Goal (SDG) target 3.4 of reducing premature mortality from NCDs by one third by 2030, discussions have centered on accessibility and quality of care [10]. However, the increasingly commercial missions and hospital-centralized organization of health systems are not well aligned with public health goals for universal access. Additionally, quality-of-care conversations are focused on efficacy, often of modest levels, to the exclusion of major attention to efficiency, patient-centeredness, and equity [11]. The promises of synthetic biology and precision medicine ignore the cost challenges of population applications. 46 years after the declaration of Alma-Ata that heath care is a human right, for most global citizens population-impacting health care is unknown [12]. Foci on quality and accessibility for isolated medical conditions like hypertension, emphasizing treatment and rarely causes, and, in particular, absent significant activities to understand patient representations of this illness in low- and middle-income countries (LMICs), have been associated with limited changes in secondary health outcomes such as heart attack, sudden death, and stroke.

From a societal-public health perspective, "the problem" is poor population health and how to improve it, and we should reframe our approaches to increase attention to the causes of this status [2]. Broadly, if instead of primarily focusing on isolated medical conditions and how to treat them in individuals, we rigorously consider the underlying causes of poor health and redefine the mission of public health given the changes outlined above, we can better address "the problem" [13,14]. Hood and colleagues have estimated that less than 20% of "health" is directly connected to medical care [13]. Such insights suggest a major need to recognize the limits in our clinical endeavors. Farmer has opined that the "focus on molecular-level phenomena has contributed to the increasing "desocialization" of scientific inquiry: a tendency to ask only "biological questions about what are in fact *biosocial* phenomena" [14]. Reinhart has called the reduction of health services to individual biomedical models "clinicism", noting the Hood et al. data [15]. In sum, successfully addressing the SDG target for NCDs calls for rethinking our approaches and the framing of our discussions, which I suggest would be facilitated by titling our efforts as "public health ecology", to help us move beyond focusing on individual medical condition silos, communicable disease only, and specific clinical care to a broader bio-psychosocial concept of medicine [14]. This emphasis may serve to increase the focus on the scope of clinical services and not solely on public policy, although this important focus will of necessity promote public policy discussions [15].

This communication first considers the dimensions and challenges of public health ecology, and then demonstrates their general and cogent relevance in reviewing the population health threats to residents in southern rural Bangladesh. This specific target population review is important because the social determinants of health in high- income countries are, in their specifics, different from those in a low-middle income country setting. For example, imprisonment, drug abuse, sex-work, and homelessness have been majorly associated with increased mortality in western country studies [16]. Finally, I suggest how we can better approach our public health improvement "problem" and how we can reverse the broad societal limitations of health in settings like those of rural Bangladesh.

Inflammation and the Dimensions of Public Health Ecology

Over the last 20 years, there has been a growing body of scientific literature suggesting a central role of inflammation as a common biological pathway for multiple interacting chronic conditions [1,3,4]. Our current broad model of health postulates that major noncommunicable illnesses –atherosclerotic vascular disease, hypertension, diabetes, allergies, metabolic syndrome, asthma, arthritis, malignancies, kidney disease, and autoimmune disorders like rheumatoid arthritis-are independent conditions in their causation and autonomous in their development. Further, our emphasis in health care is on the treatment of these illnesses, with limited attention to addressing their causes. The emerging model suggests that these chronic conditions are also the consequences of cumulative insults from multiple stressors which cause chronic inflammation. In concert with other causative factors, this inflammatory biologic process promotes the development and progression of chronic illnesses and mediates interaction among them. This paradigm commands attention to identification of the full breadth of stressors producing inflammation, and critically to efforts to limit their presence and magnitudes. Further, this interpretation of the biology of health suggests that control of the stressors producing chronic inflammation may have major benefits in the control of chronic illnesses [3,4]. The case for much greater efforts in controlling these ecological stressors for the common good is strong.

The breadth of ecological stressors deserving of medical attention is great and presents what I have called the clinical deep medicine iceberg challenge, namely medical issues-diagnoses, and biological metrics are more definable and visible, but less numerous than ecological issues critical to health [13,17]. In table 1 are presented the stressors most evident in southern rural Bangladesh, but present to greater or lesser degrees throughout our global communities. The listed items enumerate the stressors as our residents perceive

them. The remainder of this communication will consider some major characteristics of these listed stressors and then measures to decrease these. This material will indicate why moving to talk about public health ecology is now so justified.

