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A Complex Systems Account of the COVID-19 Pandemic: Illustrations from India

Sayan Das

Research Scholar, Centre of Social Medicine and Community Health, Jawaharlal
Nehru University, New Delhi, India



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Science, Scientists, and Society

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Sayan Das

Research Scholar, Centre of Social Medicine and Community Health, Jawaharlal Nehru University, New Delhi, India

Email. drsayandash@gmail.com

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Abstract. The COVID-19 pandemic in India and the rest of the world was followed by tremendous health and social consequences. Worldwide the pandemic created challenges that were unpredictable and elusive to our existing ways of thinking. The paper posits that a complex systems thinking is needed to make sense of the society-wide ramifications of a 'wicked' problem like the pandemic and devise appropriate resolutions. A complex systems thinking conceptualizes our society as emergent from irreducible interdependencies across individuals, communities and systems, and the pandemic as a complex systems problem that has consequences both immediate and future. The paper uses the complexity lens to explore the unanticipated repercussions of the pandemic control measures that further accentuated pandemic induced socio-economic disruptions, and secondly, the domain of COVID-19 treatment in India, as examples, to demonstrate that while devising a response to complex phenomena like the pandemic more needs to be accounted for than what meets the eye. It thus calls for a more caring science that understands and respects our shared existence and wellbeing and makes use of diverse, democratic and decentralised processes to forge shared pathways for navigating our complex world.

INTRODUCTION

During the first wave of COVID-19, India implemented one of the strictest lockdowns in the world, declared at just four hours' notice. Over the next few months, the whole country bore witness to how that played out, especially for the vulnerable sections of our population. Fearing starvation and death due to the sudden loss of work and income, tens of thousands of migrant workers set out on foot to return to their native villages, encountering death and destitution on their way back. Not just that, near-total shifting of resources to pandemic management also disrupted routine healthcare services like chronic disease management, immunisation and institutional delivery with deleterious effects. While the cases did come down eventually (only to surge again in the second wave of 2021), the tremendous social and economic disruptions carried on exacting their toll with the continued rise of unemployment and hunger among the already marginalised ([Azim Premji University 2021](#); [Gupta 2021](#)). Most of these developments, including the terror and trauma of the second wave, spiralled out of the pandemic control measures that seem “both inadequate and excessive at the same time” ([Priya and Das 2020](#)).

The COVID-19 pandemic thus created challenges that were not only unpredictable but also elusive to our existing ways of thinking and acting. Sophisticated modelling exercises or epidemiological estimates, none could provide us with the necessary answers or prepare for the widespread socio-economic distress in the wake of the lockdown. In response, many argue the need for their contextualisation in new post-normal science that takes uncertainty and complexity seriously ([Scoones 2020](#)). The various kinds of incertitude and complexity encountered in real life arguably stem from how our society emerges from innumerable, diverse and irreducible interactions connecting individuals, communities, systems (health, economy, governance, etc.), the nation and the world, resulting in both predictable and unpredictable behaviour. In other words, our societies represent what in systems science parlance is known as complex adaptive systems (CAS) ([The Health Foundation 2010](#)). COVID-19 pandemic exemplifies a perturbation that destabilised this whole configuration of CAS and resulted in a chaotic situation that created society-wide repercussions and exposed the limits of our entrenched methods in dealing with complexity.

THE ‘WICKED’ PANDEMIC

Without the gift of hindsight, planning, which would anticipate and address both immediate and future needs in complex situations, is not an easy task, especially when the problems they try to resolve are typically wicked. In fact, many of the social issues fall within this category of wicked problems, where the dynamic interactions between multiple stakeholders across different levels of hierarchy, informed by their specific conditions and power relations, create situations that are hard to comprehend in their totality and even harder to address

comprehensively. Given the interdependencies across systems, seeking the exact causality of social problems is often a red herring. The closer one looks, the more intricate it gets. The incompleteness of our knowledge at any given point also means a vast domain of unknown knowns and unknown unknowns. Any action targeting a wicked problem, therefore, sets in motion system-wide repercussions, often with unexpected outcomes, resolving which can be as difficult a task as defining or locating the problem (Rittel and Webber 1973). Hence, without appropriate formulation, finding pertinent solutions can become difficult. However, the dominance of narrow framings that continues to neglect the social embeddedness of situations also circumscribes the scope of knowing and responding appropriately. Moreover, both ‘what is’ and ‘what ought to be’ depend as much on our incomplete and evolving knowledge as the political contestation between different value frameworks and their explicit and implicit objectives. The crisis in the wake of COVID-19, therefore, represents a typical wicked problem where the dynamic and developing knowledge-action configurations require an epistemological shift towards more comprehensive and critical approaches that can learn from the past and the now to negotiate an equitable future with “willingness to live creatively with unresolved arguments and tensions” (Waltner-Toews 2020a).

