OPINION

Uncommon Sense

Vegetarianism: Mitigating Air Pollution, Climate Change, Pandemics, and Human Diseases

"Life is really simple, but we insist on making it complicated" — Confucious.

Air Pollution and The Need for Effective Monitoring

WHO (World Health Organization) data show that almost all the global population (99%) breathes air that exceeds the WHO guideline limits and contains high levels of pollutants, with low and middle-income countries suffering from the highest exposures [1].

Higher levels of air pollution are a pernicious global problem affecting not only densely populated countries like India and China but also countries with sparse populations, as well as regions like the Arctic and Antarctica where no population exists.

Air quality is closely related to the earth's climate and ecosystems globally**.** Whatever the reasons for the present levels and the sources of pollution, global pollution levels are highly

dynamic and are associated with atmospheric and oceanic dynamics. The resulting climate change, with a feedback loop, is now accepted and understood.

One needs to monitor the pollution levels in the spatio-temporal dimensions to adopt remedial measures to mitigate pollution effectively. Therefore, air quality monitoring involves systematically collecting physical, chemical, biological, and related data on ambient air quality, pollution sources, meteorological parameters, and other factors that influence or are controlled by ambient air quality.

The many complexities and challenges posed by ambient air quality monitoring prompted the World Health Organization (WHO) to suggest a road map for all nations for 2020 — to arrive at a consensus for effective air quality monitoring by all stakeholders.

Domino Effect of Pollution on Climate Change, Global Health, and Economy

Air pollution may result in massive impacts, causing different effects on human health, the environment (*e.g.,* ecosystem damage), and the economy of nations worldwide [2,3,4].

The Lancet Commission on Pollution and Health reported that Pollution was responsible for 9 million premature deaths in 2022 [4], making it the World's most significant environmental risk factor for disease and premature death. Nine million deaths annually correspond to the alarming number of one in six deaths worldwide.

Even the WHO 2023 [5] report states that worldwide ambient air pollution accounts for 43 % of deaths and diseases from chronic obstructive pulmonary disease, 25 % of deaths and diseases from ischemic heart disease, 24 % of deaths from stroke, 17% of deaths and diseases from acute lower respiratory infection, 29% of deaths and diseases from lung cancer.

Antibiotic resistance is another growing global issue, causing millions of yearly deaths [6]. Particulate matter (*PM*) has diverse elements of antibiotic resistance that increase its spread after inhalation. The misuse and overuse of antibiotics are the main drivers of antibiotic resistance. The rapid spread of antibiotic-resistant bacteria and antibiotic-resistance genes across global regions and sectors (e.g., human beings, animals, and environments) is vital for antibiotic resistance transmission and prevalence [7, 8, 9].

Although a thorough understanding of the contribution of $PM_{2.5}$ to global antibiotic resistance is poor, the emerging research underlines the linkages between global estimates of antibiotic resistance and the burden of premature deaths attributable to antibiotic resistance resulting from $PM_{2.5}$ pollution.

Recent research at Harvard University [10] suggested that even a $1\mu g/m^3$ level of $PM_{2.5}$ could lead to a 15% increase in fatality rates due to infections. The study demonstrated and underlined the urgent necessity and paramount importance of *effective* ambient air quality monitoring, as air quality, *or rather the lack of it,* directly affects the nation's health, economy, and security. It is imperative, therefore, to protect the air we breathe by taking actions to ensure its best possible quality. The widespread inequities between developed and

developing countries naturally demand accurate and cost-effective monitoring to ensure good air quality worldwide.

Quantifying the economic impact of air pollution, the Centre for Research on Energy and Clean Air (CREA) [11] made a conservative estimate of *USD 2.9 trillion*, or *3.3% of global GDP* in 2018, as the global economic burden caused by air pollution from fossil fuels.

For these reasons, national and international regulations typically require accurate air quality monitoring to assess the general population's environmental exposure systematically and accurately to multiple ecological contaminants.

