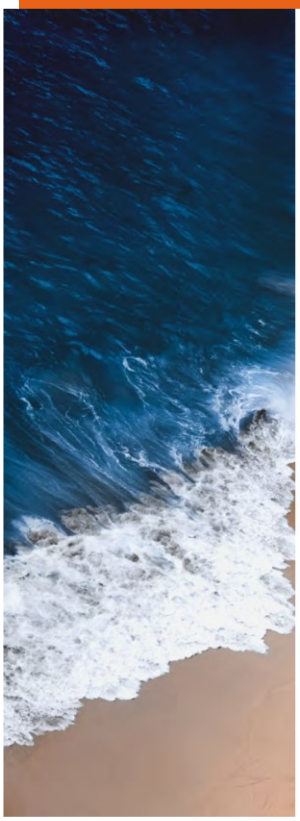

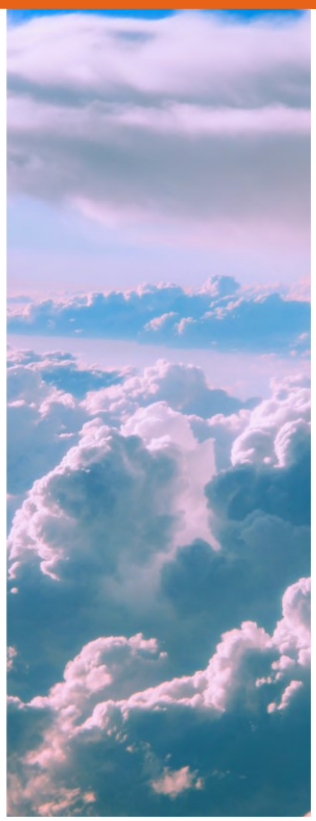

SOUTH ASIAN REGIONAL COOPERATION ON SUSTAINABLE NITROGEN MANAGEMENT

NITROGEN POLLUTION AND POLICY RESPONSES IN SOUTH ASIA

South Asia Co-operative Environment Programme (SACEP) and the UKRI GCRF South Asian Nitrogen Hub (SANH)

Nitrogen is essential for life. Yet in excess reactive nitrogen can cause catastrophic harm to people, ecosystems and to our climate. South Asia is a major global nitrogen emission hotspot, therefore policy actions, or inactions, in this region have global ramifications. This policy briefing summarizes contents of a report by SACEP and SANH that outlines the nitrogen emission trends and drivers in South Asia and provides unique insights into the nitrogen policy landscape via the assessment of 966 nitrogen related policies from the region.

Key messages

NITROGEN CHALLENGES

1. South Asia is a global nitrogen emissions hotspot.
2. Nitrogen oxide emissions have risen rapidly in the region, approximately doubling since 2000. The main source is electricity and heat generation.
3. Nitrous oxide and ammonia emissions are steadily increasing, with agriculture as the main source.
4. South Asian governments have been among the first to recognize and tackle nitrogen pollution via several initiatives.

NITROGEN POLICIES

5. We collected 966 nitrogen related policies, valid in 2019, from South Asia to form a unique policy database.
6. All policy texts were classified by sector, sink, policy type, and other indicators of quality.
7. Our analysis highlights the potential gaps and opportunities in the current policy landscape.
8. Our findings suggest that only a small proportion of policies have attempted to integrate across sectors and sinks, with a range of policy instruments.
9. To fill existing gaps, new policies may be required to tackle the nitrogen challenge, along with revising existing nitrogen-related policies.
10. Research and policy efforts towards improving nitrogen management in South Asia can help catalyse further regional and international cooperation, providing global benefits.

INTRODUCTION

Nitrogen pollution is a significant issue globally and for South Asia. Human interventions, and the production of reactive nitrogen (N_r), are harmful to human health and the environment.

Nitrogen in its unreactive form (N_2) is harmless, everywhere and invisible. Nitrogen is an important component of natural cycle processes and is necessary for supporting plant growth. Human interventions have caused reactive nitrogen to accumulate.

Excess N_r can cause a range of effects (Galloway et al., 2003). These effects can be summarized under the acronym 'WAGES', referring to effects on water, air, greenhouse gases, eco-systems and soil. The negative impacts of excess N_r include acid rain, soil degradation, ground and surface water pollution, coastal algal blooms, eutrophication (environments progressively enriched with nutrients causing excess algae/ plant growth), and dead zones.

