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The South Asian link to the Global Sustainable Nitrogen Management

OR

From South Asia to the World: Embracing the Challenge of Global Sustainable Nitrogen Management

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Abstract

South-Asian regional cooperation with the International Nitrogen Initiative and the India-led UN resolution on Sustainable Nitrogen Management (UNEP, 2019) brought South Asia into global focus. Its proactive scientific community, growing scientific capacity and international collaborations enabled the emergence of UKRI-GCRF South Asian Nitrogen Hub, with great potential, regionally and globally.

Introduction

Reactive nitrogen (N_r) can be a boon in the right place and a bane in the wrong place. Elemental nitrogen (N_2) is predominant in the air we breathe (78%) and is relatively unreactive and harmless. However, N_r compounds containing oxygen, hydrogen or carbon, while essential for the very existence of life on this planet, threaten its sustainability when they accumulate in the environment. The voluntary efforts of scientists globally to bring international and intergovernmental attention to N_r over the last two decades culminated in the India-led resolution on Sustainable Nitrogen Management¹ adopted in the 4th UN Environment Assembly (UNEA4) in March 2019. This article reflects on the emergence of South Asia as a major hub of these efforts and its future potential.

The biogeochemical cycle of N_r depends on the abiotic and the biotic worlds for interconverting its inorganic and organic forms to sustain the planet. This involves ‘fixation’ of some atmospheric N_2 into N_r , and ‘denitrification’ of excess N_r back to N_2 . Since the invention of agriculture in Asia over eleven thousand years ago, exploiting natural biological nitrogen fixation in symbiotic legumes supported human population growth and civilisation sustainably for millennia². The industrial era brought in N_r emissions as by-products of the combustion of fossil fuels for energy and transport, while the advent of the Haber-Bosch process after 1908 enabled industrial nitrogen fixation, initially for fertilizers and later also for war munitions. The resulting anthropogenic conversion of atmospheric nitrogen into reactive forms exceeded all of the Earth's terrestrial processes combined, by well over two-fold². This nitrogen pollution continues unabated today, with the accumulation of oxides of nitrogen (NO_x), ammonia (NH_3) or nitrous oxide (N_2O) in air and nitrates (NO_3^-) in water, among others. They have been affecting our health, causing eutrophication of water bodies and altering biodiversity and worsening climate change. N_2O is a greenhouse gas with 298 times higher global warming potential than CO_2 , whereas NO_x has 10 times higher potential. In addition, NO_x pollution has serious implications for human health, including respiratory disorders due to nitrogen dioxide³ (Fig. 1). Nitrates and NH_3 can contribute to fine particulate matter (PM) in air, constituting upto half of the constituents of PM 2.5 and PM 5, causing serious respiratory, cardiovascular and other diseases over prolonged exposure. WHO estimates that globally, over 7 millions die every year due to PM pollution (<https://www.who.int/airpollution/en/>). The UNEP recognized N_r as one of the emerging threats to the planet in its Frontiers Report 2018/19⁴. This report provided timely impetus to the UNEA4 resolution on Sustainable Nitrogen Management¹, which itself emerged in South Asia and was led by India.

Why South Asia?

South Asia is one of the most populous and the fastest growing regions in the world. With less than 5% of the world's land mass, 14% of the global arable land, 2.73% of the world forest area and 4% of the world's coastline, it supports over 25% of the world's population or over 45% of Asia's population. The region's ecosystem services are under pressure and its countries are already parties to all three Rio Conventions (UNFCCC, CBD and UNCCD), the Manila Declaration (2012) on nutrient pollution and Global Partnership on Nutrient Management. There are several South Asian regional intergovernmental mechanisms such as the South Asia Co-operative Environment Programme (SACEP), South Asian Seas Programme (SASP), South Asia Environment and Natural Resources Information centre (SENRIC), South Asia Coral Reef Task Force (SACRTF), the Malé Declaration on control and prevention of air pollution and its likely transboundary effects, and the South Asia Biodiversity Clearing House Mechanism.