Many of the drivers of air pollution are also sources of greenhouse gas emissions. Therefore, policies to reduce greenhouse gases offer a win-win strategy for climate and health, lowering the disease burden of air pollution and mitigating near- and long-term climate change. Framing and implementation of the right policies for air pollution mitigation necessitate accurate ambient air quality monitoring.

Complexities of Ambient Air Quality Monitoring

As we approach the end of 2023, the multifaceted and multidimensional problems related to effective ambient air quality monitoring remain herculean and extremely expensive - for wider deployment to gather realistic spatio-temporal information related to ambient air quality, to draw up effective plans to curb or mitigate the air pollution.

The process of selecting sensors and systems for effective ambient air quality monitoring has become quite complex under the garb of standards and certifications, which were ambiguous, outdated, unscientific, or outright erroneous, given the advances made in our scientific understanding. The complexities in effectively monitoring ambient air quality led to confusing practices in the siting of systems, and the empirical approaches followed by different stakeholders in arriving at averaging times related to measurement methods have resulted in ambiguous definitions of air quality, making it prohibitively expensive and unscientific. Today, the confusion is worse confounded by the advent of new entrants into the field advocating low-cost sensors with lesser accuracies for niche applications.

Novel Photonic System AUM for Ambient Air Quality Monitoring

Against this backdrop, after highlighting the impetus, complexities, and challenges posed by ambient air quality monitoring, our team has designed and developed a novel state-of-the-art photonic system *AUM* (Air Unique-quality Monitoring) for ambient air quality monitoring with higher accuracies and overarching capabilities for diverse applications [12]. We have also designed and developed a unique calibration facility for the photonic system *AUM,* which ensures that after a one-time calibration under ISO/IEC 17025-2000 and ISO 17034 International Standards, the ruggedized system can be deployed for field usage anywhere in the World, even under extreme weather conditions. Numerous field trials of inter-comparisons of the novel photonic system AUM, collocated with conventional reference monitoring stations of ambient air quality, convincingly demonstrated that AUM is far superior in sensing characteristics. In addition, *AUM* is highly economical compared to the

traditional reference stations, thus making it ideal for large-scale deployment to effectively monitor the hitherto eluded spatio-temporal variations of ambient air quality.

Shrouded with scientific temperament and curiosity and the desire to make scientific and technological advances in solving a pressing problem, little did we realize that the apathy and indifference from decision-makers would deter the acceptance of novel and advanced technology.

UN Agenda 2030 of Sustainable Developmental Goals – Sham?

Realizing the domino effects of air pollution, the United Nations has set actionable policies (Sustainable Development Goals - SDGs) to reduce air pollution [13]. Under Agenda 2030, the UNGA resolution set specific targets, with measurable indicators for each SDG, to achieve most SDG targets by 2030.

However, according to the European Commission's in-house Emissions Database for Global Atmospheric Research (EDGAR) [11], the Green House Gas (CHG) emissions continued to rise, reaching 53.8 *Gt* $CO_{2\ eq}$ by 2022. In 2022, most GHG emissions comprised fossil CO_2, accounting for 71.6% of total emissions, while CH_4 contributed 21% to the total, N_2O 4.8%, and F-gases 2.6%.

A scientific assessment of the political impacts of the SDGs in 2022 found that the SDGs have only *had limited transformative political impact* thus far [14]. The only effect seen was the publication of ambiguous policies of local and global institutions. The result has mainly been discursive, affecting the way actors understand and communicate about sustainable development, with more profound normative and institutional impact from legislative action to changing resource allocation being nonexistent, prompting the question of the efficacy of the UN and its resolutions.

Mitigation of Pollution and Climate Change – Is there a Will?

The fact of the matter is that in 2022, China, the United States, India, the EU27, Russia, and Brazil were the six World's largest GHG emitters, accounting for 50.1% of global population, 61.2% of global Gross Domestic Product, 63.4% of global fossil fuel consumption and 61.6% of global GHG emissions [15].