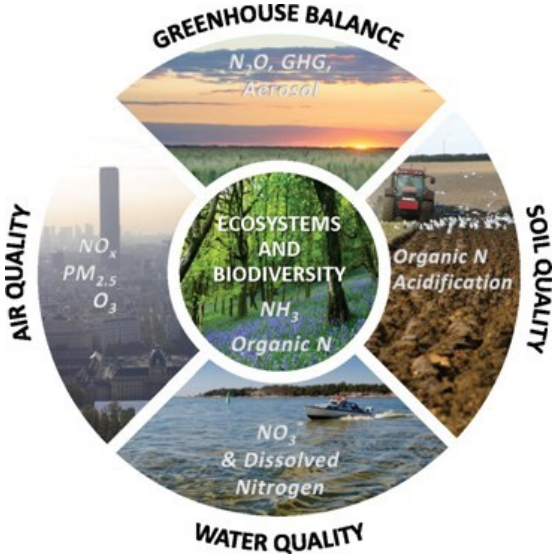

Fig.1 WAGES: N_r effects on water, air, greenhouse gases, eco-systems and soil (Sutton et al., 2013).

The main N_r compounds of concern are nitrogen oxides (NO_x), ammonia (NH_3) and nitrous oxide (N_2O) in air, and nitrates in water alongside a plethora of organic nitrogen compounds. Their accumulation over several decades, has affected our health and local environment, in addition to their contributions to climate change.

The United Nations Environment Programme (UNEP) report Frontiers 2018/19 identified N_r as one of the five emerging threats facing our planet (UNEP, 2019).

Human activities such as agriculture, sewage treatment, waste burning and fuel burning for power, transport and industry, are causing excess N_r.

South Asia (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka) is experiencing severe environmental pressure, compounded by ineffective nitrogen management.

Managing nitrogen sustainably is in everyone's best interest. Sustainable nitrogen management could contribute to the attainment of all 17 UN Sustainable Development Goals (SDGs). Furthermore by 'halving nitrogen waste' by 2030 we could save US$100 billion annually (Sutton et al. 2021).

This policy briefing summarizes the scientific evidence, current initiatives and policy landscape for nitrogen management in south Asia (SACEP–SANH, 2021).

NITROGEN EMISSION TRENDS, DRIVERS AND IMPACTS IN SOUTH ASIA

In South Asia, nitrogen pollution is high and rising, highlighting why sustainable nitrogen management is an important issue globally and for South Asia.

South Asian countries have their own country level nitrogen data, but for comparative purposes data on nitrogen emissions, sources and trends are sourced from the Emissions Database for Global Atmospheric Research (EDGARv5.0). Data are available up to 2015, for each South Asia country and for the region as a whole.

Nitrogen Oxides (NO_x)

Nitrogen oxides' emissions from South Asia make up a major proportion of global emissions. Relative to the rest of the world, South Asian emission levels have risen between 1970 and 2015. Figure 2 shows the hotspots of NO_x emissions, with major concentrations coming from urban centres in the Indo-Gangetic plain and in south India (see Decina et al., 2020).

The EDGAR data reveal India as the major contributor to NO_x emissions in the region, but on a

per capita basis, Maldives, Bhutan and Sri Lanka show higher figures. In all South Asian countries, NO_x emissions have been rising rapidly, approximately doubling since 2000, with a 107% increase observed in 2015 as compared with 2000. The greatest relative increases in NO_x emission were observed in Afghanistan (+668%), Bangladesh (+228%), and Maldives (+169%).