COMPLEXITY AND HEALTH

Looking back at the first wave, we find countries across the world largely depended on age-old epidemic control measures, informed primarily by a biomedical framework (Priya and Das 2020), to respond to the wicked problems unleashed by the pandemic. Faced with too many unknowns, our tendency is usually to target the most obvious without much thought on the wider repercussions. While such ad hoc measures may give a semblance of immediate control, unintended consequences can creep up unobserved. For instance, India implemented one of the strictest lockdowns in the world to control the pandemic, mostly ignoring the complexity of the situation and its potential system-wide implications. Naturally, with time the unanticipated consequences of such measures—the migrant exodus, for instance— became apparent, perpetuating their own sets of wicked problems and underlining the need for better understanding and planning. Enter complexity theory.

Complexity theory defines social systems as CAS having certain specific properties. Originating in the forties and fifties, complexity theory continued in the line of holistic thinking/systems approaches in other domains of science like quantum physics and evolutionary biology, questioning the ordered/deterministic appearance of the very Newtonian paradigm of science that birthed it. While responsible for great strides in science, the Newtonian paradigm is often found lacking in dealing with nonlinear systems. Linear systems operate under the principle of superposition. It means in a linear system if input A produces effect X and input B produces effect Y, then the effect of A+B together would be simply X+Y. So, breaking down a linear system into its components, studying them separately, and summing them up is good enough for arriving at solutions about the whole. But social systems are not linear where their components are neatly separable, or the outputs proportionate to

inputs. On the contrary, the large number of deeply interconnected elements in social systems dynamically interact and adapt to continuously shape each other ([Rickles D et al. 2007](#)). For instance, if we consider the pandemic, where exactly does the problem lie, and where do we direct our actions? The virus and its cure? The health service set up to treat the diseased? The social stratification and distribution of resources that determine different communities' ability to adopt the various control measures and adapt to the rapidly changing circumstances? Or all of these and their dynamic interrelations? The tremendous health and social disruptions in the wake of the pandemic across the world mark it as both a health and social problem and, at the same time, also a personal and global problem.

Unlike the reductionism of classical science, complexity theory thrives in this interdependence between the parts and the whole, where just the parts or just the whole is never enough. In complex systems, the products shape their own production ([Morin 1992](#)). Just as any system, complex systems also comprise multiple elements that interact with their environment. But unlike simple or complicated systems that can be broken down into their component parts, analysed and acted upon, the nature of interactions in complex systems stand out. Path dependence (Sensitivity to initial conditions and choices made along the way influence future behaviour. For instance, decades of neglect of public health in India influenced the absence of context-appropriate public health inputs in India's epidemic planning in the first wave or the centre's refusal to pay heed to such warnings in the second ([Indian Public Health Association et al. 2020](#); [Ghoshal and Das 2021](#)), feedback loops (Output from the process within a system circles back into the same system as an input. A complete nationwide lockdown was implemented in the first wave to prevent transmission of infection. But it inadvertently set off the migrant exodus which was then held responsible for furthering the spread of infection), emergent behaviour (The spontaneous appearance of patterns when behaviours of parts jointly shape organised behaviour across the collective whole. For instance, the sudden announcement of lockdown in March 2020 shut off work and income for India's vast section of migrant workers living amid precarity in alien lands. Fearing hunger and distress, they set off on foot for their native villages, individually or as family, but together contributing to one of the biggest migrant exoduses across India unheard of since the days of partition. Ironically, this resulted in increased congestion in trains, bus stops and camps, defeating the objective of the lockdown to reduce contact transmission) phase transitions (Tipping points that result when system parameters reach critical state and display radical change. For instance, the sudden shift in demand for telephonic health services during the pandemic led to unprecedented adoption of telemedicine services across public and private healthcare), among others, make complex systems emergent and unpredictable. Health systems, comprising highly heterogeneous interest groups and operating at multiple levels through a variety of services and functions, typically demonstrate features of CAS ([Paina and Peters 2012](#)).

COMPLEXITY AND THE PANDEMIC

There have been several instances in the pandemic that highlight typical complex systems problems. The following section employs a complexity lens to explore COVID-19 treatment as an example.