Most countries worldwide are still preparing plans to implement actions to tackle climate change. The European Union has an ambitious target set to reduce its net domestic greenhouse gas (GHG) emissions by at least 55% by 2030 compared to 1990 levels and to become climate neutral (*net zero greenhouse gas emissions*) by 2050.

At the global level, all G20 countries, covering about 75% of global GHG emissions, have decided to fix a target date in which they will become net-zero emitters. The USA, Canada, Brazil, Australia, and the European Union have pledged to reach climate neutrality by 2050, China and Saudi Arabia by 2060, while India targets net zero emissions by 2070 [15].

But the reality is that we are fast reaching the Climate tipping point of $1.5^{o}C$ rise in global warming (brought about by GHG emissions worldwide), which is a cause for grave scientific, policy, and public concern. *Therefore, the moot question remains whether the governments and politicians, with their ever-changing priorities, are concerned about climate change or only interested in mouthing platitudes for their survival.*

Practical Solutions for Societal Problems – *Citizen-driven or Government-driven?*

History is interestingly replete with numerous examples when societies have immensely benefitted from bottom-up movements reaching tipping points after passionate triggers conceived by individuals. Grand visions cannot be realized without self-organizing from the ground up. The broadest-based and most prolonged enduring transformational movements grow from the grassroots up.

Ordinary citizens have the potential to discover new solutions to wicked problems. Indeed, one is also reminded of the powerful words of the great Telugu poet *Sri Sri* (Srirangam Srinivasa Rao) [16], *who remonstrated the common public not to deceive themselves in believing that someone would come and solve their problems and, therefore, sleep over their difficulties, by forgetting the truth*.

ఎవరో వస్తారని,
ఏదో చేస్తారని,
ఎదురుచూసి మోసపోకుమా,
నిజము మరచి, నిదురపోకుమా - శ్రీ శ్రీ,

Climate change, extreme poverty, pandemics, health inequalities, and natural disasters are examples of where citizens can hold the key to driving solutions for a better world. Recent studies have shown the crucial role Citizen Science plays in finding solutions to wicked problems. For example, Air Quality Citizen Science uses low-cost sensors deployed by citizen scientists to generate spatially and temporally resolved air quality data that complement satellite observations.
Can we, the citizens, think of *a solution* to solve the pernicious problems of pollution and climate change instead of depending on Governments, bureaucrats, and politicians to find answers? *A simple solution that we can implement without forgoing our modern-day amenities and developmental lifestyles.*

Complex Problems and Simple Solutions

Solving real-world complex problems demands that we break free from a reductionist paradigm and develop a more holistic and systematic understanding of the World's complexity. Therefore, instead of improving the ability to measure, predict, and control the processes, the focus should shift towards adopting insights gained elsewhere.

In Science, we have seen that introducing insights from Chaos Theory and Nonlinear Mathematics into Systems Science sparked the development of Complexity Theory. This Science recognizes and celebrates the creativity of nature [17, 18, 19].

While looking for solutions, faced with two competing hypotheses, we will likely choose the most complex one. As a result, when we need to solve a problem, we ignore simple solutions and instead favor complex ones. Complexity bias is a logical fallacy that gives undue credence to complex concepts. To understand complexity bias, we must first define three key associated terms: complexity, simplicity, and chaos. Chaos theory is an interdisciplinary area of scientific study, and a branch of mathematics focused on the underlying patterns and deterministic laws of dynamical systems that are highly sensitive to initial conditions and were once thought to have completely random states of disorder and irregularities.

Scientifically, the advent of Chaos Theory made us realize that *i)* initial local conditions significantly affect the system's complexities globally, and *ii)* complex problems can have simple solutions. A metaphor for this behavior is that a butterfly flapping its wings in South America can cause a severe cyclone associated with widespread destruction in North America. That's counter-intuitive because it opens the door to a new way of seeing the World, acknowledging that complex dynamic systems are sensitive to initial conditions and have emergent properties.

