

Valuing Nutrients and Wastewater

Transforming hidden costs into
investment opportunities



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Join the initiative and partnership: The Global Wastewater Initiative (GWWI) and the Global Partnership on Nutrient Management (GPNM) are UNEP-hosted, multi-stakeholder partnerships working to improve environmental sustainability through better wastewater and nutrient management. GWWI addresses wastewater challenges by promoting coordinated action, investment, and a shift from viewing wastewater as waste to recognizing it as a valuable resource. Complementing this, GPNM focuses on reducing nutrient pollution, especially nitrogen and phosphorus, by promoting their sustainable use in agriculture and improving their management across sectors, helping protect freshwater and marine ecosystems. Stakeholders can engage with both initiatives by connecting with their UNEP secretariats and joining their global partner networks.



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Executive Summary



Ponidzie with Nida River in Poland at Spring © Envato / merc67

This policy brief addresses the critical global challenges posed by nutrient and wastewater mismanagement, which have significant negative impacts on economies, ecosystems, human health, and climate stability. Nitrogen (N) and phosphorus (P), essential nutrients for plant growth, are often overused or poorly managed, leading to water contamination, algal blooms, hypoxic zones, and poor air quality. Wastewater¹, if untreated or inadequately managed, exacerbates these problems and poses serious public health risks, including the spread of antimicrobial resistance (AMR).

This brief is intended for stakeholders who shape policies across agriculture, water, transportation, industry, environment, and public health, especially policymakers, financial institutions, and technical experts. United Nations Environment Programme (UNEP) promotes an ecosystem-based approach, recognizing that nutrient pollution and wastewater are deeply interconnected yet often addressed through separate lenses (e.g., agricultural productivity vs. pollution control). This brief bridges those silos and supports integrated, cross-sectoral action.

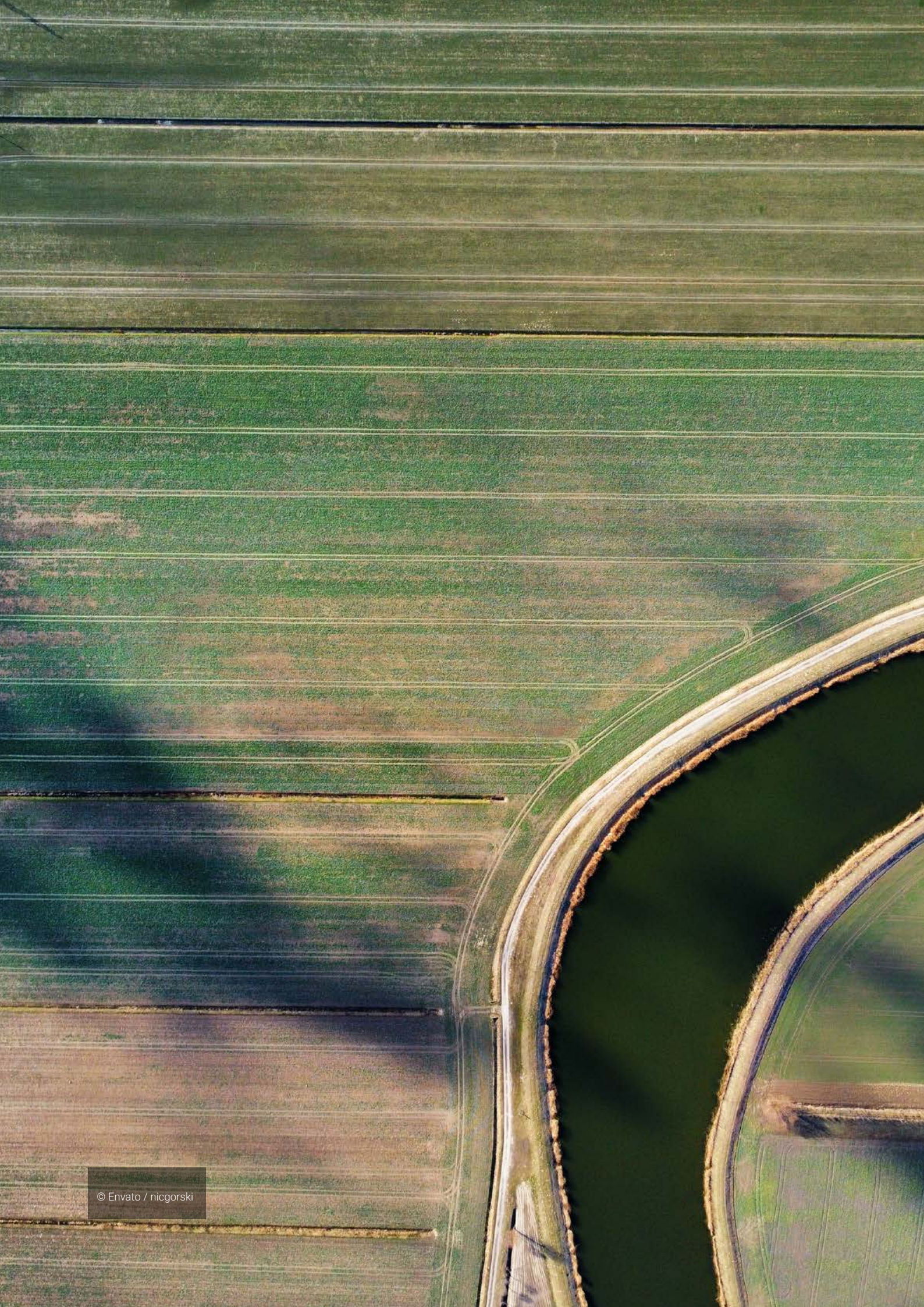
The economic cost of inaction is staggering, including billions in lost agricultural productivity, degraded fisheries, healthcare burdens, and environmental damage. Conversely, investing in sustainable nutrient and wastewater management offers substantial benefits: improved soil health, enhanced agricultural

productivity, reduced greenhouse gas emissions, nutrient circularity, biodiversity conservation, improved water quality, and climate mitigation (Figure 1). Wastewater is increasingly recognised as a resource with potential for nutrient and energy recovery, water reuse, and circular economy opportunities. However, data gaps make costs of inaction difficult to quantify. More in-depth analysis is required to help states build robust investment cases and develop integrated, science-based policy measures.

Integrated, science-based policy approaches are urgently needed to break down existing silos in nutrient and wastewater governance. Global frameworks, such as nutrient management partnerships, United Nations Environment Assembly (UNEA) resolutions, the Sustainable Development Goals (SDGs), and the One Health approach, provide platforms for coordinated action. National and regional strategies that align nutrient and wastewater management with climate, biodiversity, and public health goals are essential.

