Back to Blue

An initiative of
Economist Impact and The Nippon Foundation

THE SCOURGE OF UNTREATED WASTEWATER

The economic, environmental and human costs of inaction

Jointly supported by

OCEAN SEWAGE ALLIANCE

ECONOMIST IMPACT

THE NIPPON FOUNDATION

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About the report

The scourge of untreated wastewater: The economic, environmental and human costs of inaction is a report written by Economist Impact for Back to Blue, an initiative of Economist Impact and The Nippon Foundation. The report is additionally supported by the Ocean Sewage Alliance. This is a pilot study intended to establish a foundation to more widely explore this issue in the future. Its broader purpose is to highlight the need for countries to reduce the discharge of inadequately treated domestic wastewater.

The analysis in the report is based on a model that estimates the economic loss that selected countries suffer from domestic wastewater pollution. The model's scope in this exploratory effort was confined to five countries—Brazil, India, Kenya, the Philippines and the UK—and selected contaminants and impacts. (See the Appendix for a detailed description of the model methodology.) We intend to widen the model's scope in future research.

The model was devised and constructed by Bilge Arslan, Ritu Bhandari, Shivangi Jain and Shreyansh Jain. The report was written by Denis McCauley and edited by Naka Kondo. The initiative lead for Economist Impact is Charles Goddard.

This project has benefitted from counsel provided at various stages by a panel of experts consisting of prominent authorities on water resources and wastewater pollution. These include the following (listed alphabetically by institution):

- Jitendra Kumar Singh, water supply and sanitation specialist, Water and Urban Development Sector Office, **Asian Development Bank**
- Harry Liiv, special envoy for transboundary waters, Ministry of Climate, Estonia; vice-chair, **Bureau of the Convention on the Protection and Use of Transboundary Watercourses and International Lakes**
- Ricardo Cepeda-Márquez, head of waste strategy and technical programmes, **C40 Cities**
- Michelle Devlin, science theme lead—chief science officer, Centre for Environment, **Fisheries and Aquaculture Science (Cefas)**
- Leon Barron, reader in analytical and environmental sciences, **Imperial College London**
- Jasmine Fournier, executive director, **Ocean Sewage Alliance**

- Stephanie Johnson, senior program officer, **The National Academies of Sciences, Engineering, and Medicine**
- Richard Damania, chief economist, Sustainable Development Practice Group, **The World Bank**
- Esha Zaveri, senior economist, **The World Bank**
- Martha Rogers, senior economist, **The Nature Conservancy**
- Martin Gambrill, former lead water and sanitation specialist, The World Bank; consultant, The World Bank; visiting professor, **University of Newcastle and University of Leeds**
- Juliet Willetts, professor, Institute for Sustainable Futures, **University of Technology Sydney**
- Amelia Wenger, conservation scientist and water pollution program lead, **Wildlife Conservation Society**
- Stewart Sarkozy-Banoczy, managing director and CEO, World Ocean Council, and steering committee chair, **Ocean Sewage Alliance**

To inform our analysis, we also conducted a series of in-depth interviews with experts in this field:

- Will Le Quesne, director, Centre for Environment, Fisheries and Aquaculture Science (Cefas), UK Department for Environment, **Food and Rural Affairs**
- Nitin Bassi, senior programme lead, Sustainable Water Team, Council on Energy, **Environment and Water (CEEW)**
- Grace Wambui, water and sanitation consultant, **Dev-Afrique Development Advisors**
- Cristiano von Steinkirch de Oliveira, environmental engineer, **SEMAE Mogi das Cruzes**

Executive summary

Untreated domestic wastewater (sewage) is a killer, deeply affecting the health of humans and the environment. The harmful effects on human health, fisheries and agriculture result in economic value disappearing across sectors, leading to reduced economic growth and loss of job opportunities.There are also indirect impacts such as deterring tourists around polluted beaches and rivers. For countries that fail to act in treating their sewage, cascading impacts will further grow over time as some impacts of today (eg, poor health of school children from contaminated water) will translate into lost economic value in the future.