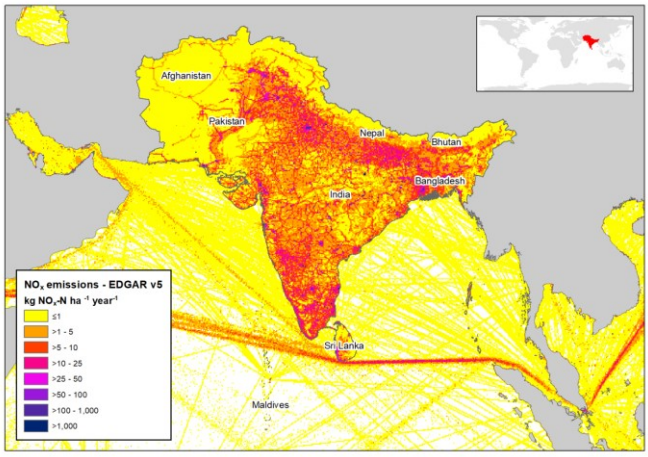

Fig 2: Nitrogen Oxides (NO_x) emissions across South Asia, 2015. *Note: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a). The darker purple to blue colours indicate high concentrations of NO_x per hectare per year.*

In South Asia, electricity and heat generation are the largest contributor to NO_x emissions (37%), followed by road transportation (27%) and manufacturing and construction (21%).

Nitrous oxide (N_2O) emissions

Nitrous oxide emissions from South Asia make up a major proportion of global emissions. Relative to the rest of the world, emission levels have risen between 1970 and 2015. A 36% increase in N_2O emissions was observed in the whole South Asia region from 2000 to 2015 (Fig 3).

India was the major contributor to N_2O emissions in the region (Fig 4), but as with NO_x, on a per capita basis, Nepal, Pakistan and Bhutan show higher figures.

The main estimated sources of N_2O emissions in South Asia are directly from managed soils (63%), indirect emissions from managed soils (9%), and indirect N_2O emissions from the atmospheric deposition of nitrogen in NO_x and NH_3 (8%). Maldives shows different patterns of emission sector contributions from the rest of South Asia, because agriculture plays a small part in its economy.

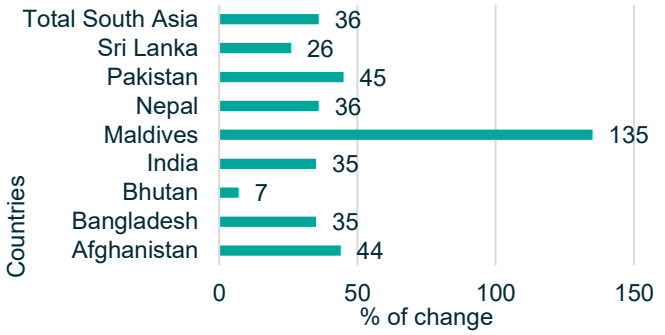

Fig. 3: South Asia Nitrous oxide (N_2O) emissions, percentage change between 2000 and 2015.
Note: EDGAR v5.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)

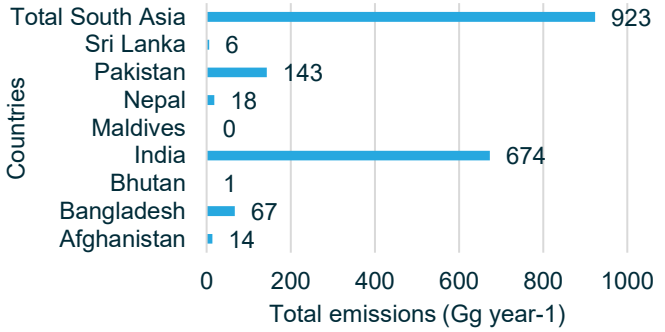

Fig. 4: South Asia Nitrous oxide (N_2O) emissions in 2015
Note: EDGAR v5.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)

Ammonia (NH_3) emissions

Ammonia (NH_3) emissions are closely linked to commercial fertilizer applications and livestock manures, with South Asia being a global hotspot. Figure 5 shows the distribution of NH_3 emissions across the region, with highest estimated emissions across the Indo-Gangetic plain.

