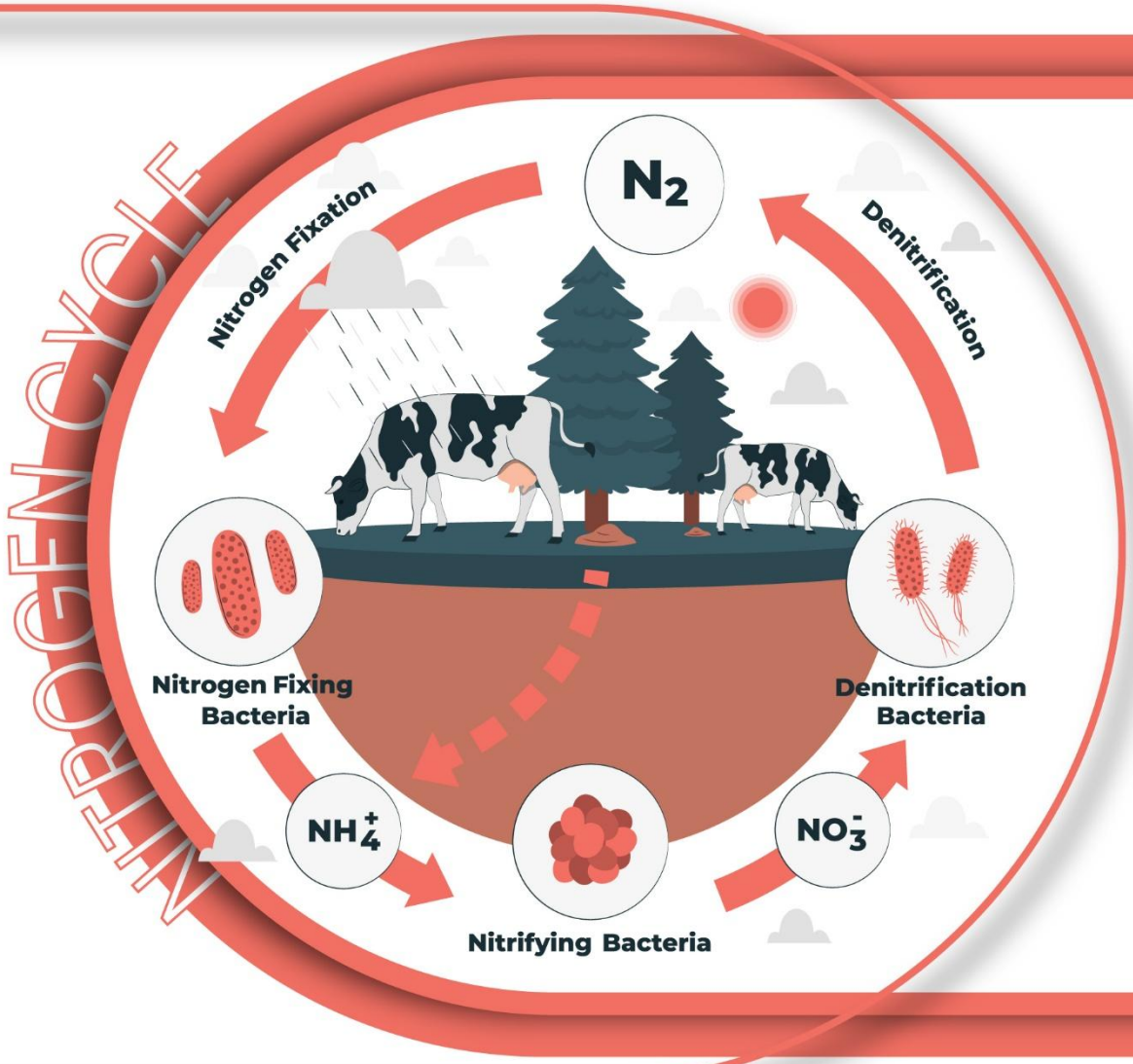

THE ROLE OF NITROGEN POLLUTION IN AGGRAVATING SOUTH ASIA'S CLIMATE CRISIS

A **Briefing Paper** on Using Bioscience, Communications, and Collaborative Actions to Save the Environment

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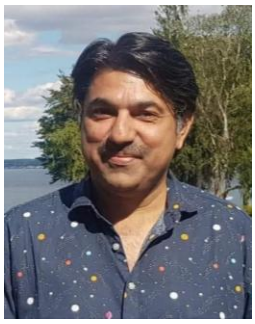
This briefing paper is the first in a series that has been undertaken to raise public awareness of climate and climate change issues in Asia, broadening and deepening our understanding and promoting people's engagement. Our mission, as experts on the field and the ground, is to translate the most technical and scientific concepts into a manner understood and engaged by the general public, in the context of an increasingly volatile climatic environment in South Asia.