This pilot study estimates the economic loss from inaction towards treating domestic wastewater. The losses represent the disastrous consequences of wastewater pollution on the ground. When wastewater reaches the sea and rivers, the changes it induces in fragile water bodies result in untold losses of fish and other marine life. The bacteria and other pathogens from these water bodies also contaminate drinking water which in turn gives rise to diseases that impact millions of lives each year, especially in the developing world. It also imposes economic costs on countries through these and other human and environmental impacts.

Untreated wastewater is an age-old problem that plagues developing and developed countries alike, yet its full impacts are not widely understood. It is also an insidious problem. Poor water quality can often go unnoticed, making it hard to track the environmental and health threats. This report seeks to help change that, by tracing and quantifying its major economic impacts. It models the economic value lost to countries from poorer health outcomes and environmental damages to the agriculture and fisheries industries. Five countries are included in our analysis: Brazil, India, Kenya, the Philippines and the UK, selected to highlight diverse experiences across the globe. This is a pilot study that is drawn from a carefully chosen set of data and parameters (see the research methodology note in the Appendix for more details). Having established the feasibility of quantifying the impacts of wastewater pollution, we intend to widen the scope of the research to many more countries in the future.

Our analysis in this initial undertaking finds that the economic losses linked to untreated wastewater are sizeable, particularly for the four lower- and middle-income countries in the model. It also finds that all five countries, the UK included, face distinct challenges relating to their wastewater management.

Key questions to measure economic loss	Economic loss estimates	Summary of how losses are calculated	Additional impacts not assessed/quantified
Environmental impacts on fisheries: What is the economic loss from reduced fish populations caused by domestic wastewater contaminants?	The fishing sector in ountries covered in this research suffers losses ranging from **0.09%* (US$500,000) in the UK** to **5.4% (US$2.2bn) in India** as a result of the loss of fish populations.	The model considers excess nitrogen (from untreated wastewater), which ends up in freshwater (rivers, lakes, ponds) and marine (ocean and sea) environments, causing excessive plant growth and oxygen depletion, harming fish populations. This model estimates the economic loss caused by these reduced fish populations.	There are other costs, such as the impact on tourism which are not quantified, as coastal areas that lack biodiversity or are contaminated are likely to be less attractive to tourists.
Agriculture impacts on crop yields: What is the economic value of crops lost as a result of soil contamination from irrigation using untreated wastewater?	The total annual economic loss to the agriculture sector from not treating wastewater across each of the five countries ranges from **0.0005% (US$460,000) in the UK** to **3.9% (US$15.7bn) in Brazil.** The quantity of production lost per crop ranges from **5,000 kg** to **17.6bn kg** (up to **8%** of a crops' total production).	The model looks at the impact of untreated wastewater for irrigation that harms crops by increasing soil salinity, a common practice in less developed countries. This model considers these crop losses to estimate economic loss.	This model only accounts for economic losses associated with the three crops that have the highest total production in each of the five countries. Actual losses would include impacts on all crops in a country's food production as well as impacts on food imports from reduced domestic production.
Health impacts from water consumption: What is the economic loss (healthcare costs and lost workplace productivity) from the consumption of contaminated drinking water caused by untreated wastewater?	The total economic costs (including both healthcare treatment cost and productivity loss) associated with diarrhoea range from **6.3% (US$14m) in Brazil** to **6.9% (US$246.7m) in India**, with no losses in the UK due to its high levels of wastewater treatment. Harmful contaminants from untreated wastewater can enter drinking water through contaminated water bodies. All countries except the UK face additional longer term costs in the form of future wage loss from school absenteeism today.	The model focuses on the health and productivity impacts associated with diarrhoea caused by the *E.coli* pathogen (current and future healthcare costs and wage loss). Consumption of, or contact with, untreated wastewater is one primary cause, amongst other factors, for water-borne illnesses like diarrhoea.	The pathogens in wastewater cause a range of water-borne diseases caused by pathogens other than *E.coli* such as cholera, typhoid, encephalitis and gastroenteritis, the impacts of which are not included in this model.