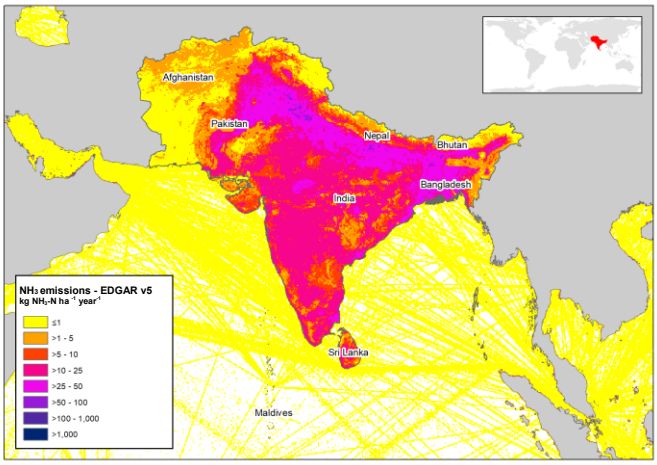

Fig. 5: Ammonia (NH_3) emissions across South Asia, 2015
Note: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa, et al (2019a)

India was the major contributor to NH_3 emissions in the region. On a per capita basis, Bhutan, Nepal and Pakistan have higher emissions, and Maldives, with its limited agricultural sector, has much lower levels.

There was a 36% increase in NH_3 emission in the South Asia region from 2000 to 2015. The highest increases in NH_3 emissions were in Afghanistan, Pakistan and Maldives, with the lowest increase in Sri Lanka.

Agriculture is the major source of NH_3 emission in South Asian countries except in Maldives and Bhutan where the consumption of biomass and fossil fuels (LPG and kerosene) in the residential and commercial and institutional settings is the major estimated source.

SOUTH ASIA INITIATIVES ON REACTIVE NITROGEN

South Asia has been proactive in recognizing nitrogen issues. In the last two decades in parallel to global developments on sustainable nitrogen management, several initiatives have taken place in South Asia to tackle N pollution (see Raghuram et al., 2021). Early actions include the establishment of the South Asian Nitrogen Centre (SANC) of the International Nitrogen Initiative (INI) in 2008. In 2010 the INI Delhi declaration on reactive nitrogen management for sustainable development was adopted.

As one of several initiatives to promote an extensive partnership on N_r research and policy, the South Asian Nitrogen Hub (SANH,) funded by UK Research and Innovation (UKRI) under the Global Challenges Research Fund (UKRI-GCRF) was established in 2019. This brought together 40 institutions from all eight South Asia countries and from the UK.

In March 2019 the Resolution on Sustainable Nitrogen Management was adopted at the 4th UN Environment Assembly (UNEA) submitted under the leadership of India. Spearheaded by Sri Lanka, in October 2019 the 'Colombo Declaration' was adopted by a group of member states with an ambition to 'halve nitrogen waste' by 2030. The declaration urges countries to make comprehensive assessments of nitrogen policy, its management, and scientific aspects to move towards sustainable nitrogen management. This briefing and the full SACEP-SANH policy report (2021) contribute towards these actions for South Asia.

EXISTING NITROGEN RELATED POLICIES IN SOUTH ASIA

South Asian countries have many policies, regulations, and legislation that are likely to impact levels of nitrogen pollution. As part of the actions towards building 'the nitrogen policy arena for South Asia', SANH collected and analysed nitrogen related policy texts from the region.

Until now, little has been known about the nitrogen policy landscape across South Asia. Assessing nitrogen-related policies is crucial to identify the gaps and opportunities for managing nitrogen. An analysis of this kind provides an essential building block to understanding what policies currently are in place to determine what is needed for the future.

Overall, 966 Nitrogen related policies (active at 31 December 2019), from South Asia were collected by SANH during 2020-2021. A summary of the policy data collection approach is provided in the original report. The policies were classified by relevance, scope, policy type, sink, sector and pollution target source. Policy quality was further assessed by considering policy integration, i.e., whether the policy considered multiple sinks, and/or sectors and included multiple policy types.

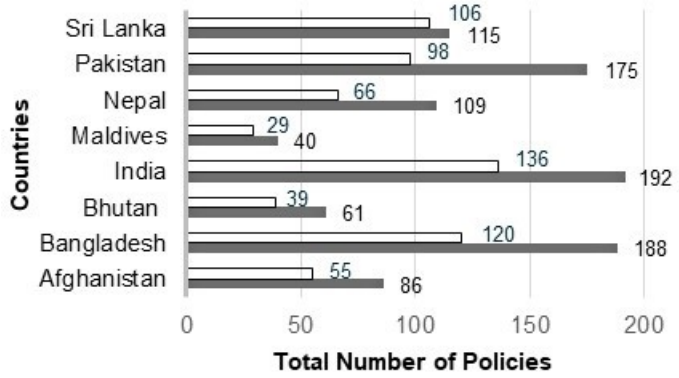

Fig. 6: Number of nitrogen related policy interventions by South Asian governments per country (total 966) (dark grey bars) and policies selected for greater relevance and scope (total 649) (White bars)