Financial mechanisms, including green bonds, nutrient trading schemes, debt-for-climate swaps, carbon credits, and public-private partnerships, can mobilize investment and incentivize sustainable practices. Technological innovations, such as nitrogen-fixing crops and advanced nutrient recovery technologies, promise to enhance efficiency and sustainability.

¹ Wastewater is considered here in a broad definition that includes urban effluents (sewage), faecal sludge, industrial effluents, agricultural, horticultural and aquaculture effluents, and stormwater and agricultural run-off.



Recommendations

- 1. Develop and Implement Integrated Nutrient Management Action Plans (INMAPs):**
Align nutrient policies with climate, biodiversity, and pollution goals at national and regional levels to reduce nutrient losses and promote sustainable agriculture.
- 2. Embed Nutrient and Wastewater Management in National Development Strategies:**
Incorporate nutrient efficiency and wastewater treatment targets into Nationally Determined Contributions (NDCs), SDGs, and climate adaptation plans.
- 3. Strengthen Wastewater Reuse and Circular Economy Strategies:**
Promote safe and sustainable reuse of treated wastewater in agriculture, industry, and urban settings, supported by rigorous monitoring and public education.
- 4. Enhance Pre-Treatment Standards and Wastewater Discharge Permitting and Regulation:**
Improve the quality of wastewater entering the system to ensure cost effective treatment and improve wastewater treatment quality. Establish stringent effluent quality standards and link permits to performance metrics to incentivize advanced treatment and resource recovery technologies.
- 5. Leverage Financial Mechanisms for Sustainable Investment:**
Expand the use of green bonds, sustainability linked loans, nutrient trading schemes, carbon credits, and debt-for-climate swaps to mobilize funding for nutrient abatement and wastewater treatment infrastructure.
- 6. Promote Technological Innovation in Nutrient and Wastewater Management:**
Support development and adoption of innovations such as nitrogen-fixing crops (e.g., N-Fix) and nutrient recovery technologies to improve fertiliser efficiency and reduce environmental impacts. Integrate renewable energy and water saving initiatives into wastewater treatment where possible.
- 7. Integrate Wastewater Management into AMR National Action Plans:**
Address antimicrobial resistance by including wastewater treatment in One Health strategies to prevent environmental spread of resistant microbes.
- 8. Foster Cross-sectoral Collaboration and Policy Coherence:**
Break down policy silos between agriculture, environment, health, and infrastructure sectors to implement integrated and systemic solutions.
- 9. Invest in Capacity Building and Public Awareness:**
Provide technical assistance, training, and public campaigns to promote nutrient-smart practices and acceptance of wastewater reuse.
- 10. Support Research and Data Collection:**
Improve understanding of the hidden costs of nutrient and wastewater mismanagement and quantify the co-benefits of interventions to strengthen the evidence base for policy and investment decisions. Assess the impact of climate change and extreme weather events on wastewater and nutrient management.

By implementing these recommendations, policymakers can unlock the significant environmental, economic, and social co-benefits of sustainable nutrient and wastewater management, contributing to global goals of food security, public health, biodiversity conservation, and climate resilience.

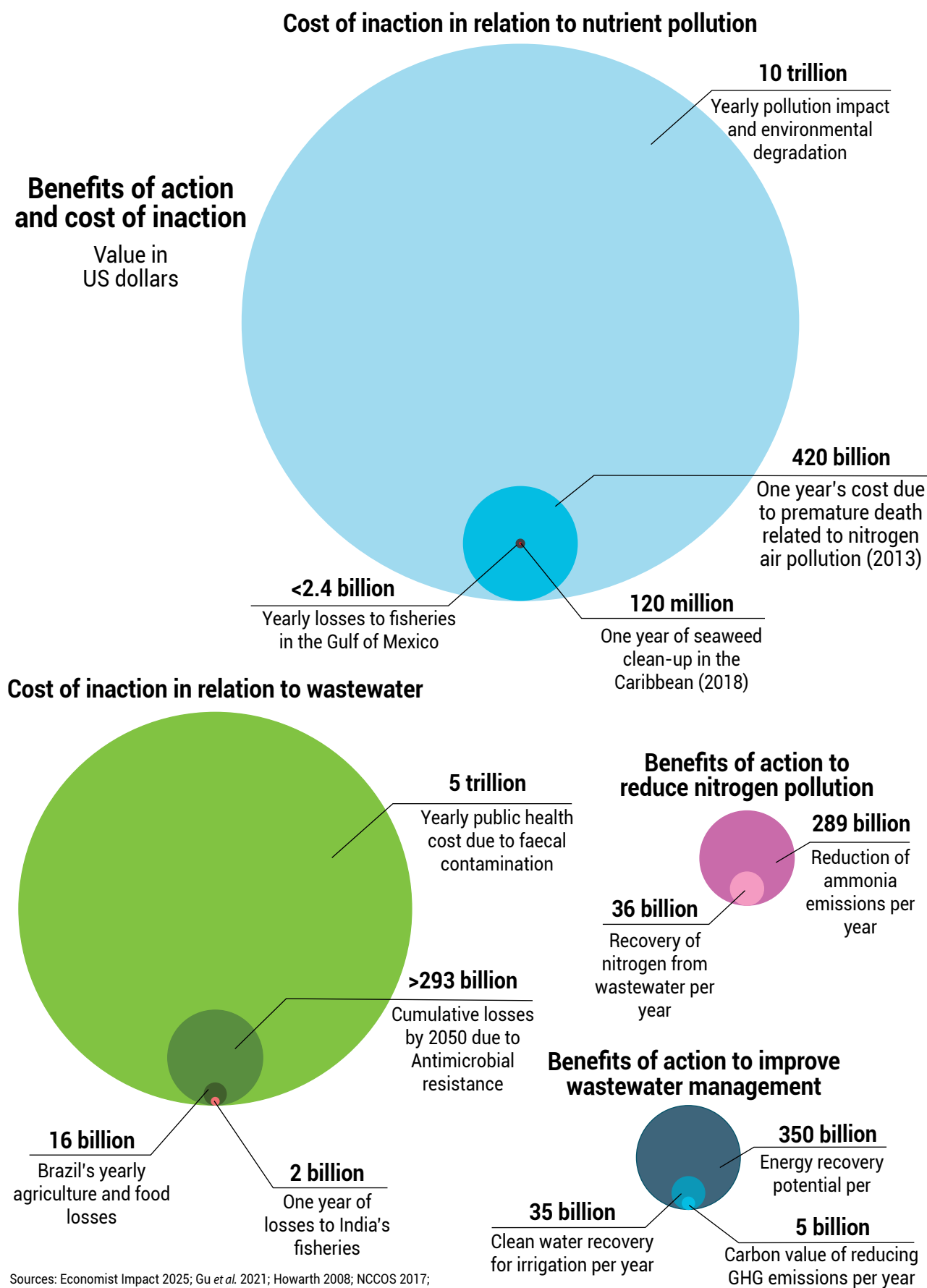


Figure 1: Benefits of action and cost of inaction.