* Economic loss in the agriculture and fisheries sector is defined as the economic value lost in each sector respectively due to the effects of inadequately treated wastewater. For the health pathway, the percentage figure denotes the extent to which economic costs associated with diarrhoea (treatment costs and wages lost) are higher.

As indicated in the table above, the losses in each pathway are almost certainly higher than our estimates as, due to the limited data availability, the latter do not capture all the possible contaminants in untreated wastewater or their impacts.

Wastewater pollution is also rife with social inequities. Its burdens fall disproportionately on the poorest layers of society, who often live in areas that lack access to sewerage and safely treated wastewater. In Africa and elsewhere, women often bear the brunt through exposure to contaminated water in domestic chores and childbirth.

The clearest path to safer wastewater is to improve water and sanitation systems, in particular through the expansion of water as well as wastewater treatment facilities. To their credit, governments in the most afflicted countries in our study are laying the policy and institutional groundwork for this, and treatment capacity is expanding. Stakeholders in the sanitation sector are also applying creative solutions, such as decentralised water treatment in Kenya and water pricing reform in India.

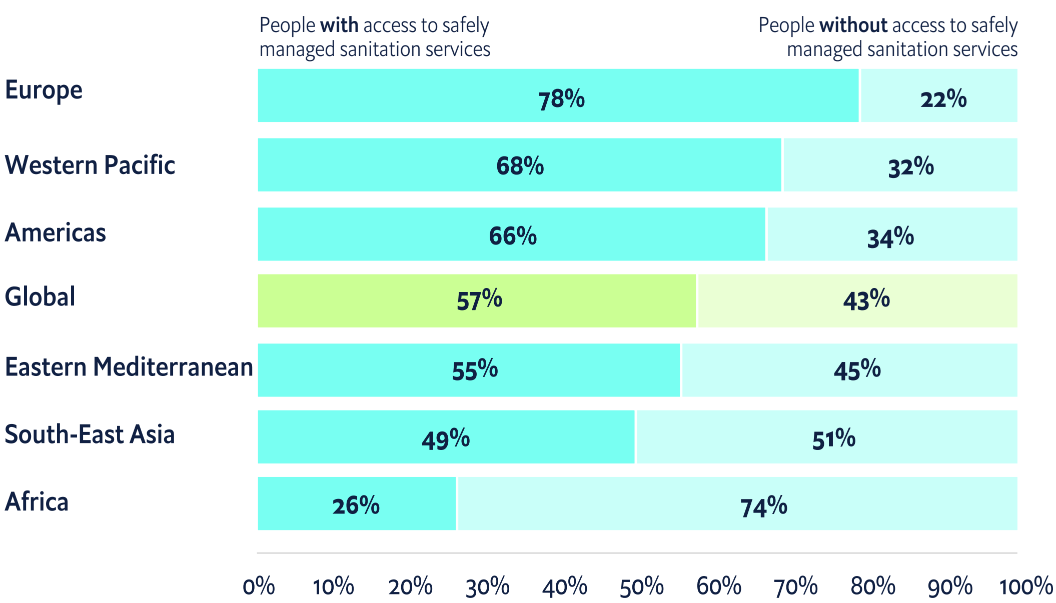
Wastewater pollution of course afflicts many more countries, and in more ways, than our pilot research captures. We aim for the study to spur further modelling and analysis so that all water stakeholders—policymakers, regulators, administrators, utility executives, investors and others—have the information they need to shape informed decisions about wastewater management.

1. Introduction

Untreated domestic wastewater is a scourge on societies. Released into the environment in raw form or having received only primary treatment, household wastewater is a major source of pollution and disease. "This is an ongoing problem and one that rich and poor countries alike must systematically address," says Richard Damania, chief economist in the World Bank's Sustainable Development Practice Group. "Untreated wastewater impacts the environment and it impacts health. That spills over directly into the economy."