We must, therefore, learn to brood over the complicated systems on which the quality of our lives depends, from microbial ecosystems to the biosphere, because we can strongly influence them, although we cannot control them.

Therefore, we must realize that the triad of pollution, climate change, and biodiversity loss are critical global environmental issues of our time, which are intricately linked, and solutions to any will benefit others.

Animal Farming, Anti Microbial Resistance, Climate Change, Diseases and Health

The nexus of animal farming, antimicrobial resistance, climate change, and biodiversity conservation represents one of the most pressing and least understood threats to a sustainable future and can, therefore, become the cynosure for convergence while searching for solutions [20, 21].

Reports of evidence of antibiotics in livestock and poultry feed, antibiotic residues in powdered milk products, and milk from various dairies [7-9] are on the rise. A September 2023 report in *Our World in Data* [22] quotes the Food and Agricultural Organization (2021) statistics to answer *how many animals get slaughtered daily*. The stark statistics are mind-numbing – 0.9 million cows, 1.4 million goats, 1.7 million sheep, 3.8 million pigs, 11.8 million ducks, 202 million chickens, and hundreds of millions of fish.

The 2021-2022 Annual Report of New York University's Centre for Environmental and Animal Protection [23] cries out that to fulfill growing meat demands, humans now manage, slaughter, and consume billions of terrestrial and trillions of aquatic animals yearly. As a result, animal agriculture is now the second largest contributor to human-made greenhouse gas emissions, contributing significantly to global climate change, exceedances of biogeochemical flows, biodiversity and wild animal loss, land, energy, and water consumption, and ecosystem destabilization. Despite the enormous amount of animal

agriculture, global food and nutrition insecurity is still a constant issue, as this sector primarily serves the industrialized World and wealthier population segments.

From the perspective of animal suffering, not only are the absolute numbers of animals killed, but also the suffering they endure while being raised in dismal conditions would be intensely gut-revolting to most persons.

According to the USA's Centers for Disease Control and Prevention, the generally common dismal conditions practiced worldwide in the animal industry are the primary cause of zoonotic diseases or those that spread from animals to humans, which account for roughly 60 percent of all known infectious diseases and 75 percent of new and emerging ones [24]. Although the exact origins of the COVID-19 pandemic remain murky, the news that the coronavirus might have first jumped into humans at a live animal market in Wuhan, China, is still fresh in our collective memory.

Vegetarianism – Panacea for Global Pollution and Climate Change?

The World now produces more than three times the meat and more than double the milk as it did 50 years ago, thus establishing adverse effects on the environment, including the destruction of native ecosystems for supporting livestock grazing and increased cultivation of animal feedstocks. Livestock and its supply chain also contribute to greenhouse gas emissions, such as carbon dioxide, methane, and nitrous oxide. Livestock farming accounts for 50% of methane and 60% of nitrous oxide emissions, which respectively have 25 and 298 times the global warming potential of carbon dioxide on a mass basis [25, 26].

Additionally, most nitrogen pollution in wastewater is due to animal-based protein sources and inefficient agricultural practices, which lead to acid rain and toxic algal blooms that cause dead zones of aquatic life [21, 26].

Air pollutants like methane and black carbon are potent Short-Lived Climate Pollutants (SLCPs) contributing to climate change and ill health. Although SLCPs persist in the atmosphere for short lifetimes, their global warming potential is often much more significant than carbon dioxide (CO_2).

Black carbon, a component of fine particulate matter, is one of the most significant contributors to global warming after CO_2. Black carbon warms the earth's atmosphere by absorbing sunlight, accelerating snow and ice melting.

Methane, another SLCP, is a potent greenhouse gas 84 times more powerful than CO_2 and a precursor to the air pollutant ozone. Ozone and black carbon affect weather processes and decrease agricultural yields, thus threatening food security [27].