Gothamie Weerakoon, PhD

Gothamie Weerakoon, PhD holds a distinguished academic and professional career and has emerged as an expert in lichens. Since 2018 she has been the Senior Curator of Lichens and Slime Moulds at the Natural History Museum in the UK. She holds membership in several societies, including the British Lichen Society, the American Bryological and Lichenological Society, and the Sri Lanka Association of the Advancement of Science. She is a Grant Reviewer for the National Geographic Society. Her interests include lichen taxonomy and the use of natural history collections in science.



Adnan Rehmat

Adnan Rehmat has a background in media development and journalism. He has been associated with the Pakistani media sector for over 35 years, with experience as a journalist, media strategist researcher, and advisor. His work has focused on improving professionalisms within Pakistan's burgeoning and diversifying media landscape including strengthening public interest journalism including on science, climate, governance, diversity and development; consolidating viability of the digital media ecosphere; and encouraging partnerships between media academia, civil society and businesses. As a journalist, Rehmat has worked for leading Pakistani media including Jang and Dawn media groups and continues to write for various international publications as a media analyst and political and technology commentator. As a media development expert, he has been working for leading global players including International Media Support, Internews Network, Reporters Sans Frontiers,

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Based in Colombo, Factum is an independent consultancy and think-tank that offers critical insights, analyses, and perspectives on International Relations, Tech Cooperation, Strategic Communications, Digital Content Interventions, and Climate Outreach.

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Contents

The Role of Nitrogen Pollution in Aggravating South Asia's Climate Crisis – Using Bioscience, Communications, and Collaborative Actions to Save the Environment

Why this Briefing Paper?

This Briefing Paper provides an overview of South Asia's liabilities and national obligations to alleviate climate change-related emissions, and policies to adapt to a changing climate – particularly those related to the impact of excess nitrogen on the region's environment.

Section 1: The Nitrogen Science Case: This section is a thoroughly scientific presentation – including evidence, review, and analysis – of the impact of nitrogen pollution and its adverse impact on the South Asian region and offers scientific solutions to addressing this pressing climate change concern.

Section 2: The Climate Communications Case: This section discusses policy and communications measures that can push progress on both mitigation and adaptation.

The overall analysis offered in this Briefing Paper suggests that while some progress on tackling the impact of nitrogen pollution in South Asia is discernible, there remains a wide scope to pursue a more integrated strategy to achieve the region's overall climate goals.

Overall Context – Climate Change and Its Crisis in South Asia

As of start of 2025, the population[i] of South Asia was over two billion – equivalent to 25.2% of the global population, or one-fourth of humanity. Spread over 6.4 million square kilometers of land mass, the region encompasses Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. It is a mostly democratic space, with nearly 1.2 billion registered voters, that holds regular national elections, and is also one of the most digitally wired regions on the planet, with over 1.3 billion active internet users.

The overall South Asia region is a large contributor to climate change, but also one of most vulnerable[ii] to it, and is under elevated climate crisis stress that impacts more people than in any other geographic region. The region is living through a "new climate normal" in which intensifying heat waves, cyclones, droughts, and floods are testing the limits of government, businesses, and citizens to adapt. More than half of all South Asians have been directly affected by one or more climate-related disasters in the 21st century. The changing climate could sharply diminish living conditions for up to 800 million people, in a region that already has some of the world's poorest and most vulnerable populations, according to the World Bank. This number is only set to grow as temperatures continue to increase.

Research suggests the Global South will suffer the most from climate change, and that South Asia will be one of the hardest hit[iii] regions. Climate migration in South Asia is predicted[iv] to triple to over 62 million by 2050, according to ActionAid International and Climate Action Network South Asia. A key factor among those that contribute majorly to climate crisis, especially in South Asia, is agriculture[v]. And withing the framework of agriculture the issue of reduced nitrogen which demands policy and public attention. This has impacts[vi] on both agriculture productivity and climate change.