Officially there have been several treatment guidelines on COVID-19, from the Indian Council of Medical Research and autonomous institutions like the different All India Institute of Medical Sciences to the different state health departments. On account of its novelty and wildfire spread across the globe, COVID-19 arrived enveloped in uncertainties and urgency, which found reflection on these various treatment protocols. While they included vitamins C and D, micronutrients like zinc, which had known antioxidant, immunomodulatory and anti-inflammatory properties, there were also controversial candidates like the antimalarial Hydroxychloroquine or antibiotics such as Azithromycin and Doxycycline. In the first wave, there was limited evidence and little time, so common sense prevailed, and drugs with feeble evidence also found a place. Despite the uncertain evidence, these received wide press and wider circulation thanks to social media forwards that skimmed out on the nuances. In fact, a parallel pandemic of misinformation - also being called an infodemic, followed close on the heels of the COVID-19 pandemic. A global social media analysis identified incorrect reports published in 25 languages across 87 countries, a fifth of which was on cure and treatment ([Islam et al. 2020](#)).

We now know that the human body is a complex system itself and health, an emergent property of interactions between the external environment and internal physiology ([Sturmberg 2014](#)). The uncertainties surrounding preventive measures and availability of treatment, past experience with inferior quality public health services or the prohibitively expensive private healthcare and inconsistent messaging from the authorities expectedly led to widespread public confusion and panic. And those who could find and afford, stocked up on these medications, consuming them without indication or prescription, and in turn creating artificial scarcity in the market and different health hazards (emergent behaviour). This further led to black marketing of essential medications, ultimately requiring the government to step in and control their circulation. While this went on outside the body, the body's physiology bombarded with excessive and indiscriminate medications created its own sets of problems which are now becoming apparent in the second wave.

The government, having declared victory against the pandemic in early 2021, was least prepared for the second wave that led to a near-total collapse of both public and private healthcare in many areas, including the nation's capital ([Dhume 2021](#)). Neglect of early warnings, questionable policy decisions (path dependence) and the rapid rise of infections led to escalating demand for oxygen and hospital beds during the second wave. Countless people died without treatment and oxygen, countless pyres lit up the night sky of the worst affected regions, and when that too got overwhelmed, countless bodies turned up on the river banks or

flowed down the river, robbed of dignity even in death. Given such tragedies unfolding all around, many cases which otherwise would have needed hospitalisation had to be treated at home. Without medical supervision, this often led to irrational and indiscriminate use of steroids even in cases (i.e., majority of COVID-19 cases being mild/moderate don't require supplemental oxygen or systemic steroids) where they were not indicated.

While evidence was lacking for many medications being prescribed for COVID-19, there was solid supportive evidence from the RECOVERY trial on the role of systemic steroids in COVID-19 treatment and its indications under specific conditions ([National Institutes of Health 2020](#)). Despite the presence of such credible evidence, curiously, both the AIIMS/ICMR-COVID-19-National Task Force protocols of 22 April and 17 May recommended higher doses (which goes even higher as the weight of the patient increases) of equivalent steroid (methylprednisolone) for hospitalised patients than the dexamethasone dosage found to be effective in the RECOVERY trial ([Ministry of Health 2021a](#); [Ministry of Health 2021b](#)). No analysis of COVID-19 treatment and outcome data from India is available yet to support the dose escalation. The wide berth allowed in the steroid dosage was ripe for abuse as institutionalised care was in short supply in the initial days of the second wave, and people had to depend on everything from the quack doctors to the local pharmacy for treatment. The already high prevalence of diabetes in India, diabetic conditions exacerbated by COVID-19, overexploitation of immune-suppressants like steroids, COVID-19 caused immune compromise, overdosage of micronutrients like zinc (while the recommended dietary allowance is 8 mg/day in women and 11 mg/day in men, in COVID-19 treatment zinc is being given 50 mg/day, over and above the dietary input) in a high ferritin environment of COVID-19, have all been linked (feedback loop) in creating a potent ground for the emergence of the epidemic of mucormycosis that has only aggravated India's COVID-19 problem ([All India Institute of Medical Sciences 2021](#); [Mordani 2021](#)). The first published epidemiological study on Coronavirus disease-Associated Mucormycosis (CAM) in India corroborated the association of improper glucocorticoid use with CAM ([Patel et al. 2021](#)). Hence, the above example illustrates how various processes, social and biological, interact and adapt to changes within complex systems, often creating unforeseen challenges.