While the South Asian Nitrogen Assessment is still underway, it is becoming increasingly clear that South Asia is one of the global hotspots for reactive nitrogen pollution with NO_x , N_2O and NH_3 causing air pollution^{5,6} and nitrates causing water pollution⁷. In relative quantitative terms, water pollution seems to be the highest in the region, followed by air

pollution due to ammonia, NO_x and N₂O, in that order⁸. Agriculture and livestock are the major contributors to ammonia and N₂O pollution of air, while sewage is fast emerging as a major contributor to nitrogenous air and water pollution in the region. Indeed, N₂O replaced methane as the 2nd most important greenhouse gas from Indian agriculture over 15 years ago and may well be true for other major agrarian countries of the region. Recent global estimates on the incidence of childhood asthma attributable to nitrogen dioxide air pollution (a major constituent of NO_x) indicate its importance in South Asia as well (Fig. 1). The contribution of NH₃, nitric acid (HNO₃) and other N compounds onto particulate matter is a serious issue in South Asia. According to WHO, most of the world's worst cities in terms of PM 2.5 pollution are in South Asia, which also accounts for the largest number of deaths due to air pollution globally (<https://www.who.int/airpollution/en/>). The Indian Nitrogen Assessment included a review on the health impacts⁹ of reactive N, building on the global awareness on nitrogen pollution developed by the International Nitrogen Initiative (INI).

International Nitrogen Initiative and Indian Nitrogen Group

The need for an international organization to highlight the scientific and policy aspects of reactive nitrogen was first felt in 1998 during the First International Nitrogen Conference held in The Netherlands and crystallized in 2001 during the Second International Nitrogen Conference held in USA. INI's eventual formation in 2003 was co-sponsored by the Scientific Committee on Problems of the Environment (SCOPE) and the International Geosphere-Biosphere Program (IGBP), both originally established by the International Science Council (then ICSU). INI's main goal has been to optimize nitrogen's beneficial role in sustainable food production and minimize nitrogen's negative effects on human health and the environment resulting from food and energy production. It grew rapidly with regional representatives in North America, Latin America, Europe, Africa, Asia and now in Australia (initrogen.org).

Around the same time, the Indian Nitrogen Group (ING) was independently taking shape as a voluntary network of Indian scientists under the Society for Conservation of Nature (SCON), a registered non-governmental organisation based in New Delhi (www.scon-india.org). Soon, ING and INI came into contact with each other and set up a South Asian Nitrogen Centre for INI (Fig. 2), while China continued to represent the countries of East Asia. Over the years, the INI became a major international voice on scientific and policy aspects of reactive nitrogen. It has been consistently highlighting the growing importance of reactive nitrogen through scientific collaborations, science dissemination, policy messages and stakeholder engagement with the governments, UN, civil society and fertilizer industry. The policy briefs and conference declarations of INI have been as important as research articles in mobilizing wider awareness. The third INI international nitrogen conference (2004) brought out the Nanjing declaration on 'Nitrogen Management'. This was followed by Delhi Declaration on 'Reactive Nitrogen Management for Sustainable Development' (2010), Kampala Statement for 'Action on Reactive Nitrogen in Africa and Globally' (2013) and the Melbourne Declaration on 'Responsible Nitrogen Management for a Sustainable Future' (2016) during the fifth, sixth and seventh INI

conferences respectively (Fig. 2). They were all submitted to UN agencies and disseminated widely among all stakeholders. The forthcoming eighth INI conference in Berlin in 2021 being sponsored and hosted by a national government for the first time (Germany) amply indicates the impact of INI on the global nitrogen landscape.