SECTION 1: The Science Case – Nitrogen Pollution: The Publicly Ignored Climate Villain

Climate change due to nitrogen pollution and the use of bioindicators for the sustainable management of biodiverse tropical South Asian environments

Nitrogen is an essential gas for life on earth. It constitutes 78% of the planet's atmosphere but becomes a limited resource when in its biologically available form, that is referred as "reduced nitrogen", or Nr. The limited supply of Nr is vital to the structure and function of all the species and ecosystems of our planet. Since Nr is limiting the primary productivity of each ecosystem, partitioning of Nr among species rationalizes their co-existence and evolving patterns of biodiversity.

The "Green Revolution", which started in the 1950s, was driven by exhaustive application of Nr-enriched natural and synthetic fertilizers, increasing farmland productivity, and accelerating population growth. It also resulted in a release of excess nitrogen into soils, water, and air. Nr is released from burning fossil fuels, which further opens a path to climate change. Excess nitrogen from these combustion and agricultural sources is a pollutant that has now exceeded planetary boundaries, triggering global climate change. The United Nations Environment Programme (UNEP) "Frontiers Report" emphasized nitrogen pollution as one of the five biggest threats facing our planet including, most hazardously, climate change.

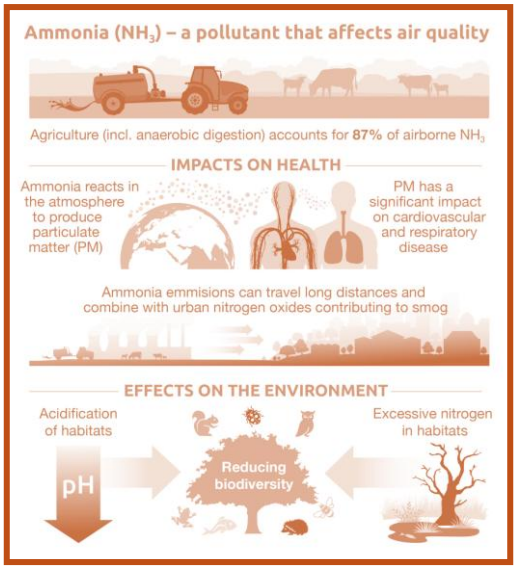

Figure 1: Ammonia and its major effects summarized
(Source: https://ahdb.org.uk/knowledge-library/ammonia-emissions-on-dairy-farms)

Nitrogen pollution expanded first in the temperate zone of Europe and North America. Policies for nitrogen management, such as the European Union's Environment Action Programme, were developed and enacted to reduce and stabilize the release of excess nitrogen. Further, these policies were supported by the biological nitrogen indicators – "bioindicators."

Adversely Impacting Life, Health, Environment, Economy and Species

Bioindicators are helpful in demonstrating the actual impact of excess nitrogen on species and planet's ecosystems. Bioindicators are also useful for both monitoring and public engagement. The upper limit at which species and ecosystems become affected by Nr is defined as "critical levels" and "critical loads." These levels are targets for a goal-orientated nitrogen pollution reduction approach aimed at slowing down climate effects of the planet.