Another such challenge brewing amidst the pandemic, however, has received far less attention in India so far: the indiscriminate use of antimicrobials in treating COVID-19 and its potential impact on the silent pandemic of antimicrobial resistance (AMR). AMR poses a major threat to public health, with an estimated ten million deaths annually by 2050. In the backdrop of COVID-19, the situation has become even more worrying. A rapid review from 2020 revealed that while over 70% of COVID-19 patients had received antimicrobial treatment, less than 10% had any actual fungal or bacterial coinfections ([Rawson et al. 2020](#)). Another study from the US pointed out a 10% rise in resistance against different classes of antibiotics in an institution compared to 2019, most probably due to indiscriminate antibiotic use in COVID-19 treatment ([Nori et al. 2020](#)). India, having one of the highest incidences of bacterial infections globally, is also one of the largest consumers of antimicrobials worldwide, and a rise in AMR would threaten advances made over decades, causing serious harm to people's health. India has a National Action Plan on AMR, also an 'Antimicrobial Resistance Surveillance and Research Network' initiated by ICMR in 2017 ([Ganguly 2021](#)). Yet, there's hardly any research like those

from the US that study antibiotic misuse in COVID-19 treatment or any action plan to prevent such misuse. A complexity lens can be very useful to map the intersecting pathways of AMR in the backdrop of COVID-19 and develop appropriate responses.

From India's hybrid vaccine policy leaving the vulnerable behind and in turn jeopardising global pandemic response to the tremendous plastic waste of personal protective equipments (PPE) threatening planetary health, the COVID-19 pandemic is truly a global and social problem, calling for coordinated action across domains and nations ([Kaur and Kapil 2021](#); [Chowdhury 2021](#); [Zhang et al. 2021](#)). A complex systems lens is invaluable in dealing with such complex systems' problems to unearth many such potential challenges in the making and the various interactions shaping them. Collaborative systemic probing, dynamic sense making with an eye on emerging patterns and responding in a way that allows desired effects to self-organise while not discounting uncertainties, unpredictability and novel outcomes are some ways in which complexity science can inform the future response to pandemics and other complex systems problems. But for that, we need to deepen our engagement with complexity first.

EMBRACING COMPLEXITY

Complexity science is often exalted as the science of the 21st century. However, in effect, complexity is still seen as something that needs to be unravelled to be acted upon but seldom as an epistemic process that teaches us to look at social phenomena in a different light and respond to them with more democratising efforts and humility. This means accepting turmoil, uncertainties and unknowability as par for the course and evolving creative ways to navigate them with understanding and patience. That we're as much part of the problem as the solution would also mean developing a more caring science that is mindful of the planet that we share between ourselves and other species and looks out for our shared health and wellbeing ([Waltner-Toews 2020a](#); [Waltner-Toews 2020b](#)). The COVID-19 pandemic and the five public health emergencies that we faced in the last decade alone represent what happens when this shared existence is disvalued, and dangerous disruptions appear along the human-animal-environment interface ([Das 2020](#)). Yet the more our knowledge fragments into expertise-driven domains, the more difficult it is becoming to truly see this shared whole. Still, society-wide events like the pandemic represent ruptures that underline the necessity to radically broaden our vantage points ([Stevens et al. 2020](#)). Seeing how interconnected health is with ecology, economy, technology, education, governance, and many other areas, and how power dynamics between different interest groups and their ideologies determine democratizing possibilities within health, a critical collaboration between diverse perspectives and world views across geographic, cultural or political divides—a whole-of-society approach ([Lancet 2020](#))—that foregrounds issues of equity, democracy and justice in health, needs to be the way forward.

Competing interests and pre-existing social tensions between contending perspectives and people would perhaps be the most difficult to resolve. The priorities in health systems are

already heavily stacked against systemic, long term approaches that attempt to address the causes of causes affecting the marginalized majority. Ignoring the history and politics underlying these dynamic processes can lead to merely tokenistic approaches lacking substantive possibilities. Health systems are thus political systems too, requiring engagement with the politics of knowledge production to policy formulation to implementation, to search for political alternatives that facilitate critical dialogue by nurturing trust, transparency, and most importantly, democratic engagement. Dialogue and democratic engagement have been consistently missing from India's COVID management plan. The joint statement by three leading public health associations from India pointed out how India's COVID-19 response in the first wave predominantly relied on inputs from 'clinicians and academic epidemiologists with limited field training and skills' and general administrative bureaucrats for its operation. It further noted the limited engagement with diverse voices from the fields of epidemiology, public health, preventive medicine and social sciences, contributing to 'incoherent and rapidly shifting strategies and policies' that appeared more as 'afterthought' and 'catching up' ([Indian Public Health Association et al. 2020](#)). Absent a holistic and critical public health paradigm, India's epidemic response, in fact, moved along a pre-conceived path of technical risk management and control informed by decontextualized global health influences, at the cost of the many social and epidemiological realities of the country ([Priya and Das 2020](#)). The consequences affected all of us in the country in different degrees but will continue to haunt the marginalized disproportionately more in times to come. Both the first wave and the second wave reveal that while normal science has been great at identifying the different viral strains and their pathogenic mechanisms, essential for risk reduction measures and curative regimes, it has been far less remarkable in making sense of the unfolding of the pandemic within varied contexts and thus its differential impact across different sections of the society, for now, and the future.