Synergy with the United Nations

INI and its South Asian representatives had important roles in ensuring that nitrogen became an important focus in the Global Partnership on Nutrient Management (GPNM), currently chaired by India, under the UNEP Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA). Nutrient pollution due to nitrogen and phosphorus compounds that caused eutrophication of marine ecosystems mostly emerged from terrestrial activities like agriculture and industry and needed to be addressed at source. The representation of INI Chair and the ING in the steering committee of GPNM, as well as the establishment of its N-use efficiency task force provided a strong mechanism for engagement of UNEP on nitrogen. Its Asia focus was obvious in the very first GPNM project on Global Nutrient Cycling (GNC), funded by the Global Environment Facility (GEF) and implemented by UNEP (2012-2016). It mainly focussed on two highly populous but contrasting developing country sites, the urban Manila Bay in the Philippines, and the rural Chilika lagoon on the east coast of India. An interesting insight that emerged during this project was that the nutrient pollution of Manila bay was not entirely urban and was also affected by agricultural runoffs into the adjacent lake, Laguna de Bay (<https://www.unenvironment.org/news-and-stories/story/paralysed-growth-lake-under-siege>). Similarly, the nutrient loading of Chilika lagoon was not entirely from rural/agricultural runoffs and included urban effluents from the nearby urban areas (http://www.nutrientchallenge.org/sites/default/files/documents/files/Chilika%20Rpt%20Card_A4%20web.pdf). These findings highlighted the importance of understanding local/regional linkages to global assessments, especially when they are intended for intergovernmental cooperation.

The success of this project and that of the first global overview on nutrient management¹⁰ prepared by GPNM and INI, led to a dedicated major project on nitrogen. This ongoing \$ 6 million GEF project is titled ‘Targeted Research for Improving Understanding of the Global Nitrogen Cycle Towards the Establishment of an International Nitrogen Management System (INMS)’. It is being implemented by UNEP, executed by INI and hosted at the UK Centre for Ecology and Hydrology (<https://www.thegef.org/project/targeted-research-improving-understanding-global-nitrogen-cycle-towards-establishment>). It includes tools for understanding and managing the global N cycle, quantification of N flows, threats and benefits, regional demonstration of full nitrogen approach etc. (<https://inms.international/>). Learning from the previous global carbon assessments, this project combines seven regional nitrogen studies in all the INI regions, including the first ever South Asian Nitrogen Assessment, due to be published in 2022.

The emergence of South Asian champions

The establishment of the Indian Nitrogen Group in 2006 and the South Asian Nitrogen Centre of INI in New Delhi in 2008, which co-hosted the 5th International nitrogen conference of INI in 2010, galvanized interdisciplinary expertise on nitrogen at national and regional levels in South Asia. This was initially galvanized by a civil society organisation, the Society for Conservation of Nature (SCON) and later by the Sustainable India Trust (SIT), both voluntary non-governmental organisations (NGOs) free from institutional rigidities of universities and national laboratories. These organisations also built the agenda for International Nitrogen Assessment for the first time at a side event during the Conference of Parties (COP11) to the Convention of Biological Diversity (CBD) at Hyderabad, India in 2012. The event no. 2776 titled ‘The challenge to produce more food & energy with less pollution: Towards a Global Nitrogen Assessment’ was organized in association with INI and UNEP-GPNM to highlight the linkages between nitrogen, nutrients and the 20 CBD-Aichi Targets set in 2010 to be met by 2020. However, they remain unmet by most countries till date, while India exceeded most of its targets (www.cbd.int/aichi-targets/).