Table 1: Major interdependent ecological stressors in rural Bangladesh associated with increased systemic inflammation and multiple interacting chronic health conditions.

- **Social/psychological:** Poverty and financial insecurity; severe illness or death in family; loneliness; personal habits: tobacco smoking, betel-nut chewing, limited exercise [13-21].
- **Environmental/climate change:** heat; noise; light; weather extremes; natural disasters; air quality fine particulate matter <2.5 micrometers, particulate matter <10 micrometers, nitrogen dioxide, ozone [22-28].
- **Nutritional:** Food excesses in animal protein and fat, salt, and sugar. Ultra-processed foods of high caloric content containing substances extracted from whole foods or synthesized, often high in starch, sugar, saturated fats, salt, additives, and emulsifiers. Vitamin D deficiency. Food scarcity/famine [29-35].
- **Viral:** Hepatitis B, Human papilloma virus, COVID-19, Dengue [5-8,21,36].
- **Oral health:** Dental cavities, gum disease [37,38].
- **Chemical exposures:** Arsenic, lead, cadmium, PFAS (forever chemicals), fossil fuel-derived endocrine disruptors, microplastics [39-52].

Interdependent Ecological Heath Stressors in Rural Bangladesh

Social and Psychological stressors

Outside of academic social studies communities, it has perhaps been Katharine Boo's account of life in a Mumbai India slum that has most opened medical providers' eyes to the day-to- day stresses for people who live lives of deprivation [53]. In the public health community, led by the British epidemiologist Michael Marmot, however, there has been a wealth of research firmly documenting the role of material conditions on health [14-16,18-20]. In current interviews about hypertension, our residents say: "Poor people don't hope for anything"; "My worry is about family matters; I am always worried". "There's no sleep in the eyes at night"; "Worries mean, I will tell you the worries…like I have been worried for 5 days, I have a cow, it's sick,".

In particular poverty with associated financial insecurity and debt, is firmly linked to poor nutrition, inadequate housing, and limited integration into society, all leading to ill health (18, pp. 215-6). Further, literature is clear that poverty is linked to poorer mental health and that the effects of poverty accumulate through life to adversely impact health [15]. The central biological mechanism focused on has been the 'fight or flight' response with increased cortisol levels in response to stress. However, recent literature has emphasized inflammation [3,4].

In our Rampal project population-based interviews of 4770 households, the leaders in 4578 (96%) said that their greatest concern was financial insecurity [54]. General population research data for Bangladesh focusing on nutritional status suggest a serious picture: In children under age 5 years, stunting in 30%, underweight status in 22% and anemia in 51% [31].

The recent SARS-CoV-2 and dengue pandemics in Bangladesh have contributed major social stresses in households through acute deaths from these infections but also, as worldwide, excess deaths following the acute phases, and critically increased poverty [9,15].

In American literature, in the context of the SARS-CoV-2 pandemic, there has been more attention to loneliness and its adverse effects on health [20]. The receptions our interviewers have had in rural Bangladesh recently have highlighted to us the presence of this major stressor in our rural residents' lives. Personal habits, particularly tobacco smoking, betel-nut chewing, and limited exercise unquestionably have major adverse effects on health in Bangladesh [21]. It is an incomplete assessment, however, to ignore the social factors important in these behaviors (18, pp. 240-255).

Environmental/Climate change

Consequent to climate change, Bangladesh is ranked as the 7th most adversely affected country [22]. In general**,** affecting southern rural Bangladesh, under-recognized are the adverse impacts on food production (rice especially), and on increased salinization of potable water with associated increase rates of hypertension [23,24]. Additionally, the adverse impact of climate change on the mosquito population with a consequent dengue epidemic in 2023, has brought this disease vector change issue to the fore, with consequences to be considered below.

Weather extremes with storms or high temperatures have been the most considered concerns about environmental changes in public discourse, understandably because these have increased in number by almost 50% in the last 20 years in Bangladesh. Shindell and colleagues have estimated that there are currently 100,000 annual deaths in India from heat exposure [25]. There do not seem to be current similar estimates for Bangladesh, but considering the comparable climates, at one eighth the population of India, these Indian figures suggest that Bangladesh may suffer 12,000 annual deaths from excess heat exposure. Individuals with otherwise compromised health are at greatest risk.