The number of nitrogen related policies collected per country are shown in Figure 6. These range from 192 national level policies for India to 40 nitrogen-related policies for Maldives. The number of policies is not, however, indicative of a country doing better in terms of nitrogen management. Rather the content of the policy text itself can provide certain insights relevant to policy innovation and to improve effectiveness.

Figure 6 also indicates the number of policies classified as having greater relevance and (potential) impact for nitrogen management. For example, in Bangladesh 120 out of the 188 policies were identified as having significant relevance. For South Asia a total of 649 policies were selected according to nitrogen management relevance and scope, comprising 67% of the overall policy database. Our analysis focused on only these selected policies.

Economic sectors

We classified policies by economic sector based on whether they refer to one or multiple sectors in their policy text. Economic sectors included *transport, energy, agriculture, waste, and industry, urban development and tourism*, *land use change, food* and '*other*' (for example health policies with N_r management implications). In some policies, sector(s) were not referred to in the text and they mentioned only environmental sink(s).

The most common classification was that referring to multiple sectors, with 200 policies (31% of the selected policies); see Figure 7. We consider this a favourable policy characteristic as an indicator of policy integration.

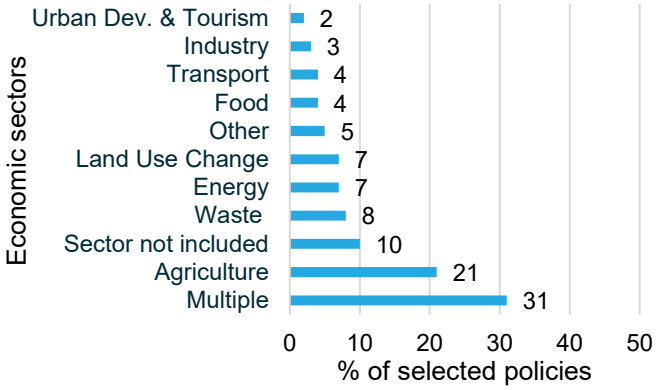

Fig. 7: Percentage of selected nitrogen-related South Asian policies by economic sector

The agriculture sector was the second most common classification, with 135 policies (21%). This is perhaps not as large as would have been expected, given that agriculture is such a substantial part of South Asian economies and land use (except for Maldives). Policies classified as 'sector not included' were the next most common, i.e., 10% of all policies focused solely on environmental sink(s).

All the other sectors (energy, food, industry, land use change, transport, urban development & tourism, waste and other) were at 8% or below. Whilst policies on these sectors were less commonly found in the selected policies they address some of the highest emitting sources of N_r pollution for South Asia. The sectors emitting the most significant sources vary by country and indicate possible policy gaps and opportunities, where nitrogen pollution needs further attention.

Environmental sinks

An environmental sink refers to a reservoir that takes up a nitrogen compound, or where nitrogen loads can accumulate and can have an impact. A policy was classified as having a particular sink only if the policy objective or content mentioned one or more sinks. The classification was not based on assumed nitrogen environmental links or impacts. The classification for environmental sinks included *water, air, ecosystems, climate, soil*, and *multiple* sinks and sink not included, i.e., where the policy refers only to sector(s).

The most common classification was for policies that did not mention any sinks, with 248 policies (38%) focused only on sectors (Figure 8). These policies have implications for the environment and yet currently do not specifically consider it. This is a policy gap that needs attention, especially if these sector-based policies are not linked to, or supplemented by, other policies that aim to mitigate or minimize negative environmental impacts.