01 Purpose and objectives

This brief highlights the critical need to address nutrient pollution and wastewater mismanagement - two interconnected challenges with profound long-term implications for climate, economies, ecosystems, and human health.

As a call to action, it highlights the multiple co-benefits of sustainable nutrient and wastewater management, such as climate mitigation and adaptation, nutrient and energy recovery, soil recovery and more efficient water use, and the importance of valuing nutrients and wastewater.

A growing body of evidence underscores the significant economic benefits of taking action on nutrient and wastewater pollution, as well as the substantial risks associated with continued inaction. To address these challenges effectively, the brief calls for breaking down siloed policy approaches. This integrated approach aims to unlock opportunities for climate mitigation and adaptation, nutrient and energy recovery, soil restoration, and more efficient water use (Food and Agriculture Organization [FAO] and UNEP 2021).

Despite the mounting impacts of nutrient and wastewater pollution, the issue is often overlooked, even though it is closely linked to global challenges of climate change, food security and human health. States can work through UNEP to advocate for sustainable nutrient and wastewater management. UNEA is a powerful platform for driving global action, with recent resolutions² supporting this agenda.

In 2026, it is critical that policymakers capitalize on the opportunities offered by sustainable nutrient and wastewater management. This can be achieved through targeted strategies, financial incentives, regulatory frameworks, and cross-sectoral partnerships. Such efforts are crucial to accelerating the transition to sustainable and integrated solutions.

² UNEA Resolutions: 4/14 2019 Sustainable nitrogen management; 5/2 2022 Sustainable nitrogen management; 5/7 2022 Sound management of chemicals and waste; 7/4 2025 Strengthening the global response to the massive influx of sargassum seaweed blooms.



Grand-popo, Mono, Benin © GRID-Arendal / Rob Barnes

02

Opportunities versus business as usual

Cost of inaction versus benefits of action related to nutrients

Nitrogen (N) and phosphorus (P) are essential for plant growth. They feed the world, but when applied in excess or in the wrong place, they contaminate air, degrade water and soil quality, and alter the balance of the Earth's biogeochemical cycles (Sutton *et al.* 2011; Peñuelas and Sardans 2022).

Policymakers and financial markets often fail to account for the external costs of nutrient pollution and fertiliser overuse, which consistently undervalues nutrient flows. This undervaluation is perpetuated by tax structures, subsidies, and regulatory environments that do not reflect the true environmental costs of nutrient mismanagement (UNEP 2025). Some examples of these costs include:

- **Inefficient and damaging food production practices.** Globally, it is estimated that food production incurs approximately **US\$ 10 trillion annually** in hidden costs, including those related to nutrient loss, pollution, and environmental degradation. These costs are not reflected in food prices, leading to distorted market signals and underinvestment in sustainable nutrient solutions (Ruggeri Laderchi *et al.* 2024).
- **Poor water quality.** Algal blooms caused by excess nutrients have huge economic and social costs. A recent review (Baker, Thygesen and Harris (2024)) identified more than 1000 hypoxic or eutrophic coastal “hot spots” around the globe. One notable hotspot caused by excess nutrient runoff is located in the Gulf of Mexico, where the resulting hypoxic zone was estimated to cost Gulf fisheries between **US\$ 552 million and US\$ 2.4 billion annually** from 1980 to 2017 (Boehm 2020). In the United States, one tonne of nitrogen, which has a current value of approximately US\$ 600, is estimated to cause US\$ 642 of environmental damage due to algal blooms³. In 2025, about 25 per cent of the South Australian coastline has been impacted by an algal bloom caused by excess nutrients transported in floodwaters from the Murray River (Australia, Government of South Australia 2025).

The bloom has affected marine tourism, fishing charters, aquaculture, and seafood exports. The government has so far provided AU\$ 28 million to support impacted industries and fund the cleanup.

Seaweed blooms, particularly of *Sargassum* species, represent another nutrient-related issue. Vast quantities of rotting seaweed that accumulate on beaches impose significant economic and environmental burden on affected coastlines⁴. In 2018, the estimated cleanup cost across the Caribbean alone was **US\$ 120 million** (United States Environmental Protection Agency [US EPA] 2025a).

- **Poor ground water quality.** Nitrate pollution of groundwater is increasingly common. In China, a recent review found that nitrate pollution levels almost doubled between 1990 and 2020, largely driven by agriculture. The authors found that 44.7 per cent of 4752 groundwater samples exceeded the WHO maximum contamination level of 10 mg/L (Zhou *et al.* 2024). Exposure to high levels of nitrate is linked to health issues such as methemoglobinemia (blue baby syndrome) and increased cancer risks (Bouchard *et al.* 1992).
- **Poor air quality.** Especially in urban areas affected by ammonia and nitrogen oxides (NO_x), nitrogen air pollution was estimated to have caused 23.3 million years of life lost in 2013, equating to a welfare cost of **US\$ 420 billion for premature death** (Gu *et al.* 2021).

While the cost of inaction is staggering, the cost of action is far more favourable and offset by savings and co-benefits. For example, a recent global study (Zhang *et al.* 2025) found that implementing 32 mitigation measures across seven sectors in 185 countries could halve global ammonia emissions at a cost of US\$ 279 billion, while delivering benefits **worth US\$ 568 billion**, resulting in a **net co-benefit of 289 billion**. Among these measures are fourteen low-cost options targeting agricultural fertiliser use and domestic food waste, which together could reduce ammonia (NH₃) emissions by 84 per cent.

³ Taylor and Heal 2021 – recalculated from US\$ 583 per ton.

⁴ UNEA Resolution 7/4 (2025) strengthens the global response to the massive influx of sargassum seaweed blooms, recognising them as a severe and escalating socioeconomic and environmental challenge in the wider Caribbean and West Africa, with potential impacts elsewhere. The resolution notes the adverse effects on tourism, fisheries, livelihoods, health, marine biodiversity, and the conservation of marine and coastal ecosystems.

The associated benefits include improved health, food security, and climate outcomes. The highest net social benefits were projected in India and China, where nutrient-pollution burdens and population exposure are greatest.