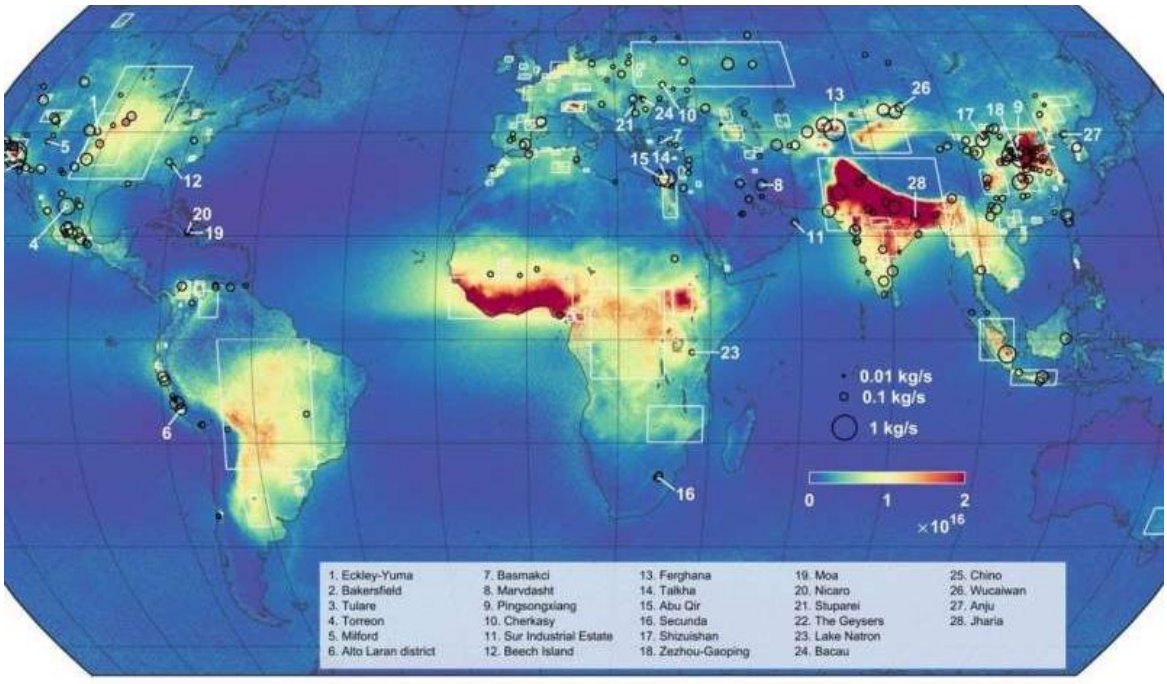

Figure 2: Van Damme *et al.* (2018) Industrial and agricultural ammonia point sources exposed
(Source: *Nature*, doi:10.1038/s41586-018-0747-1)

Nitrogen pollution is now expanding rapidly into the tropical zone of the planet. South Asia, one of the tropical regions, unfortunately has become the "hot spot" which has experienced the most rapid increase in nitrogen pollution. Nitrogen is c. 8 μgm³ in Europe, but in South Asia it is greater than 30 μgm³ with among the highest global concentrations centered on the Indo-Gangetic Plain (See figures 1 and 2 above).

Combating the adverse impact of nitrogen pollution in South Asia

The key question is: how to prevent further environmental catastrophe and human suffering caused by nitrogen pollution? The following scientific evidence is offered to policy makers across South Asia to pursue targets for reducing nitrogen pollution in the region.

Vision: The highest amount of excess nitrogen is the major contributor of the atmospheric nitrogen pollution that gets released from natural and synthetic fertilizers in South Asia. Hence, excess nitrogen causes multi-sectoral challenges in the region, including the following:

- Very high levels of nitrogen pollution correspond with tropical biodiversity hotspots in South Asia where individual and social well-being are entirely dependent on stable functioning ecosystems in the region.

- Excess nitrogen is a forerunner of the atmospheric particulates such as $PM_{2.5}$ and PM_{10} that cause dreadful human health impacts (contributing to around seven million excess deaths annually on the planet).

- Nitrogen pollutants are greenhouse gases. Nitrous oxide itself has 300 times the global heating potential than carbon dioxide, which is a better publicly acknowledged climate change villain than nitrogen, whereas nitrogen is much more dangerous than carbon dioxide

- The economical cost of nitrogen pollution at a regional scale is estimated up to €320 billion per annum.

South Asia is home to the planet's most biodiverse ecosystems such as Himalayan Mountain region and Western Ghats of India and the Sri Lanka Highlands biodiversity hot spot. Individual and social wellbeing both continue to be entirely dependent on the stability of functioning ecosystems in South Asia (see Figures 3 and 4).

South Asia as a case study region: Considering these listed reasons, South Asia was chosen as a Case Study Region to study nitrogen impacts. The UKRI-funded GCRF South Asia Nitrogen Hub was established in South Asian region as it is home to planet's most biodiverse ecosystems and home to over two billion people. At the same time, it is here that global nitrogen pollution is accelerating most rapidly (Figure 2). Trends for the period 2000-2015, sourced from the Emissions Database for Global Atmospheric Research (EDGAR v. 5.0), indicate a 36% increase in ammonia emissions for the South Asia region.