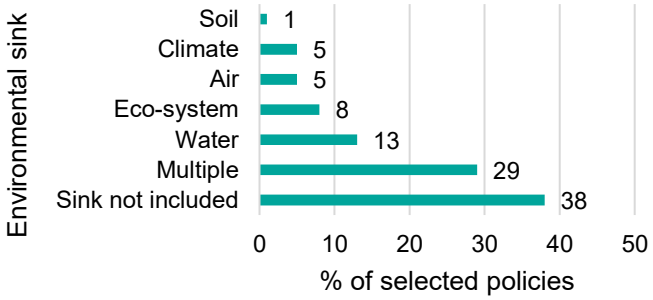

Fig. 8: Percentage of selected nitrogen-related South Asian policies by environmental sink

The second most common classification is *multiple* sinks. These policies indicate a favourable direction for policies because N_r impacts affect multiple sinks, and these policies recognize that sinks are not isolated from each other.

The third most common classification, for a single sink, was for *water* (13%) including policies related to water laws, water quality, drinking water, river conservation plans etc. For *ecosystem, climate* and *air*, classifications were at 8% or below. *Soil* was the least common sink referred to, despite agriculture,

more specifically soil, as a significant N_r emission source.

Policy type

The policy type classification distinguishes between several different policy mechanisms that can impact environmental pollutants. The policy type classification includes *regulatory, economic, framework, data and methods, research & development (R&D), commerce and pro-nitrogen,* where the last (pro-N) refers to policies promoting nitrogen use, e.g., subsidizing fertilizer prices. In our classification it is possible to allow for multiple policy types, recognizing that a policy may propose multiple instruments.

For policy type, 549 policies were classified as having a framework element, by far the most common policy type found within the database, see Figure 9. The second most common policy type was 'Data & Methods', with 173 policies, followed by. R&D, included in 154 policies. Regulatory and economic policy elements are the fourth most common. 145 policies included regulatory policy elements and 110 policies were classified as having economic elements. The least common policy types were commerce and Pro-N. 54 policies included commerce elements and 36 policies were identified in the SANH database as pro-nitrogen.

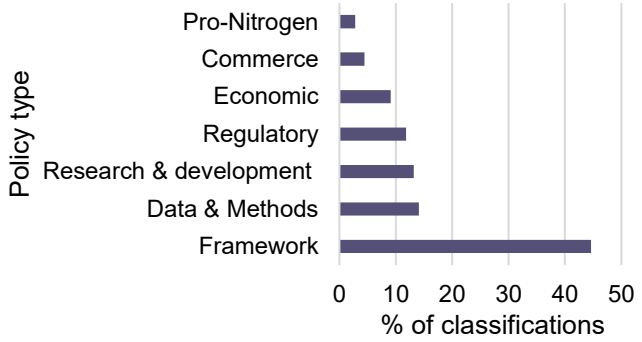

Fig 9: Percentage of selected nitrogen-related South Asian policies by policy type taken from the total number of classifications (1,177) *Note: This is higher than the total number of policies as each policy could be classified as having more than one policy type.*

Over half (53%) of the selected nitrogen-related policies we identified had multiple policy instruments. We regard these as comprehensive policies, as they propose applying a combination of policies to secure better environmental outcomes than is possible from individual policy instruments, delivered on their own. Such an approach is advocated by the Intergovernmental Panel on Climate Change (IPCC) (Gupta et al., 2007, p.765).

Policy quality

Policy quality is usually assessed in terms of the impact of the policies, as indicated by changes in the scale of pollution. This policy analysis deals only with a policy's intent (as expressed in the text of a policy document) and the likelihood that the tools it proposes will have the envisaged effects, and not on any evidence about actual impacts. The quality of nitrogen related policies is assessed here by considering three main aspects: *impact direction; existence of pollution source targets*; and *level of integration,* i.e., whether multiple sinks, sectors and policy types have been considered.

For direction of impact, policies could be coded as *positive, negative or mixed/neutral*. Of the selected policies, 403 (62%) were classified as having a potentially positive impact on N_r management. The second most common classification was for mixed or neutral impact, at 209 (32%) of the selected policies. The least common category was policies likely to increase N_r pollution at 37 (6% of the 649 selected policies).

Pollution source types were assessed to identify whether a policy targeted, or showed awareness, of the different types of sources of N_r pollution: non-point source (NPS) and point source. A total of 78 policies (12%) referred to targeted point source pollution. NPS was less commonly recognised, with only 35 policies (5%). However, more policies (152, or 23%) recognised both pollution types. Such policies provide useful examples for N_r management as they recognise the differences of pollution sources and the need to measure and mitigate these different types.