Even as the Indian Nitrogen Group was championing the cause of reactive nitrogen through brainstorming meetings with various Indian ministries and other stakeholders, the first opportunity for regional intergovernmental engagement in South Asia came in 2013. The South Asian Cooperative Environment Programme (SACEP) commissioned a study entitled “Nutrient loading and Eutrophication of coastal waters of the South Asian seas” under a UNEP-funded project. This scoping study outlined the N losses to freshwater and marine environments and consequent threats to critical marine habitats and suggested coordinated interventions through intergovernmental cooperation (http://www.sacep.org/pdf/Scoping_study_on_Nutrient_loading_in_SAS_Region.pdf). The acceptance of this study report by South Asian member governments was an important milestone in the regional recognition of reactive N as an important issue and laid the foundation for the ongoing South Asian N assessment. The ‘Global Overview on Nutrient Management’¹⁰ mentioned earlier also offered regional insights on nitrogen pollution in South Asia. These efforts demonstrated the scientific capacity and boosted the appetite for national/regional N assessment as the best way to join global efforts through intergovernmental cooperation¹¹.

Following the global interest on nitrogen triggered by the first ever European nitrogen assessment¹², a major impetus for South Asian leadership came from the first ever comprehensive ‘Indian Nitrogen Assessment’¹³. Indian scientists carried it out in citizen science mode without waiting for Indian government’s commissioning or funding. They compiled published data on the Indian sources and sinks of anthropogenic reactive nitrogen in all sectors of human activity, the potential for reduction of nitrogen pollution and included an assessment of the nitrogen policies and scenarios¹⁴. Such a national scale assessment was to provide scientific support to the Indian government for informed domestic actions, as well as for international negotiations on nitrogen. This led to envisaging “India as an emerging nitrogen champion”⁸. The

civil society umbrella provided by the SCON and SIT also proved instrumental in formulating the proposal for a preliminary South Asian Nitrogen Assessment under the INMS project. These bodies established partnership with regional governments through SACEP, which hosted the first meeting of South Asian partners at Male', Maldives, in Sept. 2017. Based on the previous INI conference declarations and Indian N Assessment, a draft resolution on 'Sustainable Nitrogen Management' was adopted for submission to the UN Environment Assembly. SACEP mobilized the support of its member countries for this resolution, which was submitted to UNEP by the governments of India, Sri Lanka and Bangladesh in 2018. The Indian government also highlighted reactive nitrogen and the Indian Nitrogen Assessment during the World Environment Day celebrations hosted in New Delhi in 2018. Eventually, the nitrogen resolution was piloted and successfully negotiated by Indian diplomats in the fourth UN Environment Assembly (March, 2019) with the scientific support of INI and INMS. The passage of the UN resolution was a historic moment for Indian and South Asian leadership on the global issue of reactive nitrogen.

Indo-UK Virtual Nitrogen Centres and South Asian Nitrogen Hub

The above successes were primarily led by scientists and were partly helped by international projects. But they cannot be sustained without liberal investments from the member countries of South Asia and the rest of the world. The Indian government utilized one such opportunity to support research by investing in four virtual joint centres bilaterally with UK, focusing on rice (NEWS-India-UK), wheat (INEW), millets and others (CINTRIN) and legumes (IUNFC) during the period 2016-2019 (Moring et al., 2021a, under review). The NEWS-India UK combined plant science, agronomic and environmental aspects to provide insights on agricultural nitrogen management from lab to national scales. Its highlights include the phenotype for NUE in rice (Sharma et al., 2021, under review), emission reduction with neem-coated urea, potential to replace 50% urea with manure and biofertilizer, whole farm systems models for rice, wheat and sorghum, ammonia inventories and national budgets for agricultural nitrogen. Another highlight was the development of the first ever Massive Open Online Course (MOOC) on reactive nitrogen, launched in several languages by the University of Edinburgh on Edex platform (Moring et al., 2021b, under review).