Regional barrier to nitrogen management: The recent benchmark report of "*Nitrogen Pollution in South Asia*" has reviewed 966 regional policies that were operative in 2019. The report concluded that "*South Asian nitrogen policies are typically qualitative in nature and rarely set quantitative targets for reduction. Very few policies try to manage nitrogen pollution and climate effects in a measurable way.*" This lack of quantitative data, and especially the absence of target-led goal-orientated policy, was identified as a principal barrier to effective nitrogen management in South Asia, intensified by inadequate stakeholder engagement.

Bioindicators to the rescue: Strong scientific evidence supporting the use of nitrogen bioindicators is central to overcoming the above listed barriers. Policies established to mitigate nitrogen pollution that successfully stabilized the release of excess nitrogen in Europe and North America were based on nitrogen bioindicators. By setting up the South Asian Nitrogen Hub, it was possible to demonstrate effectiveness of bioindicators in driving down nitrogen pollution in South Asia following similar approaches in Europe and North America. The problems identified by the South Asian Association for Regional Cooperation on Sustainable Nitrogen Management could be addressed using the results of the project.

Project approach and results: In Sri Lanka, a long-term monitoring plot was established at a mountain forest reserve that was co-managed by the South Asian Nitrogen Hub, the University of Peradeniya, and the Dilmah Climate Centre. Using an enhancement system, ammonia was monitored bidirectionally for an undisturbed highland tropical forest (See Figure 3). Ammonia was the center in this approach.

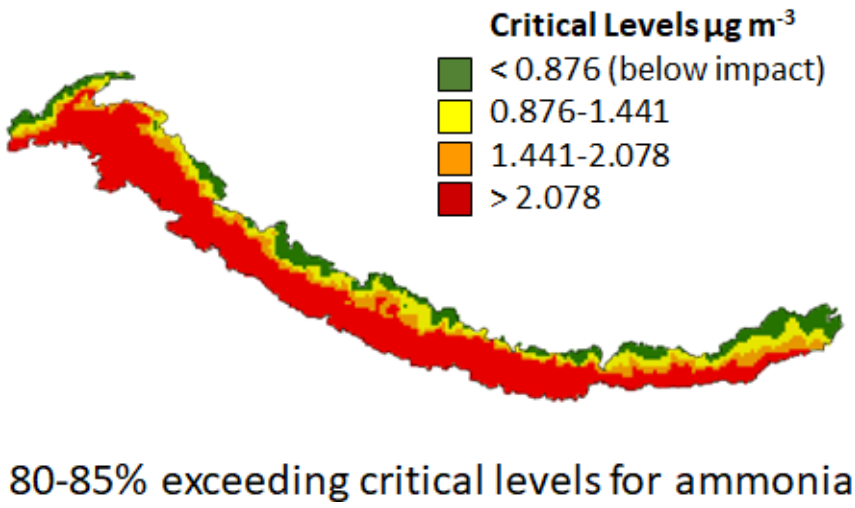

Figure 3: Critical level of ammonia along Himalayan Region of the South Asia

As can be seen, it is the Nr release product from natural and synthetic fertilizers and the start point for excess nitrogen pollution that leaks across ecosystem boundaries. Our proposed approach solves the problems identified in the vision sub-section above. (Also see Figure 4).