As discussed before, this is partly due to the deterministic approaches of Newtonian science that, in order to appear in control, blanks out the messy social and political entanglements of real life, but as a result, also risks losing sight of the real. Partly responsible are also the entrenched socio-economic-cultural systems that prefer and legitimize such monoculture of thinking to suit its preservation and perpetuation. In India, such techno-managerial approaches, informed by more controlling and commercial pursuits than compassion and collective interests, dominate decision making in health and in general ([Nayar 2013](#)). As the sudden lockdown during the first wave displayed, they not only can fail to comprehensively understand or address the system-wide ripples but can also end up harming people, usually the already vulnerable. Complexity science, on the other hand, encourages the opening up of diverse values, viewpoints and visions. Instead of a few institutionally privileged forms of expertise, it argues for more dialogue and deliberation across disciplinary boundaries, even going beyond disciplinary boundaries to engage all of the affected as part of an 'extended peer community' ([Waltner-Toews 2020a](#)). In other words, it seeks to break disciplinary disjunction to call forth interdisciplinary and transdisciplinary approaches that privilege social learning.

"When facts are uncertain, stakes high, values in dispute and decisions urgent," complexity science implores us to make use of the widest possible pluralised and diversified

knowledgebase, to facilitate robust strategies and context-relevant resolutions ([Waltner-Toews 2020a](#)). For instance, the diverse community initiatives in the pandemic showed how common people attempted to negotiate the mounting uncertainties and unmet needs with creativity and candour, displaying imaginations beyond command and control ([Loewenson et al. 2021](#)). Listening to and learning from these diverse stories can help broaden public policy by understanding ground conditions and policy gaps. Amplifying and encouraging effective endeavours with enabling support can further flourish creative resolutions from the below.

The second wave too witnessed similar self-organisation from the below as the formal system crumbled all around: social support groups sprung up overnight across different social media platforms that registered healthcare needs, searched for and verified leads, and connected people to them; individuals came together to set up oxygen parlours and safe homes; people ran funding drives to procure COVID-19 relief material for the slums and interior districts; doctors made their phone numbers public and slotted time for free teleconsultation. The list could go on. And in some places, the governments also listened. The West Bengal health department, for example, released a directive that allowed local clubs to set up safe homes if they so felt and further promised support in the form of making available health workers for running them. Kerala government held wider societal consultations to understand the problems of different sections for appropriate action and also enabled people's initiatives like the community kitchens or Sannadha Sena ([Tiwari et al. 2020](#)).

Like everything else in a complex system, this too is a complex balancing act. There is a risk of the authorities interfering too much in the name of support and stifling spontaneous creativity. There is also the possibility of authorities using people's initiatives as an excuse for shirking their responsibilities and shifting the burden of care on people, which is likely to harm the already marginalised most. Here lies the importance of political systems in shaping the course to either open up critical and creative engagement or close down to enforce top-down control. Political systems that are relatively more democratic, inclusive and egalitarian, and have historically grown through vibrant people's movements, are arguably less likely to fall for command and control imperatives. There can be many more knowable and unknowable fallouts. However, complex systems thinking, promoting democratic practices, diversity, and decentralised action, among others, also carries an ethical dimension that can help navigate these tricky terrains.

Despite the massive socio-economic cost of both waves of the pandemic, in India, a narrow political vision continued prioritizing only magic bullet approaches like vaccination, neglecting issues of access or social support. A complex systems thinking would have forewarned us about the effects of unequal and delayed vaccination for the pandemic, and the consequences of lockdowns sans adequate social protection measures for the vulnerable. Nevertheless, the examples from the communities or enabling steps from some governments demonstrate the distributed possibilities existing within our very society that can open up diverse pathways of dealing with complex systems problems like the pandemic. We need

wider recognition and practice of complex systems approaches to perceive and potentiate such possibilities to navigate an increasingly volatile, uncertain, complex and ambiguous world.

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