Other measurable economic, environmental, and public health gains that could be accrued across sectors and regions include:

- **Enhanced soil health and agricultural productivity.** Better nutrient management can reduce dependency on synthetic inputs. There are huge savings to be made in fertiliser efficiency: nearly 75 per cent of applied nitrogen and more than 50 per cent of phosphorus are not used by crops (Ritchie 2021). Experiments in China have shown that smallholder farmers, many of whom are women, can produce more grain with less fertiliser through optimising application rates (Ren *et al.* 2022).
- **Lower greenhouse gas emissions.** Nitrous oxide (N₂O) accounted for 6 per cent of greenhouse gas emissions in the United States in 2022 (United States Environmental Protection Agency [US EPA] 2025a) and has risen by nearly 25 per cent globally since pre-industrial era (Tian *et al.* 2024), mostly as a result of fertiliser use. In 2019, agriculture contributed approximately 46 per cent of global anthropogenic methane (CH₄) emissions (Hegde *et al.* 2025).
- **Nutrient circularity.** Recovering nutrients from wastewater could offset **~13.4 per cent** of global agricultural nutrient demand (Qadir *et al.* 2020). EU modelling suggests expanding RENURE to include nitrogen recovery from manure could cut nutrient loss by **50 per cent**, fertiliser use by **20 per cent**, and costs by **~5 per cent** in livestock-dense regions (Vingerhoets *et al.* 2025).
- **Biodiversity conservation.** Reducing the **60 million tonnes** per year of nitrogen pollution exported from rivers into the ocean (Howarth 2008) could help restore balance in aquatic and terrestrial systems. Recovering the nitrogen loss from fertiliser and sewage per year⁵ could be worth more than **US\$ 36 billion**.
- **Improved water quality.** Access to clean water has multiple economic and social benefits, including increased labour productivity and improved educational outcomes. In developing states, women and girls

are disproportionately affected by poor water quality due to their roles in household water management and caregiving. Improved water quality can reduce time spent collecting water and lower health risks, especially for pregnant women and children. In addition, improving the quality of water entering the coastal and marine environment reduces the likelihood of costly eutrophication events.

Cost of inaction versus benefits of action related to wastewater

Untreated wastewater poses significant risks to human health (particularly for children), ecosystems, and economies, yet its management offers transformative opportunities. The cost of inaction includes hundreds of billions in lost agricultural productivity, degraded fisheries, and increased healthcare burdens (Hernandez-Sancho *et al.* 2015). For example,

- **Public health costs.** About half of the world's wastewater enters the environment without treatment (United Nations Human Settlements Programme [UN Habitat] and World Health Organization [WHO] 2021). Water-related diseases kill over 1000 children under the age of 5 every day (United Nations Children's Fund [UNICEF] 2023). Women, particularly mothers and caregivers, are on the frontlines of managing household health and sanitation. Gender-responsive wastewater management can reduce caregiving burden and improve maternal and child health outcomes (UNICEF 2017). While exact health costs of wastewater related illness and death are difficult to quantify due to data gaps, **annual public health costs** are estimated in the **trillions of US\$**. For example, WHO estimated that in 2019 there were more than 1 million deaths related to faecal contamination and 74 million disability-adjusted life years (DALYs). Using a conservative estimate this represents a loss of **US\$ 5.074 trillion**⁶ (WHO 2025).

Contaminated wastewater is also a hotspot for antimicrobial resistance (AMR), with microbes, genes, and residues circulating into water bodies, agriculture, and food chains (Hanna *et al.* 2023). UNEP (2023a) frames AMR as a pollution-driven challenge with serious cross-sectoral implications. AMR contributes to almost 5 million deaths globally a year (UNEP 2023a), and the number could rise to

⁵ Calculated using US\$ 600 tonne of N (as urea)

⁶ Calculated using death = US\$ 5 million, DALY = US\$ 1000

8.22 million a year by 2050 (GBD 2021 Antimicrobial Resistance Collaborators 2024) highlights growing evidence on the key role the environment plays in the development, transmission and spread of AMR. AMR is also closely linked to the triple planetary crisis of climate change, biodiversity and nature loss, and pollution and waste. Strengthening wastewater management and nutrient governance provides a direct and cost-effective entry point to prevent and reduce the environmental dimensions of AMR. There are significant economic benefits from taking action: under the worst-case AMR scenario, cumulative global losses by 2050 could exceed **US\$ 293 billion** (Fernando and McKibbin 2025).

Removal of PFAS in Minnesota


US\$ 12 billion to US\$ 25 billion
 Estimate for removing
 PFAS from wastewater
 effluent in Minnesota

Source: MPCA 2023

Figure 2: Removal of PFAS in Minnesota

This figure includes projected healthcare costs, agricultural losses, reduced economic productivity, and environmental degradation.

In addition to AMR, chemicals of emerging concern (CECs), such as per- and polyfluoroalkyl substances (PFAS) and microplastics, pose growing risks to aquatic ecosystems and human health due to their persistence and resistance to degradation. Most

conventional wastewater treatment plants are not designed to effectively remove these contaminants. The cost of removal is projected to be prohibitively high for many communities. For example, the Minnesota Pollution Control Agency (Minnesota Pollution Control Agency [MPCA] 2023) estimated that removing PFAS from the wastewater effluent could cost between 12 and 25 billion over the next 20 years⁷ (Figure 2). While PFAS cost between US\$ 110 and 2200 per kg, the cost of removing and destroying them from municipal wastewater ranges from US\$ 5.97 million to nearly 40 million per kg (Figure 3) (MPCA 2023). These figures underscore the importance of urgently reducing the discharge of dangerous substances.

- **Environmental degradation.** A recent report found that Brazil faces an estimated US\$ 16 billion annual loss in crop yields due to wastewater-induced soil salinity, while India's fisheries sector has suffered over US\$ 2 billion in losses from contaminated waterways (Economist Impact 2025).

Conversely, the opportunities from action are substantial. Effective wastewater treatment can improve public health, restore ecosystems, and create circular economies through water reuse and nutrient recovery (UNEP 2023c). Many benefits of wastewater management, such as reduced disease burden (especially for children) and improved environmental quality, are not considered by the market, leading to chronic underinvestment (Hernandez-Sancho *et al.* 2015). Addressing this gap through integrated valuation and policy reform can unlock sustainable development gains and climate resilience.