The success of NEWS-India-UK bilateral project involving the past and current chairs of INI, along with their involvement in the GEF-UNEP project on INMS paved the way for a more extensive South Asian partnership on reactive nitrogen research and policy (Fig. 2). This ongoing £20 million project (2019-2023) funded through the Global Challenge Research Fund (GCRF) of UK Research and Innovation (UKRI), entitled 'GCRF South Asian Nitrogen Hub (SANH)' involves 40 institutions all over South Asia and UK, led by the UK Centre for Ecology and Hydrology. Through the INMS and SANH projects, several consultations and workshops were held throughout 2019 in Kathmandu, Nairobi, Dhaka, Male', New Delhi and Chennai. These contributed to the launch of the UN Global Campaign on Sustainable Nitrogen Management at a high level summit hosted by the Sri Lankan government in Colombo in

October 2019. This campaign is now promoting the goal to ‘halve nitrogen waste’ by 2030, highlighting the multiple benefits across all the UN Sustainable Development Goals. The Colombo declaration built on the UNEA4 resolution on Sustainable Nitrogen Management. This was followed by the establishment of a ‘Nitrogen Working Group’ at UNEP in 2020 with a national representative from each member country, to work towards the establishment of an ‘Inter-convention Nitrogen Co-ordination Mechanism’ involving UNFCCC, UNCBD, UNECE etc. These developments further strengthened the UNEP-UNI-INMS-SACEP-SANH partnership and enabled South Asian leadership on nitrogen, while building wider international support.

Policy implications for South Asian Nitrogen Management

It is becoming increasingly clear in South Asia that reducing nitrogen pollution is possible and a necessary policy goal for every country of the region. The current policies for reactive nitrogen monitoring and control are neither uniform nor adequate in any country of the region. As N-pollution emerges from different sectors such as agriculture, energy, transport, industry etc., governed by different ministries/departments in South Asian countries, assigning nodal ministries for each N-pollutant could help avoid the complications of inter-ministerial coordination. Policy interventions for Sustainable Nitrogen Management can include technology choices, emission/effluent standards, taxes, subsidies, public procurement pricing etc. As pollution sensitivity may be different for human consumption (air, water or food), forests, rivers, marine produce or coral systems, it is highly desirable to have ecosystem-specific standards for best results to protect the ecosystem services and livelihoods. The solutions to reduce N pollution require increasing the fertilizer N equivalence value of animal manure and recycling waste water nutrients, reducing fossil fuel dependence in power, transport and industry, promoting energy-efficient gadgets and systems, reducing food waste and meat consumption etc. The available global best practices need to be adapted to local situations, apart from development and adopting new technologies to recapture and reuse reactive N.

Regional intergovernmental coordination is also important because of the emerging evidence that nitrogen pollution spills over across borders through air and water, affecting neighbouring countries of the region. It is not only possible but also highly desirable to develop a common policy framework for South Asian cooperation for national and regional N assessment and management. It also helps to coordinate a regional approach for global implementation of the UN resolution on Sustainable Nitrogen Management. There is adequate scientific capacity in the region to support evidence-based policy interventions. If necessary, it can be supplemented by international scientific expertise from UNI and others to realize the full potential for South Asian leadership towards sustainable nitrogen management, regionally as well as globally.

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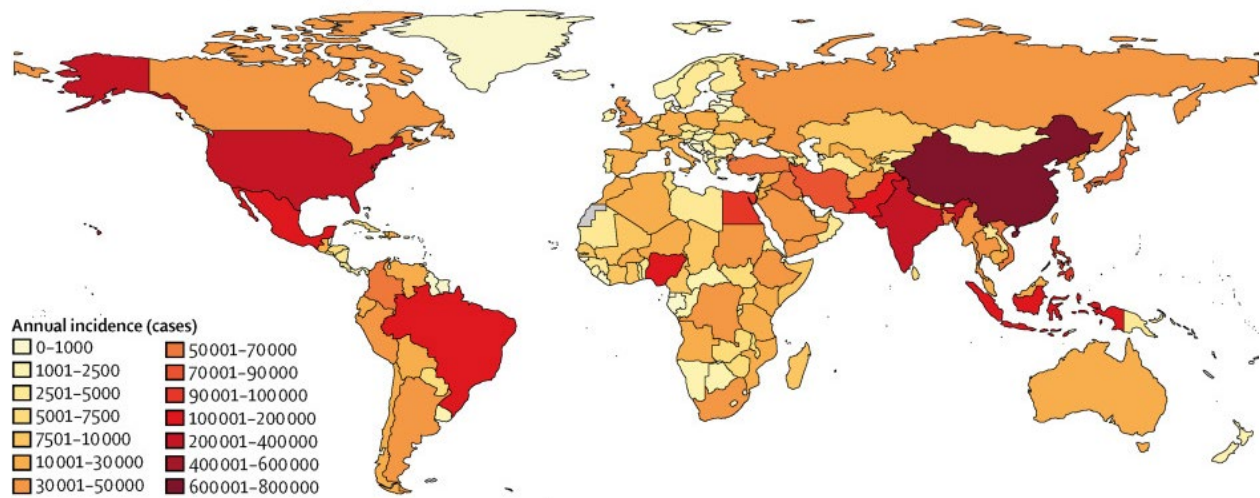