It was, however, common for policies not to refer to pollution types or to the differences between the two. These 199 policies were classified as unspecified (31%). A further 29% of the policies were coded as non-applicable, including policies that were classified as having a negative impact direction and/or those indirectly relevant to nitrogen.

Policy integration was assessed using the classifications for sinks, sectors and policy type. As identified already in this policy brief, multiple was a common classification for sinks and sectors. A total of 99 selected policies (15%) were classified as both multiple sink and multiple sector. These policies stand as progressive examples for having integrated objectives. Policies were further assessed to see if

they had an 'integrated approach,' i.e., if they had been associated with multiple policy instruments.

For policy type the majority were classified as having multiple interventions. However, only 61 of the selected policies, (9%), were found to have multiple sinks, multiple sectors and multiple policy instruments. It is encouraging that these 61 policies with integrated objectives and approaches met this criterion, yet a potential policy gap is also visible.

CONCLUSIONS AND POLICY IMPLICATIONS

The main SACEP-SANH report (2021) outlines the impacts, trends, and drivers of nitrogen pollution and waste in South Asia, providing an overview of the region's nitrogen-related policies and their characteristics. Our assessment highlights that excess N_r is a significant problem that requires national and international cooperation and commitment to resolve. Nitrogen emissions are increasing across all South Asia countries, and for the region, exceeding in most case global averages, underlining that more still needs to be done.

In summary:

- Reducing nitrogen waste is possible and is a highly desirable policy goal that can limit adverse environmental effects and health impacts, with co-benefits for food production and the wider economy.
- The SANH database, containing 966 policies, provides an initial overview of the current nitrogen policy landscape for South Asia.
- The policy analysis - described in full detail in the SACEP-SANH report - highlights potential gaps and opportunities in the current policy landscape.
- Some policies indicate integrated policy features (with multiple sink and sectors and policy instruments) – a desirable direction for future policy. Overall, integrated policies are lacking in the region and having more of these in place would help address nitrogen issues systematically.
- There are opportunities for shaping existing policy, especially for indirectly nitrogen-related policies, where minor amendments could further specify nitrogen links to have a greater impact in promoting sustainable nitrogen management.
- There is scope to increase nitrogen 'core policies' i.e., regulatory and/or economic instruments, to provide quantifiable limits and incentives to improve N_r management.
- Existing experience and best practices could be starting points, if optimized to local conditions and needs. Countries can learn from each other which approaches work best in the region, and how to fill any gaps.
- The South Asia region can be world-leading in addressing the challenge of sustainable N_r management. Efforts so far lay the foundation for catalysing further regional and international cooperation and actions to improving nitrogen management in South Asia.

For full details, please see the SACEP-SANH report: https://sanh.inms.international/publications/SACEPSANHPolicyBrief

For any further enquires please contact the SANH office: sanh-office@ceh.ac.uk

ACKNOWLEDGMENTS

We gratefully acknowledge funding from UK Research and Innovation (UKRI) through its Global Challenges Research Fund, which supports the GCRF South Asian Nitrogen Hub (SANH) which made this work possible, together with underpinning support from the project "Towards the International Nitrogen Management System" (INMS), supported by the Global Environment Facility through the UN Environment Programme. We also acknowledge the valuable contributions of our SANH colleagues Ulrike Dragosits (UKCEH), Pete Smith (University of Aberdeen), Vera Eory (Scotland's Rural College), and the former Directors-General of SACEP Dr Abas Basir (2019-21) and His Excellency Mr Ashraf Haidari (2021). The support from the SANH coordination team, especially Dr Clare Howard and Ms. Madison Warwick has been very valuable. This briefing contributes to the work of the International Nitrogen Initiative (INI) and the Global Partnership on Nutrient Management (GPNM)

REFERENCES

Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Oreggioni, G. 2019a. EDGAR v5.0 Global Air Pollutant Emissions. European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/377801af-b094-4943-8fdc-f79a7c0c2d19

Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Lo Vullo, E., Solazzo, E., Monforti-Ferrario, F., Olivier, J.G.J., Vignati, E.E. 2019b. EDGAR v5.0 Greenhouse Gas Emissions. European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/488dc3de-f072-4810-ab83-47185158ce2a

Decina, S.M., Hutyra, L.R. and Templer, P.H. 2020. Hotspots of nitrogen deposition in the world's urban areas: a global data synthesis. Frontiers in Ecology and the Environment, 18 (2):92-100.