⁷ This does not include the additional considerable cost of removing PFAS from WRRF biosolids or landfill leachate (MPCA 2023)

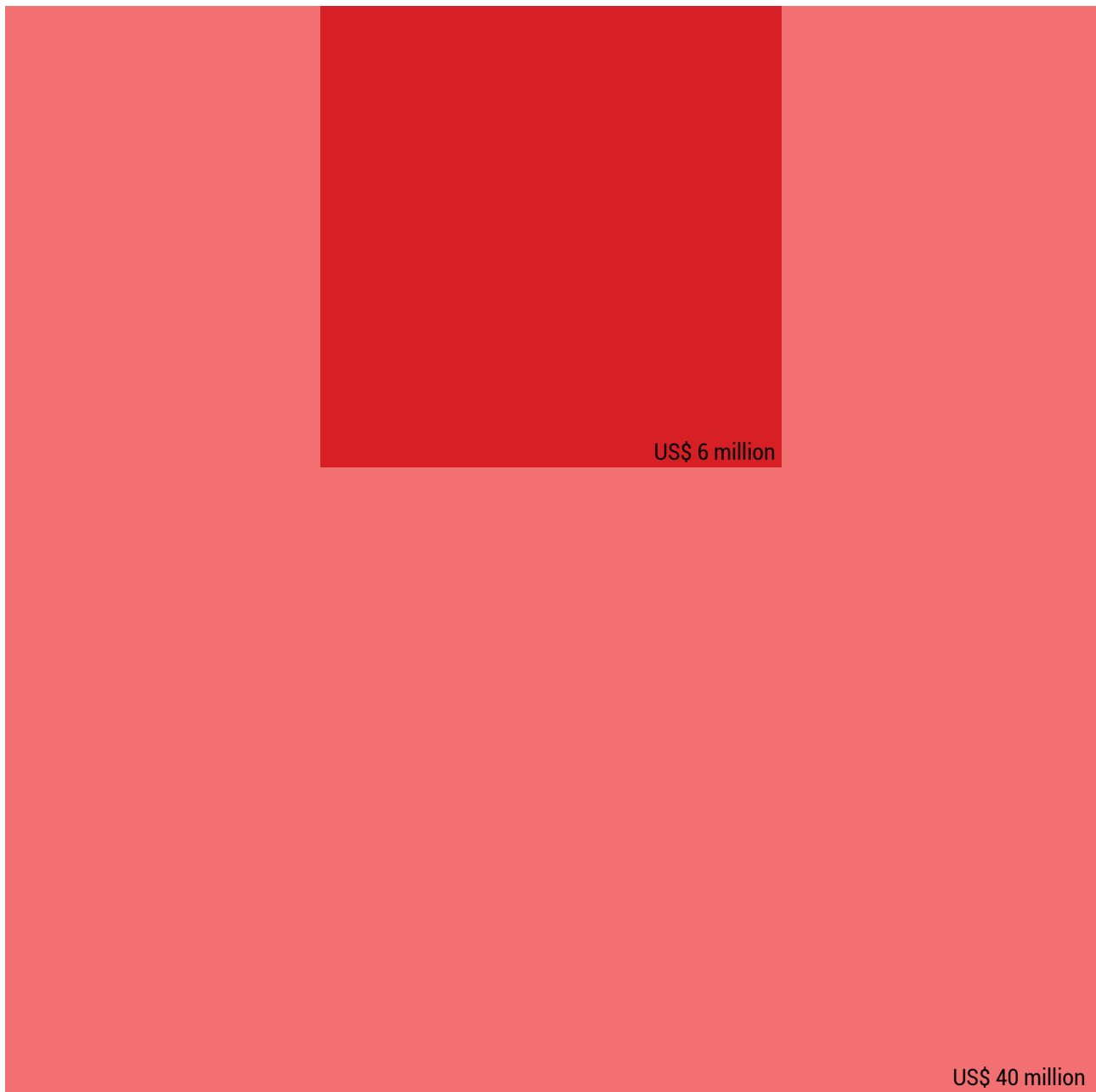


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The costs of PFAS

PFAS cost US\$ 110 to US\$ 2200 per kilo **to buy**, while

PFAS cost nearly US\$ 6 million to US\$ 40 million per kilo **to clean-up and destroy**



Source: MPCA 2023

Figure 3: The costs of PFAS



Large-scale centralized wastewater treatment as an energy source in Hamburg, Germany.
© Kristina Steiner for Hamburg Wasser

The list below documents specific economic costs and benefits related to wastewater management:

- **Energy from wastewater.** It is estimated that wastewater contains 5 times the amount of energy needed for treatment (Hao *et al.* 2019). Wastewater could potentially provide nearly 2 trillion kWh - enough energy to supply up to half a billion people (Qadir *et al.* 2020). Using an average global energy price of US\$ 0.165 per kWh, this energy could be worth **US\$ 350 billion per year**. An additional benefit can also come from recovering nutrients and upgrading recovered nutrients into other products (see Box 1). Human urine could provide 15-20 per cent of global agricultural nitrogen (US\$ 14.4 billion) and 20-25 per cent of P (US\$ 9.6 billion) as well as a significant amount of potassium (K) (US\$ 4.8 billion)⁸. The total annual value of urine could be **US\$ 28.8 billion**.
- **Recovery of clean water from wastewater:** Globally, water use has been increasing by 1 per cent per year over the last 40 years, according to FAO's FAOstat database (Food and Agriculture Organization of the United Nations [FAO] and United Nations Environment Programme [UNEP] 2021), with the highest increases in middle- and lower-income economies (Ritchie and Roser 2018). Currently, **up to 3.2 billion people live with water stress** at some point every year. The reuse of well-treated wastewater could provide 30-50 per cent of irrigation demand (FAO 2025b). As irrigation water this

could be worth as much as **US\$ 35 billion per year**⁹.

- Alternatively, this **350 billion m³** of water is enough water to cover the annual water footprint of **252 million people**¹⁰. Improved access to clean water through wastewater recovery can significantly reduce the time and physical burden women and girls face in water collection. This frees up time for education, income-generating activities, and caregiving. It also enhances household hygiene and health, which especially benefits children as they are most vulnerable to waterborne diseases.
- **Carbon market or climate mitigation:** In general, **1–2 direct jobs** per 1,000 people are created by improved wastewater infrastructure (International Labour Organization [ILO] 2021). If wastewater treatment were universal, an additional 3.6 billion people (United Nations Educational, Scientific and Cultural Organization [UNESCO] 2023) would have safely treated wastewater – extrapolating, this could generate 3.6 million to 7.2 million direct jobs. In addition, wastewater treatment's estimated 1.57% share of global GHG emissions (Dickin, S. *et al.* 2020), applied to 52.4 GtCO₂eq global emissions in 2019 (PBL 2020), equates to roughly 822 million tonnes CO₂eq annually – worth up to US\$ 4.9 billion at voluntary carbon market prices (World Bank 2024).

⁸ Calculated assuming average person produces 500 l urine per year which contains 6 g N/l, 0.8 g P/l, and 1.5 g K/l and a global population of 8 billion. Therefore 24 million tonnes/year N, 3.2 million tonnes/year P and 6 million tonnes/year K. Average price of 1 tonne N = US\$ 600, 1 tonne elemental P US\$ = 3000 and 1 tonne elemental K = US\$ 800.