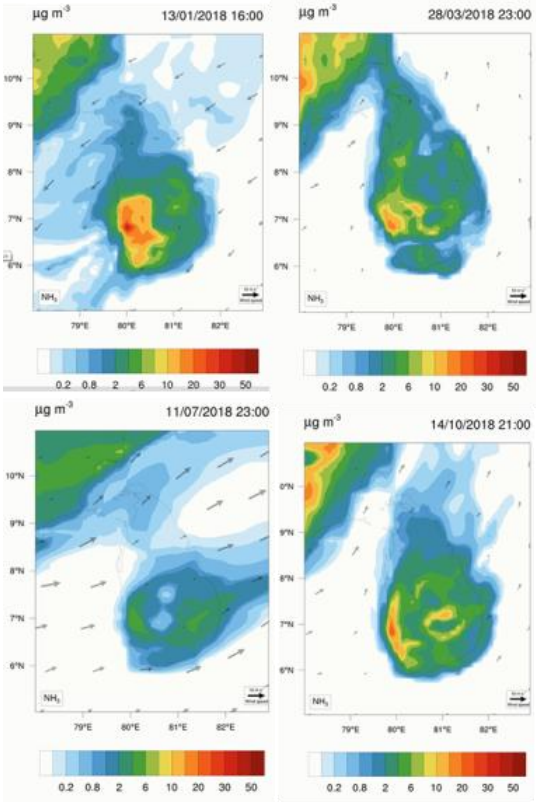

Figure 4: Modelled wind and ammonia concentration for Sri Lanka
(modelled by Massimo de Vieno on 2018 data)

Bioindicator response: The aim is to resolve the functional link between nitrogen pollution and the response of tropical lichen bioindicators. Field and laboratory experiments used a series of standard protocols which the project team either pioneered, or for which they have extensive experience. Monitoring was conducted in Pakistan, Nepal, Bhutan, and Sri Lanka to understand how lichens would respond to excessive nitrogen in the atmosphere.

Lichen diversity values: The Shannon Diversity Index (H´) measure the diversity of species in a community. Often it is used to compare several communities in the means of the species diversity. By recording lichen diversity in selected sampling plots in Pakistan, Nepal, Bhutan, and Sri Lanka, the H´ for each country was calculated and compared.

The calculated H´ values for each country were Pakistan= 0.28, Nepal= 0.32, Bhutan= 0.35, and Sri Lanka= 0.37 respectively. These values reflect an increase in lichen diversity across Himalayan region from Pakistan to Bhutan and a comparatively high diversity in Sri Lanka.

This highlights the responses of lichens to the atmospheric quality and the potential use of lichens as bio-indicators to monitor air pollution. The lowest H´ value in Pakistan shows the severity of Nr problem there, while the highest H´ value recorded from Sri Lanka shows lower Nr values in the island's atmosphere compared to Pakistan, Nepal and Bhutan.

SECTION 2: The Climate Communication Case – Aiding Solutions through Regional Collaboration

South Asian Status on Combating Nitrogen Pollution

Currently, none of the countries in South Asia has a central "nitrogen policy" that offers an oversight role referencing the often dozens of laws and regulations related to environment and climate issues. This is a major problem in terms of strategizing the mitigating of the effects of nitrogen pollution as described in the Science Case above. This limits a clear public and stakeholder understanding of and national clarity on specifically combating nitrogen pollution as a key source of climate crisis. However, most countries do have in place multiple laws and regulations that accommodate recommended actions on nitrogen pollution challenges.

South Asia has, however, been proactive in recognizing[vii] nitrogen issues. Mirroring parallel global initiatives, the countries of the region in recent years have made tentative collaborative steps related to sustainable nitrogen management. These include:

- The establishment of the South Asian Nitrogen Centre[viii] of the International Nitrogen Initiative, in 2008.
- The adoption of the Delhi Declaration[ix] on reactive nitrogen management for sustainable development, in 2010.
- Partnership[x] on Nr research and policy between the South Asian Nitrogen Hub, funded by UK Research and Innovation under the Global Challenges Research Fund, in 2019.
- The adoption of the Resolution[xi] on Sustainable Nitrogen Management at the 4th UN Environment Assembly submitted under the leadership of India, in 2019.
- The adoption of the Colombo Declaration[xii] with an ambition to "halve nitrogen waste" by 2030, spearheaded by Sri Lanka, in 2019.
- The release of the SACEP-SANH Nitrogen Policy Report[xiii] for South Asia, in 2021.
- Country Nitrogen Profiles for Bangladesh[xiv], Bhutan[xv], India[xvi], Nepal[xvii], Maldives[xviii], Pakistan[xix], and Sri Lanka[xx].

The Way Forward Against Nitrogen Pollution – Recommendations

It is apparent that the prevalence of excess nitrogen in the soil, water and air in South Asia arising from dominant fertilizer related agriculture practices and unchecked use of fossil fuel to drive farming and economies is hurting the region and contributing to an exacerbation of climate crisis.