Untreated wastewater is not just a developing world problem. According to the World Health Organization (WHO), only 57% of the world's population currently has access to safely managed sanitation services.[1] The figures vary widely between developed and less developed regions (Figure 1), but even in Europe, about 20% of the population lacks access. And while wealthy countries have well-developed sewage systems, much of that infrastructure is ageing and prone to leakage.

Figure 1: Share of population using safely managed sanitation services, WHO regions



Source: World Health Organization, The Global Health Observatory (data for 2022, the latest year available). See: https://www.iucnredlist.org/resources/summary-statistics

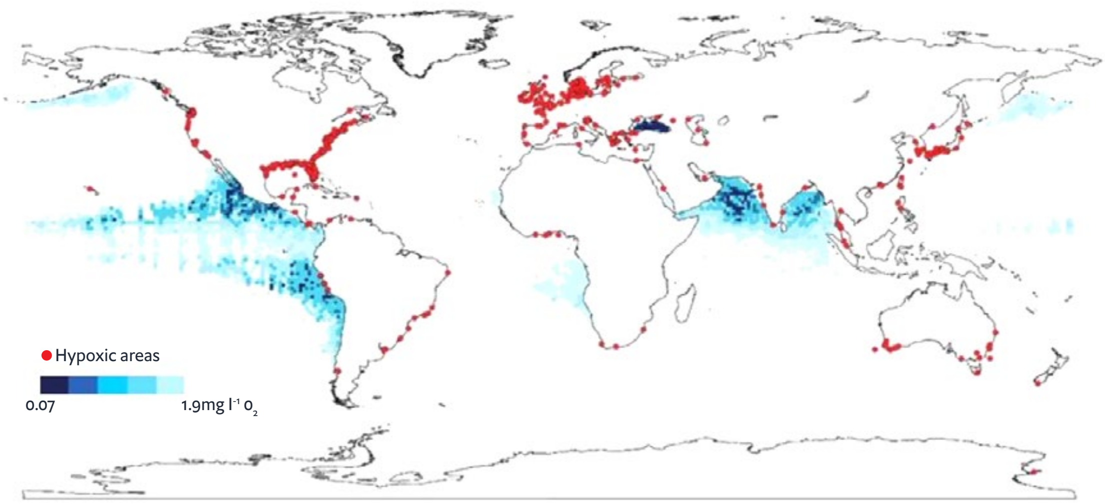
The inadequate definition of 'safely treated' wastewater

Domestic wastewater, more commonly known as sewage, may undergo three levels of treatment. Primary treatment typically removes suspended solids. Secondary treatment removes smaller organic matter that escaped removal in the preceding stage. Tertiary treatment is the most advanced stage, involving the disinfection of water from microorganisms.

Throughout this report, we use the terms 'untreated' or 'inadequately treated' to describe wastewater that has undergone no more than primary treatment. UN Water—the main source of data used in our study—employs the term 'safely treated' for wastewater that undergoes treatment in compliance with national and local standards or, in their absence, by secondary or higher processes.[2] In particular, secondary treatment does not necessarily remove all potentially harmful matter, particularly concerning the environment.[3]

Untreated wastewater damages ocean health once it reaches coastal zones via rivers and streams. It negatively impacts marine biodiversity and marine productivity, creating dead zones—areas where oxygen falls to such low levels that most marine life cannot survive, across the globe in developed and developing countries (Figure 2).[4] "Even localised coastal impacts can have very adverse impacts on the benefits that oceans bring to society" says Will Le Quesne, director of the International Centre for Ocean Protection and Use at the Centre for Environment, Fisheries and Aquaculture Science, which is part of the UK government's Department for Environment, Food and Rural Affairs.