⁹ This assumes that a m3 of irrigation water is worth US\$ 0.10

¹⁰ See Jones *et al.* 2021 – 252 million people assumes an average water footprint of 1385 m3 per capita per year between 1996 and 2005 taken from Hoekstra and Mekonnen 2012

Box 1: Unlocking High-Value Markets Through Recovered Nitrogen

Product	Global market (US\$ billions/year)	Market price (US\$ per metric ton)	Use(s)
N-fertiliser (Urea, ammonium nitrate, anhydrous ammonia, etc.)	57.1 (2021)	360–570	Agriculture
Nitric acid	29.8 (2022)	300–400	Explosive, dye
Amines	15.6 (2021)	2900–3500	Surfactants, pesticides, carbon capture
Animal feed	570.7 (2022)	150–370	Livestock, aquaculture
Amino acids	27.2 (2023)	1400–10 000+	Food flavouring, cosmetics, pharmaceuticals
Acrylonitrile	11.2 (2022)	1900–2400	Fibres, thermoplastic polymers
Acrylamide	3.6 (2023)	1300–2200	Wound care, slow-release fertiliser
Nylon	34.4 (2023)	2000–3200	Automobile, engineering plastics
1,4-diaminobutane	0.1 (2018)	–	Nylon 4/6 (PA46)

Adapted from Apraku et al. 2025

Recovered nitrogen can serve high-value markets beyond agriculture. Wastewater treatment plants can convert nitrogen into valuable compounds for industry and biotechnology

Examples of value streams:

Industrial chemicals

Recovered nitrogen, particularly in the form of ammonia, can be used to produce compounds such as alkyl amines, nitric acid, and nitroglycerin, which are essential in the production of rubber, pesticides, and solvents for carbon capture. These chemicals are part of established global markets with consistent demand and pricing.

Alternative proteins via cyanohydrin

Cyanophycin is a nitrogen-rich biopolymer composed of amino acids like arginine, lysine, and aspartic acid, which are commonly found in soybean and fish meals. It offers a sustainable alternative for animal feed, reducing greenhouse gas emissions (especially nitrous oxide) and land use, while improving nitrogen efficiency in food systems.

High-value biochemicals

Extracted amino acids and nitrogen-based compounds can be refined into pharmaceuticals, food additives, and cosmetics, or processed into specialty chemicals such as acrylonitrile, acrylamide, and 1,4-diaminobutane, which are key inputs in multi-billion-dollar material markets. Investing in nitrogen recovery supports emission reductions, regulatory compliance, and Environmental and Social Governance (ESG)-aligned revenue generation. These attributes make nitrogen recovery projects highly attractive to green finance, infrastructure funds, and climate-focused investors.



Aerial view directly above the water tanks at a Water Treatment plant. © Envato / jacksonnick

03

Addressing the nutrient and wastewater challenge: policies and frameworks

Global conventions and frameworks targeting nutrient and wastewater pollution

Addressing nutrient pollution and improving wastewater management requires integrated policies and frameworks that span environmental protection, public health, agriculture, and infrastructure. Global initiatives such

as the SDGs, the Kunming-Montreal Global Biodiversity Framework, and AMR action plans provide strategic entry points (Table 1). These frameworks promote circular approaches to resource recovery, encourage cross-sectoral coordination, and support evidence-based investments that unlock co-benefits, such as enhanced agricultural productivity, improved water security, and climate resilience.

Table 1: Global Conventions and Frameworks Targeting Nutrient and Wastewater Pollution

Convention / Framework	Focus Area	Mechanism	Geographic Scope
UNEP Working Group on Nitrogen (WGN)	Sustainable nutrient use	Global Nitrous Oxide Assessment. Policy and technical support for national action plan on sustainable nitrogen management	Global
Regional Seas Conventions & Action Plans	Marine pollution, eutrophication	Nutrient Pollution Reduction Strategies, eutrophication assessment tools	Regional (e.g., Caribbean, Mediterranean, Northwest Pacific)
Global Partnership on Nutrient Management (GPNM)	Nutrient pollution from agriculture, wastewater	Knowledge products, pilot projects, regional platforms	Global with regional hubs
UNEA Resolutions 4/14 & 5/2	Sustainable nitrogen management	National action plans, technical and financial support	Member States of UNEP
Basel Convention	Hazardous waste management	Controls transboundary movement of waste, including nutrient-rich sludge	Global
SDG Framework (esp. SDG 6 & 14)	Clean water, ocean health	Targets on wastewater treatment, nutrient pollution reduction	Global
Kunming-Montreal Global Biodiversity Framework	Biodiversity protection	Pollution reduction targets including nutrient runoff	Global
One Health Approach	Human, animal, and environmental health	Integration of wastewater into AMR action plans	Global
Global Methane Pledge	Voluntary agreement with 111 countries participating	Aim to cut methane emissions by 30 per cent below 2020 levels by 2030. Includes energy, waste and agriculture sectors	Global

National actions to reduce nutrient loss and improve efficiency

UNEA Resolution 4/14 (UNEP 2019) called for coordinated policies across the global nitrogen cycle at national, regional and global levels, highlighting fragmentation and the need for an integrated approach. This resolution laid the groundwork for the formation of the UNEP Working Group on Nitrogen, tasked with supporting global coherence in nutrient management. In 2022, UNEA Resolution 5/2 called on all Member States to step up action to cut global nitrogen waste by 2030 and beyond and asked UNEP to help develop national action plans and strengthen policy coordination.

Traditionally, policies and regulations governing nutrient management in agriculture, wastewater processing, and industry have been developed in isolation and for distinct purposes. For example, in the United Kingdom, nutrients are predominantly framed as a pollution risk, with limited recognition of their resource value (Yuille *et al.* 2022). Globally, policies focus on water pollution while neglecting air and climate impacts (Kanter *et al.* 2020). Given cascading effects of nutrient pollution across ecosystems, an integrated systems approach reduces the risk of shifting pollution from one sink to another (Velenturf *et al.* 2018; Kanter *et al.* 2020).

A national plan to support integrated nutrient management policy actions and implementation frameworks could include:

1. Developing National and Regional Integrated Nutrient Management Action Plans (INMAPs)

These plans align nutrient policies with climate, biodiversity, and pollution goals. In 2024 and 2025, UNEP supported Sri Lanka and Trinidad and Tobago in developing national action plans for sustainable nitrogen management, engaging stakeholders from ministries of agriculture, industry, environment, energy, academia, and the private sector.

Moreover, the European Union's INMAP coordinates nitrogen and phosphorus management across agriculture, urban systems and environmental compartments (air, soil, water) and aims to reduce nutrient losses by 50 per cent by 2030 (Grizzetti *et al.* 2023).