Poor air quality air quality by four metrics: fine particulate matter <2.5 micrometers, particulate matter <10 micrometers, nitrogen dioxide, and ozone, throughout Bangladesh, is perhaps the greatest of that for any country in the world [26]. Shindell calculates that at present 200,000 Bangladeshis die each year of air pollution (double the number of annual deaths from all malignancies) [25]. What has been under-appreciated (but not unrecognized) is the major degree to which brick kilns, widespread in Bangladesh, contribute to poor air quality [27]. Finally, in Bangladesh cooking fire smoke in homes, a culturally intractable problem, is estimated to cause over 100,000 deaths annually [28].

Nutritional

While the concerns about food excesses in calories, sugar, animal protein and fat, and salt have been increasingly highlighted in

high-income country discussions, in association with population increases in obesity, such concerns have been less voiced in low- and middle-income countries like Bangladesh [29]. What is particularly striking in the food markets of our rural communities is the increasing promotion and availability of ultra-processed foods, which are contributing to similar food consumption excesses in this society, along with their associated additives and emulsifiers. These changes are occurring in a society where, as noted above, undernutrition in children is significantly prevalent [30]. Additionally, under-appreciated is the emerging long-term population impact of the 1974 Bangladeshi famine, in ways similar to those that have characterized the long-term health of the survivors of the Dutch famine, with as one manifestation increasing rates of non-alcoholic fatty liver disease [31,32]. Sadly, globally, population famines are increasing [33]. Further, our population is adversely impacted by increased salt consumption [24,34]. Finally, surprising to many observers, are the data that large fractions of the populations are vitamin D deficient [35].

Viral

The importance of certain viral infections and critically their long-term adverse effects have been clear in Bangladesh for the hepatidic and papilloma viruses, but population vaccination efforts have been incomplete [21]. As alluded to in the introduction here, however, what is emerging is a disturbing picture of the major chronic effects of SARS-CoV-2 infections on populations, with a strong message that other significantly large population-affecting infections, like dengue, may cause similar bad consequences for health [5-9,36]. The SARS-CoV-2 story is framework-changing for our discussions about public health for populations. This pandemic and its management have focused discussions on the public health dimensions of the acute illness burden and measures to decrease this masking, social distancing, vaccinations. The newer extended discussions have been about presumed limited, but nevertheless large fractions of the infected populations that appear to develop a post-infection syndrome called "long-COVID" [5,6]. What is now becoming more evident is that there are huge population-impacting consequences of this infection that have been recognized first in the excess mortality data seen in multiple populations [9]. An investigation of "long COVID" in Nepali women revealed that many of the "unrecovered" women did not have the common "long COVID" syndrome-suggested symptoms, but nevertheless knew that they were not back to their previous state of wellness [6]. And now recently, consistent with this assessment, two large prospective population studies of cognitive dysfunction with SARS-CoV-2 infection have found persistent dysfunction developing by three months and continuously present over three years [7,8]. Further, an adverse interactive effect of poor air quality and SAR-CoV-2 infection is being seen worldwide and is certainly likely the case in Bangladesh [26]. Collectively, these findings suggest for viral infections that we need to be thinking about the premise put forward in this communication: that public health can no longer be framed as a domain of acute illness only.

Oral health

Globally, poor oral health of teeth and gums affects almost half the world's population and is little considered as a contributor to systemic conditions [37,38].

Selected chemical exposures

Arsenic

One third of the Bangladeshi population or 50 million people are at risk from elevated arsenic intake in drinking tube well water, vegetables, and rice [39]. Elevated arsenic levels in humans are associated with a spectrum of chronic health conditions. It is estimated that 5.6% of Bangladeshi deaths are consequent to arsenic poisoning. Huge public health efforts have been made over the last 30 years in Bangladesh, but population coverage has been incomplete. Experts opine that arsenic-exposed populations need to be brought under the coverage of a regular surveillance program [39,40].

Lead

Unlike in high-income countries where lead paint has been a major source of lead poisoning in children, in Bangladesh urbanization (vehicle exhaust and fossil fuel consumption), lead smelting, and used lead acid battery-associated exposures with air, water and soil contamination are the major causes of high blood lead levels, partially through consumption of contaminated vegetables (gourds and tomatoes), turmeric powder, and fish [40,41]. Studies of lead contamination in Bangladesh are extensive the dimensions of the problems and excessive exposures are well documented. The Khulna district in which our rural health activities are based has been found to be among the most lead-polluted areas of the country [40]. Coastal area fish may be less contaminated. Vegetables have been found to be the most lead-contaminated sources. This observation is notable because some high-lead contaminated vegetables, such as gourds, also have high levels of health-promoting antioxidants, and increased vegetable consumption is widely encouraged (vide sopra). Limited capacity for waste treatment-waste water discharge, and recycling in the smelting and used lead battery industrial sectors from which the greatest volume of lead contamination arise, are major challenges in exposure control [40,41]. This brief overview of lead exposures underscores the complexities and breadth of scientific expertise and data necessary to define population health enhancement for our rural residents.