Figure 2: Map highlighting that dead zones* in the ocean are spread out across developed and developing countries



Source: UN's Intergovernmental Oceanographic Commission (2018). See: https://www.science.org/doi/10.1126/science.aam7240, https://www.weforum.org/stories/2018/01/dead-zones-in-our-oceans-have-increased-dramatically-since-1950-and-we-re-to-blame/
*Dead zones are areas of the ocean where oxygen has fallen to such low levels that most marine life cannot survive

The pathways to lost value

Wastewater directly pollutes marine environments and coastal ecosystems. However, the additional impacts are much more far-reaching beyond the ocean and rivers, which our economic model aims to capture. Soil salinity affecting agricultural crops and pathogens (eg, E.coli that causes diarrhoea) spreading illnesses—are other important policy considerations, highlighting the urgency of the wastewater problem. The model focuses on quantifiable impacts, supported by qualitative analysis to make up for any data limitations and provide a more complete picture of the wastewater impacts.

In quantifying the costs of inaction on wastewater pollution, five countries were selected for examination: Brazil, India, Kenya, the Philippines and the UK. For each country, the economic impact of untreated domestic wastewater is assessed through:

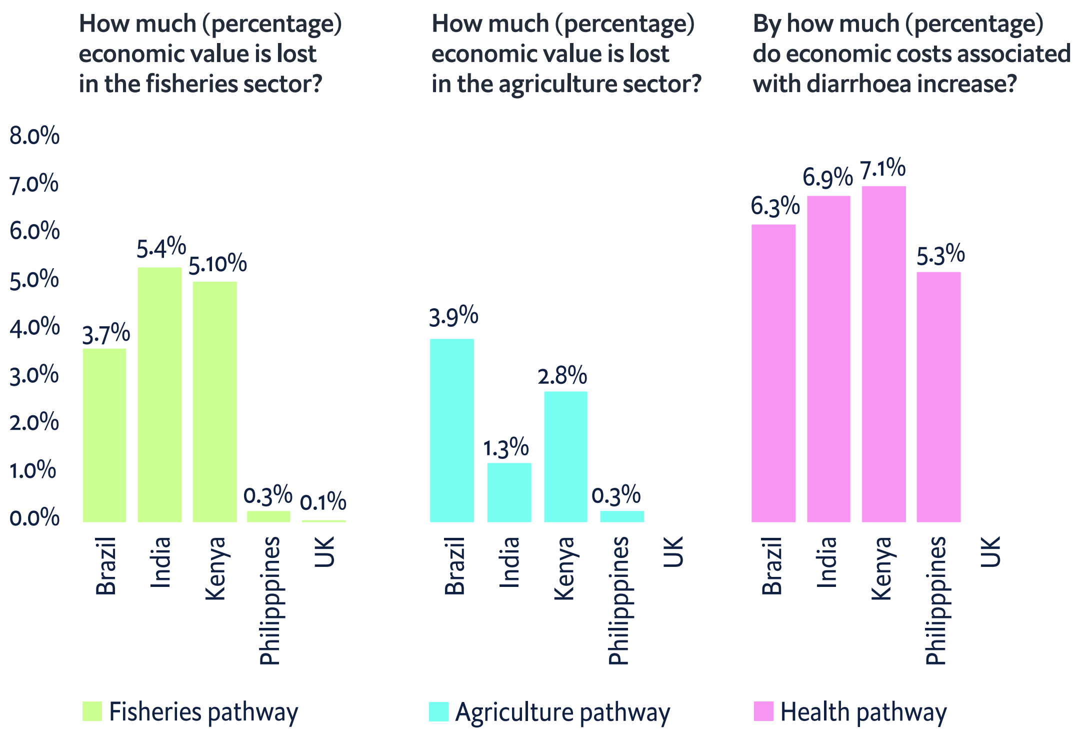
- **The environmental impact on fisheries:** the leakage of untreated wastewater from sewers and other sanitation infrastructure (such as septic tanks) into rivers, lakes, streams and coastal waters leading to reduced fish populations (our focus: nitrogen concentration in watersheds).