Meat production, therefore, has several significant negative impacts on the environment, wildlife, and human health.

Therefore, moving towards Vegetarianism and a meatless future, reducing human consumption of animal protein, coupled with effective screening for antibiotic residues in milk

and other food products, is one of the most effective things we can and should do personally for both environmental and human health and animal welfare. Moreover, an emerging body of research indicates that diets higher in plant proteins—pulses, legumes, and coarse grains—could offset losses in animal protein by providing nutritionally dense foodstuffs, thereby contributing to food security and protein needs while providing several environmental co-benefits.

Personal Dietary Choice: The Bridge Between Personal and Planetary Health

A growing number of research studies have established that vegetarians have lower risks of heart disease, diabetes, and cancers compared to non-vegetarians. Based on data from 12 surveys, a systematic scientific study assessed the nutritional quality of vegetarian diets and found higher healthy quality levels among vegetarians than omnivores, establishing the bridge between personal and planetary health [28, 29].

According to the Academy of Nutrition and Dietetics, vegetarian diets are nutritionally adequate for all stages of life if they are well-planned. However, some precautions to minimize the risk of nutritional deficiencies are warranted. Vegetarianism has gained more visibility in recent years. Understanding the effects of adopting a vegetarian diet beyond its nutritional aspects is essential. Studies have also indicated that a vegetarian diet could have positive outcomes, such as better physical health, positive feelings related to adopting a morally correct attitude, an increased sense of belonging, and lower environmental impact.

Benefits of Vegetarianism

Numerous scientific studies showcased the significant benefits of reducing meat consumption and becoming vegetarians [28, 30]:

Less land use for agriculture and more biodiversity: The use of land for agriculture is the primary driver of biodiversity loss. Today, almost half of the World's ice- and desert-free land is used for agriculture, most of which is used by livestock. The total global land use for meat and dairy production is 37 million square kilometers, an area as large as the entirety of the Americas.

Studies have shown that if we do not eat meat, it would be possible to reduce agricultural land from 4 to 1 billion *hectares*. Therefore, a change towards less meat consumption would have enormous benefits for animals worldwide as wilderness could regrow to provide habitats for wildlife.

Benefits for the World's Climate: Reducing global meat consumption would also help to address climate change — it would reduce direct emissions from burping cows and nitrous oxide from manure and reduce emissions from deforestation and land use change.

Less antibiotic resistance: Reducing the World's meat consumption would decrease the use of antibiotics in livestock farming, a practice that contributes to the rise of antibiotic-resistant bacteria. This reduction could preserve the efficacy of existing antibiotics and people's health worldwide.

Lower risk of pandemics: Many infectious diseases originate in other animals. The high-density conditions in many meat production facilities create ideal environments for the mutation and spread of pathogens. Reducing global meat consumption would reduce the risk of zoonotic diseases and the chances of another pandemic.

Less animal suffering: Less meat consumption would mean less harm to animals.

The panacea hidden in plain sight: Vegetarianism

Facing a plethora of complex problems of increasing levels of pollution, climate change, rising incidences of diseases, deteriorating human health, and growing burdens on national economies, and standing on the cusp of the rapidly closing window for humanity's climate action, we must realize that all the problems are inextricably intertwined.

Against the backdrop of the prevailing unbridled practices in animal farming, non-compliance of the agriculture industry (especially overuse of antibiotics in dairy and animal farming, chemicals and pesticides in agriculture), ineffective regulatory bodies, and in different global leadership, *perhaps* individuals practicing Vegetarianism coupled with strict control of the use of chemicals and pesticides in agriculture, maybe the panacea hidden in plain sight for the issues related to pollution, climate change, antimicrobial resistance, and global health and economies.

Our collective personal actions and choice of switching over to a vegetarian diet can have positive effects. While individual efforts may seem small, they can swing the needle in the right direction. Perhaps the personal choices of integrating into the complex nature of systems with humility would be the necessary *initial condition* to ensure a positive and sustainable world.

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