Figure 1. National annual estimates of number of new asthma cases attributable to ambient nitrogen dioxide (NO₂) exposure for children aged 1–18 years as per Achakulwisut et al. (2019), who derived the values shown using the central mean relative risk estimate and assuming a counterfactual NO₂ concentration of 2 parts per billion.

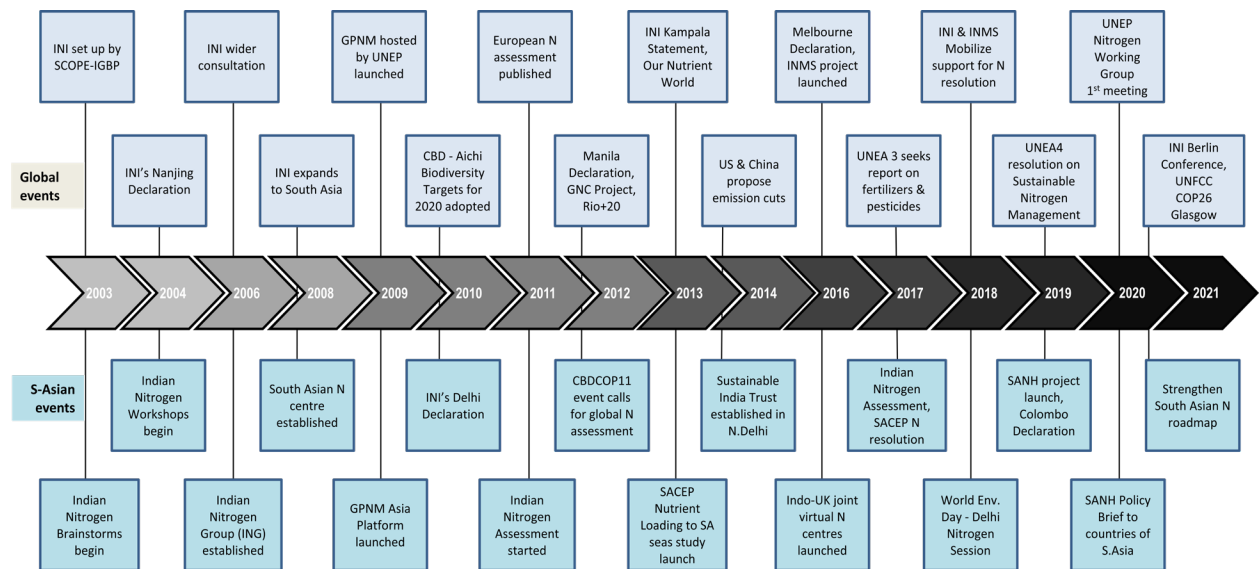


Figure 2. Timeline of global and South Asian developments towards global cooperation on Sustainable Nitrogen Management. The events above the timeline depict international developments while the events below the timeline depict South Asian developments.