Cadmium

There is a breadth of adverse health issues associated with excess cadmium exposures and tissue levels, notably renal and hormonal [42]. Multiple industrial processes (Nickel-cadmium batteries, plastics) are the dominant sources through high waste discharge levels, which are likely increasing. Fish, chicken (from contaminated feed) and vegetables (gourd, again) and rice have been found to have high cadmium levels [43]. The extent of exposures and food contamination varies, but clearly exceeds global standards in some foods, and particularly rural children are at greater risk for neurological insult [40,42,43].

Per- and polyfluoroalkyl substances (PFAS) [44,45]

PFAS is an umbrella term for a class of thousands of

chemicals widely used in nonstick applications-cookware and food packaging, and plastics production. Exposures to these chemicals through product use and drinking water have been linked to a variety of adverse health effects, perhaps most notably immune suppressing effects, and low birth weight [44]. Because of their persistence in the environment, they are called "forever" chemicals. For our rural Bangladeshi population, the uncertain magnitude, but very likely increasing exposure to PFAS, is of concern looking towards population-impacting strategies for reducing stressors overall.

Fossil Fuel-Derived Endocrine Disruptors [44,46]

Endocrine disruptors (ED) are specific chemicals (some considered above) or mixtures of chemicals which interfere with hormone action. Of notable ED effects are those on metabolism, of major importance because of the increasing prevalences of metabolic syndrome and diabetes. Specific attention is warranted to these EDs because there appear to be no risk-free levels of exposure [44]. Ubiquitous and perpetual exposures occur through contaminated air food and drinking water. With respect to the general discussion in this communication, promoting a broader framing of challenges to public health, there has been new emphasis on studying cumulative ED exposures [44].

Micro plastics [47-52]

In recent years, it has become more evident that plastics are incurring major costs to human health [47,48]. What has been less recognized is that inhalation or ingestion of micro-or nano-plastics are associated with releases of harmful chemicals, found in almost entire populations [47-49]. Now specifically, direct evidence of a previously suspected relationship to disease has been reported [50]. In an Italian study, worse outcomes myocardial infarction, stroke, or death from any cause were associated with presence of microplastics and nano-plastics in cardiac vessel plaques [51]. Critically, for the case being made in this communication about a role for inflammation in chronic disease conditions, in this Italian study the patients with microplastics in their plaques had elevated levels of circulating inflammatory markers [51].

In our rural Bangladeshi community, despite the country's total ban on plastic bags first in the world in 2022 plastic trash is everywhere, and single-use plastic items, plastic bottles and bags are increasingly present day by day, primarily because of the absence of alternative carriers and containers [52]. Of note however is that an initiative to develop reusable jute bags is close to providing the missing alternative for bags. Perhaps plastic bag use is less in Bangladesh compared with other countries, but the limited recycling capacities in this country contribute to a huge waste plastics environmental contamination problem [52].

Public Health Ecology: Societal, Social Policy and Health System Approaches

We are challenged by the ubiquity, high numbers, and complexity of health stressors to develop what Topol and others have called "deep medicine", and what here I am suggesting we term public health ecology [3,17,55]. I am advocating use of this term because the deep medicine appellation suggests that the focus of efforts needed should be at the individual patient care level, when the circumstances in fact confirm that community activities are needed and likely to be most impactful. Whether at community or individual patient care levels-optimally at both levels the issue to be addressed is identifying the extents of stressor exposures and their interactions to increase systemic inflammation, and then defining interventions to decrease these, noting the possibility that successes with specific stressors may have disproportionately positive effects for health overall.

Given the enormous adverse impact of poverty, the first major policy effort for health is in fact economic development which leads to increased resident disposable income. But more non-specifically, we need to start at the local level, bottom up, with local listening and data acquisition to better understand what our residents' lives are about, more of Katharine Boo type studies [53]. We need idea champions and activist groups, such as a social and medical community justice work corps, as suggested by Reinhart [15]. Armed with greater knowledge and big picture understanding of the implications, we need to summon the will to address these broad health challenges outlined in table 1. Rather than being overwhelmed by their extent and the complexities of intervening we should be excited about our new health insights, which should provide a renewed sense of purpose.