2. Embedding Nutrient Management in National Sustainable Development Strategies

NDCs and SDG strategies increasingly recognize the importance of nutrient management (e.g. CCACs Guidance on Including N₂O in NDCs 2024). However, as of 2019, fewer than 25 per cent of countries included mitigation commitments on fertiliser and manure management in their NDCs (Nieuwkoop 2019). Costa Rica explicitly promotes nutrient efficiency in its NDCs with measures such as precision fertilization, organic alternatives, improved manure management, and soil health practices, and integrating nutrient management into broader climate-smart agriculture strategies.

3. Developing Regional and Localized Nutrient Strategies

Tailoring nutrient policies to regional ecosystems and watershed conditions and using demonstration sites to test and scale up region-specific solutions can be useful. Examples include the Coordinating Body on the Seas of East Asia (COBSEA) *Collaborative Action Framework on Nutrient Management* and the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region or Cartagena Convention *Regional Nutrient Pollution Reduction Strategy and Action Plan for the Wider Caribbean Region* (United Nations Environment Programme, Caribbean Environment Programme [UNEP/CEP] 2021)

Box 2: Technological innovations in nutrient management

Emerging biological approaches to nitrogen management include seed-inoculation technologies developed through research at the University of Nottingham, using *Gluconacetobacter diazotrophicus*, a bacterium first identified in sugarcane. Once established intracellularly, the bacterium can convert atmospheric nitrogen into ammonia within the plant, offering a pathway to reduce reliance on synthetic nitrogen fertilisers in wheat and other non-leguminous crops (Cocking and Dent 2019; Sebring *et al.* 2022; Ceballos-Aguirre 2025).



Box 3: Nutrient Trading and Market Mechanisms

Nutrient credit trading can be a cost-effective complement to regulation, provided MRV systems ensure real, additional reductions and guard against hotspots. The Chesapeake Bay watershed's programme (since 2005) is a long-running example. In 2020, ~150,000 kg of total N and ~40,000 kg of total P were traded (US EPA 2024). Overall, bay health has improved since 2002, reflecting multiple strategies including trading (University of Maryland 2024).



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4. Supporting the use of technology (Box 2) and tools

Implementing the use of nutrient risk assessment tools, such as those recommended by the Southland Regional Council in New Zealand, can be highly beneficial. In Southland, farmers are required to prepare a nutrient budget or conduct a nutrient loss risk assessment (Southland Regional Council 2025). Councils can also set nutrient limits, require annual reporting of fertiliser and manure use, and mandate buffer zones. Furthermore, governments and authorities can enhance these efforts by providing technical assistance, micro-grants, and training for nutrient-smart practices, support farmer cooperatives and peer learning networks to share innovations and recognize and reward local champions of nutrient stewardship.

5. Establishing Nutrient Trading and Market Mechanisms

Establishing nutrient trading and market mechanisms like carbon trading, can (see Box 3) cost-effectively meet nutrient reduction targets. However, the system requires careful monitoring and verification to ensure real reductions and trading can allow some sectors or areas to maintain high nutrient loads if reductions are made elsewhere. This can create local hotspots.



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National actions to improve wastewater management and build a wastewater circular economy

UNEA Resolution 3/10 calls for halving the proportion of untreated wastewater by 2030 and urges support for developing countries to build capacity for wastewater treatment, integrate gender perspectives, and adopt sustainable technologies (UNEP 2017). In 2023, a UNEP rapid response assessment reframed wastewater as a valuable resource with major circular economy potential (UNEP 2023b).

However, a recent review (Ratnaweera, Heistad and Navrud 2021) highlighted the monetary valuation gaps in regional and global cost benefit analysis guidelines, which are crucial for justifying investments in wastewater treatment. In response to UNEP's recommendations (UNEP 2023c), national strategic plans to support integrated wastewater management policies and implementation frameworks, designed to capture the co-benefits of improved wastewater practices, could include:

1. Integrating wastewater into national water and climate policies and AMR national action plans by embedding wastewater management into broader water security, climate adaptation and circular economy strategies, governments can promote the recovery of water, nutrients and energy. This approach transforms wastewater into valuable inputs for sustainable development and reinforces circular economy principles. It can also stimulate innovation in treatment and help to create markets for circular products like fertiliser and other recovered resources (UNEP 2023c).
2. Including wastewater in AMR national action plans helps prevent antimicrobial resistant pathogens and residues from entering aquatic systems. This is essential for safeguarding both ecosystem and human and animal health, consistent with the One Health approach. These actions also support the necessary cross-sectoral coordination among health, agriculture, environment, and infrastructure ministries.
3. Developing comprehensive frameworks that promote safe and sustainable reuse of treated wastewater in agriculture, industry, and urban landscapes, can be included in the plan. This may include guidelines for water-quality standards, monitoring protocols of pollutants including AMR and pharmaceuticals, and information campaigns to build public acceptance. The use of treated wastewater and by-products such as sludge fertiliser can be problematic due to associated pathogen and contamination risk. The United Arab Emirates is an example of safe and productive use of treated municipal wastewater for irrigation use. The United Arab Emirates has implemented a national strategy for treated wastewater reuse that includes rigorous monitoring of soil and crop health and public education (Global Water Awards 2024).
4. Strengthening wastewater discharge permitting systems can help enable a circular economy for wastewater by creating a framework that encourages safe reuse and resource recovery. Thresholds of effluent water quality, including chemicals (like Per- and Polyfluoroalkyl Substances (PFAS)) and pharmaceuticals ensure that discharged wastewater is safe for reuse and by linking permits to performance metrics, governments can incentivise utilities and industry to adopt advanced treatment technologies that include resource recovery and reuse.



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**Soybean crop seedling field irrigation,
agricultural sprinklers watering plants.**
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04 Financial mechanisms

Financial mechanisms to address nutrient pollution and develop the potential of wastewater need to align economic incentives with environmental sustainability. Several countries, regional organisations and markets have started to create definitions of sustainable finance that include sustainable nutrient and wastewater management (Organisation for Economic Co-operation and Development [OECD] 2020). These taxonomies can be used to help correct market failures by aligning public and private investment with sustainability goals. They can be used to determine which projects qualify for green bonds, sustainability-linked loan financing bonds, transition bonds, and blended finance (Box 4).

Box 4: Green and blue bonds and sustainable bonds

Green bonds are financial instruments used to raise capital for projects related to reducing GHG emissions or deliver other environmental benefits. Since the 2015 Paris Agreement, the green bond market has grown exponentially, reaching a market capitalization of US\$ 2.9 trillion in 2025. In 2024, green bonds outperformed conventional bonds by 2 per cent, according to the Bloomberg Global Bond Index. Market analysts expect continued growth, with the European Union remaining the dominant issuer and significant expansion anticipated in Asia (Plé 2025). The International Finance Corporation (2025) recently released the Guidelines for Blue Finance 2.0. These guidelines build on the green bond principle and are designed to help identify investments that contribute to the sustainable use of water and ocean resources. Eligible activities include those that reduce the use of fertiliser and improve water and wastewater management.