Addressing the challenge of combating nitrogen pollution is better when national and regional strategies are fleshed out for their relevant stakeholders and collaboration on needed actions is prioritized at both levels. Some of the actions that can aid this include, but are not limited to, the following:

1. Narrowing in nationally on nitrogen: Acting on the UN Environment Program's identification of nitrogen pollution as one of the five distinct primary causes of climate change, various national policies, laws, and regulations on climate related issues need coalesce into a single National Nitrogen Management Policy in each of the South Asian states. The SANH's detailed country profiles and research on fragmented nitrogen related components of various policies, laws, and regulations can serve as a guide for bringing them under a single policy draft in each country.

   Projected Outcome: **This will promote national coordination on nitrogen management.**

2. Collaborating regionally on nitrogen: While South Asia has historically struggled to collaborate on political and trade matters, the disregard that nitrogen as a natural element has for political and administrative borders should encourage the region's countries to cooperate against pollution. There is already consensus available among the regional states on priorities and actions as outlined in the Delhi Declaration, Colombo Declaration, and UN Environment Assembly Resolution on combating nitrogen pollution in South Asia. Existing regional non-governmental partnerships and initiatives need to be resourced by the global community, including multilateral platforms like the United Nations, World Bank, International Monetary Fund, and Asian Development Bank for regular and recurring calendar engagements.

   Projected Outcome: **This will catalyze coordination actions among governments and incentivize regional progress.**

3. Ranking the region on nitrogen actions: An action index ranking annual performance of the South Asian states and other relevant stakeholders on their nitrogen policies, procedures, and practices needs to be developed and produced to generate accountability and incentivize concerted actions.

   Projected Outcome: **This will aid public visibility for the issue, as well as strengthen evidence-based policy advocacy and decision making.**

4. Developing scientific indicators for action target: The benchmark report "Nitrogen Pollution in South Asia" that reviewed hundreds of operative nitrogen-related regional policies concluded that these national policies are typically qualitative in nature and rarely set quantitative targets for reduction. Most struggle to manage nitrogen pollution and climate effects in a measurable way. South Asia will benefit from a set of well evidenced nitrogen bio-indicators for setting target-led and goal-orientated policies.

   Projected Outcome**: Drafting these scientific indicators and adoption by the South Asian states will help in combating nitrogen pollution. This will involve key stakeholders – especially the scientific community.**

5. Promoting public nitrogen communication through science journalism: Most journalism in South Asia related to climate issues is based on event-related reporting that noticeably lacks scientific literacy and thematic analysis. On nitrogen pollution, it is nearly non-existent. Government-managed science establishments (including environment, climate, and agriculture related organizations), including the community of scientists, are often poorly organized in public communication capacities and strategies. Media, including indie digital platforms that focus on local communities, and climate-related organizations in all South Asian states, should be capacitated in professional and public interest-focused coverage of climate and nitrogen issues. A regional South Asian coalition for science journalism as a stakeholder community of practice should be supported, as indicated by this research paper[xxi], to improve regional communication on nitrogen actions.

   Projected Outcome: **Besides aiding regional accountability on nitrogen obligations, this will strengthen science journalism improve evidence-based rationalist climate narratives in the public domain.**

6. Encouraging youth and tech diplomacy on nitrogen: South Asia has the largest[xxii] population of young people in the world, with 30% of the world's total number of adolescents (340 million) calling South Asia home, a significant proportion of which is digitally and technologically savvy. This tech-friendly demographic dividend holds tremendous potential to drive social development. Youth and mid-career scholars should be engaged to serve as young ambassadors for the region on climate.

   Projected Outcome: **This will strengthen youth and tech diplomacy in the region on climate and nitrogen actions and improve regional consensus on collaborative solutions.**

7. Promoting academic collaboration on nitrogen research and advocacy: Concerted climate change education in South Asia has the potential to catapult research and advocacy on nitrogen issues centred on scientific approaches and evidence. Research studies have urged[xxiii] the use of relevant theoretical frameworks and local knowledge systems within the academia that support effective strategies for adaptation, preparedness, response, and recovery in climate-induced challenges. Collaboration among universities in South Asian states that teach climate studies should be promoted to strengthen nitrogen research and advocacy.

   Projected Outcome: **This will strengthen academic regional linkages on climate issues and help augment the scientific approach to climate research and technical expertise that can drive informed engagement with policymakers.**

Acknowledgements, References and Sources

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