To begin, we need better framing and interpretation of the broad scope, trends, interactive nature, and cumulative dimensions, of emerging biological and psychosocial models for health, and forecasting the implications of these. We need greater social science inclusion at the health policy and services tables: economics, anthropology, sociology, psychology, political science, public policy, philosophy-ethics. law, ethnography, and communication. What follows, in a context of promoting public good "it's about us" must be better communication concerning this scientific picture in open, honest, understandable, consistent, and repeated ways. This is the huge lesson from the SARS-CoV-2 pandemic the need for better communication [56]. Honesty implies addressing disinformation and dealing with the challenges of vested and conflicting financial interests. We need greater organizational energy to explore social change mechanisms, led by idea champions for getting to more integrated, population-impactful interventions [57,58]. Some specific examples are:

- Guaranteed basic income [15,59,60].
- Support of international campaigns such as the Global Plastics Treaty.
- Support for enforcement of plastic bags bans [52].
- Grass roots demonstration projects such as clean air centers with air filtration units, reduction of medical facilities plastics use, recycling facilities for plastics and lead batteries, solar power facilities, water filtration systems for salt and PFAS, monitoring systems for arsenic lead and cadmium in potable water.
- Connection of climate change with increased potable water salinization and associated increased hypertension [24].
- Advocacy for routine surveillance for all major chemical exposures, as currently for air quality (Table 1).

Health system approaches

System

Health facilities should be models for green infrastructure-promoting, environment-protecting measures with goals of zero net energy use and waste (especially plastic) limitation and daily air quality report postings. Nature helps; we need more health facilities with gardens and cooling stations. Health facilities need to address the full scope of health stressors with learning centers [17].

Specific Patient Care

We need significantly greater community health presence [61,62]. In our Rampal project and a more recent hypertension study, our interviewers from the same villages repeatedly tearfully recounted what they saw and heard; they were stunned by the depth of squalor and psychosocial distress of their neighbors [54,63].

Individual Stress Load Phenotyping

I have noted that "Topol considers deep medicine to have three components: #1. Deep phenotyping, meaning the breadth of data which define an individual's health status; these are life-long detailed biological and ecological factors. #2. Deep learning, meaning synthesis and comprehensive analyses of all phenotypic data, in light of up-to-date scientific evidence. And #3. Deep empathy and connection, meaning having the rich relationships to get #1, and apply meaningfully #2" (17; 55, pp. 16-17). As Topol and others have opined, we have the capacities to do such deep phenotyping with help of virtual medical assistants to continually gather and update individual patient health information and survey the medical literature in a deep neural network to create virtual health guidance [55,64]. Our primary care systems need to be much better organized and supported to allow this kind of activity [61,62]. Broadly, we need to address regularly psychosocial, environmental, and nutritional stressors (Table 2). Expressed awareness of financial insecurity with empathy can be more impactful than is commonly appreciated. Attention to personal habits is always worthwhile. Expressions of concern about environmental stressors and encouragement of masking with poor air quality should be routine. Nutritional intake and status evaluation should also be routine, with required interventions for caloric insufficiency, and efforts to maximize antioxidants intake (which requires awareness of safest sources) and Vitamin D supplementation.

Table 2: Proposed scope of virtual medical assistant continual survey for rural southern Bangladeshi residents.

Ecological exposure	Data sources
Social/psychological stress	Resident occupation
	Medical problem list:
	Poverty
	No family regular income
	Insecure home environment
	Parental stress
	Death of first degree relative in last year
	Home family member with major health problem
Environmental:	
Excess heat	Public record for home area
Air quality	Public record for home area
Cooking fire smoke	Medical problem list
Biological:	
Non-recovery from SARS-C0V-2 Poor oral health	Medical problem list:
	Patient self-assessment
	Medical problem list
Nutritional	
Caloric deficiency	Medical problem list: BMI
Vitamin D deficiency	Medical test result
	Risk estimate from Demographic population data.
Salt consumption excess	Risk estimate from demographic population data.
Personal famine exposure	Birthdate prior to 1974
Arsenic, lead, cadmium	Resident home/union water and food survey data.
Potable water salinity	Resident home/union water survey data
Endocrine disruptors	Any country survey data

Conclusion

The scope of the challenge of improving population health has to change from considerations majorly of communicable diseases thought to have only adverse effects of limited duration, to broader ecological stressors psychosocial, environmental, nutritional, chemical, and poor oral health. Adoption of public health ecology language is encouraged to facilitate this change.

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