Beyond green and blue bonds, other sustainability-linked financial products are also gaining traction. These include Sustainability-Linked Loan Bonds (SLLBs), which allow financial institutions to issue bonds backed by portfolios of sustainability-linked loans (Box 5). These loans tie financing terms to specific sustainability performance targets, such as improving water quality (International Capital Market Association [ICMA] 2024).

Box 5: Role of financial institutions

Financial institutions have a critical role to play in addressing nutrient pollution and improving wastewater management by embedding these environmental risks into their core decision-making frameworks. Banks can incorporate nutrient and wastewater risks into ESG assessments and offer sustainability-linked loans that incentivize borrowers to reduce nutrient discharges or increase wastewater treatment and reuse. Investors can prioritize transition finance for circular nutrient systems, supporting innovations that close nutrient loops and reduce environmental leakage. Insurers can help manage risk by underwriting pollution liability and infrastructure losses stemming from nutrient-driven events such as harmful algal blooms. Central banks, meanwhile, could integrate nutrient and wastewater risks into national financial stability stress tests to better understand systemic vulnerabilities. These initiatives align with frameworks like the Principles for Responsible Banking and Sustainable Insurance.

Financing nutrient abatement

While existing taxonomies may reference pollution reduction, projects specifically targeting nutrient abatement (distinct from wastewater treatment plant upgrades that incidentally reduce nutrient loads) have little visibility in either the green or blue bond market. The omission currently limits investment in critical infrastructure and innovation aimed at mitigating nitrogen and phosphorus pollution from agriculture, wastewater, and urban runoff. A key barrier appears to be the lack of clear measurable standardized impact metrics. In addition, nutrient removal projects, such as wetland restoration, are often viewed as public good with diffuse benefits. Unlike energy or transport projects, these benefits have been slow to attract market-based monetization, further hindering private sector engagement.

Financing sustainable wastewater management

Wastewater projects often secure sustainable finance due to measurable outcomes (cleaner water, public health) and multiple revenue streams (UNEP 2023c). Europe alone is likely to invest 20-30 billion euros in new and upgraded WWTPs over the next few years to comply with the forthcoming Urban Wastewater Treatment Directive (extrapolated from Kardos *et al.* 2025).

However, wastewater management financing in most developing countries has seen limited success, with progress constrained by infrastructure gaps, financial limitations, institutional capacity issues and policy challenges. Innovative financing mechanisms such as debt-for-climate swaps offer a potential pathway (Box 6). These arrangements involve forgiveness or acquisition of a country's debt in exchange for commitments to environmental improvements. In the context of wastewater management, countries can redirect resources currently allocated to servicing debt to enhancing wastewater infrastructure and systems (Elmahdi and Jeong 2024). It is estimated that more than US\$ 100 billion of debt in developing countries could be released to support climate change adaptation, including water reuse and nutrient recovery. Debt-for-climate swaps have been utilised in Cabo Verde, Ecuador, and other developing states (International Institute for Environment and Development [IIED] 2024).

Box 6: Debt-for-climate swaps in Barbados

In 2024, Barbados partnered with the Inter-American Development Bank, the European Investment Bank, and the Green Climate Fund, in a debt-for-climate resilience swap, structured around a Sovereign Sustainability-Linked Loan (SSLL) backed by US\$ 300 million in guarantees. This arrangement unlocked US\$ 125 million in savings, reinvested in climate-resilient infrastructure, including upgrading the South Coast Sewage Treatment Plant to a state-of-the-art water reclamation facility agricultural reuse, groundwater recharge, and ecosystem restoration (European Investment Bank [EIB] 2024).

Other mechanisms include carbon credits (e.g., methane capture), payments for ecosystem services, polluter-pays instruments, revolving funds, and public-private partnerships (PPPs). Integrating SMEs into recovery value chains (nutrient recycling, biogas, reuse) can stimulate local economies and enhance circularity. Together, these create a diversified, resilient finance ecosystem for sustainable wastewater management.



05 Conclusions and way forward

The current understanding of the implications of nutrient pollution, especially excess nitrogen and phosphorus, is still evolving. However, evidence indicates that both contribute significantly to the current environmental crisis. While climate policy has focused on carbon dioxide (CO₂) emissions, human-induced nitrogen and phosphorus flows have exceeded safe limits for maintaining stable, life-supporting systems, also referred to as planetary boundaries (Rockstrom *et al.* 2009a; Rockstrom *et al.* 2009b). The impacts of nutrient pollution are unevenly distributed around the planet, mainly due to differences in fertiliser application. Many countries in Africa, for instance, are nutrient deficient, which limits food production. These locations need more nitrogen and phosphorus to achieve food security, while the regions that have pushed us past the planetary boundary need to find ways to reduce the loss of nutrients while maintaining agricultural productivity. It's a delicate balance. Similarly, wastewater volumes are steadily increasing, and despite some progress in treatment and reuse over the past decade, untreated wastewater remains a major global challenge. Approximately half of the world's wastewater still enters the environment without adequate treatment.

Unlocking the value of wastewater requires a fundamental shift in how we perceive and manage this resource. Safe and appropriate wastewater management for resource recovery and reuse goes beyond achieving water security - it offers a range of co-benefits, including improved environmental and human health, protection of biodiversity, reduced reliance on synthetic fertilisers, and opportunities for diversified energy production and

economic development. Crucially, it reduces the risk of AMR development and spread, strengthening the resilience to one of the most pressing global health, economic and sustainable development threats. To advance this agenda, there is an urgent need to better understand the hidden costs of nutrient and wastewater mismanagement and to quantify co-benefits, such as increased agricultural productivity, reduced healthcare costs, improved water security, and climate mitigation. Without a robust evidence base, projects struggle to demonstrate compelling economic returns, making it difficult to attract funding from governments, donors, and private investors.

To accelerate progress on nutrient and wastewater circularity, Member States need to consider adopting a coordinated implementation pathway under UNEP's leadership. In the short term, this approach could leverage the experience of the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA) and the UNEP Working Group on Nitrogen to deliver quick wins through pilot projects, regulatory guidance and knowledge sharing platforms. In the longer term, the pathway would support integration of nutrient and wastewater circularity into national development agendas and global governance. This includes aligning financing with the SDGs, the Kunming-Montreal Global Biodiversity Framework, and climate adaptation strategies. Currently, fragmented governance strategies and underdeveloped or underused finance taxonomy are impeding progress.



06

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