Galloway, J.N., Aber, J.D., Erisman, J.W., Seitzinger, S.P., Howarth, R.W., Cowling, E.B. and Cosby, B.J. 2003. The Nitrogen Cascade. Bioscience 53 (4):341-356

Gupta, S., Tirpak, D., Burger, N., Gupta, J., Höhne, N., Boncheva, A., Kanoan, G., Kolstad, C., Kruger, J., Michaelowa, A. and Murase, S., 2007. Policies, Instruments and Co-operative Agreements, chp.13: In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge.

Kanter, D.R., Chodos, O., Nordland, O., Rutigliano, M. and Winiwarter, W., 2020. Gaps and opportunities in nitrogen pollution policies around the world. Nature Sustainability, 3(11), pp.956-963.

Raghuram, N., Sutton, M.A., Jeffery, R., Ramachandran, R. and Adhya, T.K. 2021. From South Asia to the world: embracing the challenge of global sustainable nitrogen management, One Earth, 4 (1):22-27.

SACEP & SANH. 2021. South Asian Regional Cooperation on Sustainable Nitrogen Management: Nitrogen Pollution in South Asia: Scientific Evidence, Current Initiatives and Policy Landscape, SANH Policy Paper PP1, Colombo & Edinburgh.

Sutton, M.A., Bleeker, A., Howard, C.M., Erisman, J.W., Abrol, Y.P., Bekunda, M., Datta, A., Davidson, E., De Vries, W., Oenema, O. and Zhang, F.S. and others 2013. Our Nutrient World. The challenge to produce more food & energy with less pollution. Centre for Ecology & Hydrology, Edinbugh.

Sutton, M.A., Howard, C.M., Kanter, D.R., Lassaletta, L., Móring, A., Raghuram, N. and Read, N., 2021. The nitrogen decade: mobilizing global action on nitrogen to 2030 and beyond. One Earth, 4(1), pp.10-14

UNEP. 2019. Frontiers 2018/19: Emerging Issues of Environmental Concern. Nairobi: United Nations Environment Programme

AUTHORS

Yang A.L, Adhya, T.K., Anik, A.R., Bansal, S., Carnell, E., Chowdhury, S., Das, S., Hassan R., Jayaweera, A., Jeffery R., Joshi, R., Kaushik, H., Khaleel, Z., Nayak, D., Nissanka, S., Panda, A., Pokhrel, A., Porter, S., Raghuram, N., Safi, Z., Sharmin, S., Sharna, S.C., Shazly, A., Sutton, M.A, Tomlinson, S., Tshering, D., & Watto, M.A.

South Asia Co-operative Environment Programme (SACEP) is an inter-governmental organization, established in 1982 by the governments of South Asia to promote and support regional protection, management and enhancement of the environment. SACEP eight member countries include Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. http://www.sacep.org/

The South Asian Nitrogen Hub (SANH) is a UKRI GCRF funded research partnership that brings together 32 leading research organisations and project engagement partners from South Asia and the UK. SANH is working towards enabling South Asia to 'adopt and champion a strategic approach to nitrogen management, as a key step towards the Sustainable Development Goals'. SANH aims to provide relevant scientific insights, identify barriers to change, and demonstrate the economic benefits of tackling nitrogen. https://sanh.inms.international/ pollution

RESEARCH PARTNER INSTITUTES

THE UNIVERSITY of EDINBURGH
University of Peradeniya
Sustainable India Trust
UK Centre for Ecology & Hydrology
Kalinga Institute of Industrial Technology
University of Agriculture Faisalabad
Kathmandu University
TERI School of Advanced Studies
Bangabandhu Sheikh Mujibur Rahman Agricultural University
The Maldives National University
UNIVERSITY OF ABERDEEN
Royal University of Bhutan
Kabul University
Nourish Scotland
Society for Conservation of Nature