- **The environmental impacts on agriculture:** farms' use of untreated wastewater for irrigation purposes leading to crop losses (our focus: the effects of increased soil salinity on the three most produced crops in a country).

- **The health impacts from consumption of contaminated water:** the diseases that humans contract from consuming or coming into contact with water that is contaminated by inadequately treated sewage which carries pathogens such as *E.coli*, leading to healthcare costs and lost wages (our focus: the incidence of diarrhoea caused by the *E.coli* pathogen).

The study defines the 'cost of inaction' as the economic loss incurred by a country's failure to treat domestic wastewater adequately. The losses vary widely by country and pathway but can be considerable. In Brazil, for example, 4% of potential agricultural value is lost from the inadequate treatment of wastewater used in irrigation. India and Kenya lose 5.4% and 5.1% of their economic value in the fisheries sector respectively. In both these countries, diarrhoea related economic costs (US$247m for India and US$66m for Brazil respectively) are also much higher due to lack of safe treatment of wastewater. While the UK reports high wastewater management standards, there has been increasing evidence of untreated sewage discharges flowing from storm overflows, which is particularly harmful for fisheries.[5]

Figure 3: The costs of inaction of inadequately treating wastewater*



* Economic loss in the agriculture and fisheries pathways is defined as the economic value lost in each sector respectively due to the effects of inadequately treated wastewater. In the health pathway, the percentage figure denotes the extent to which economic costs associated with diarrhoea are higher.

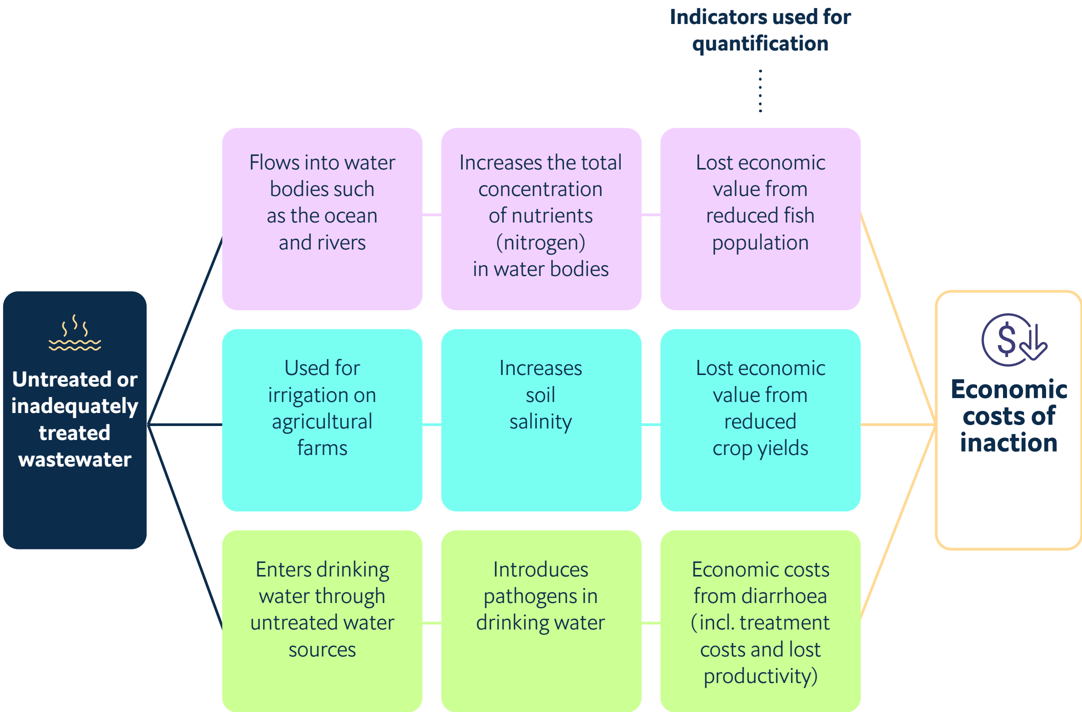
Source: Economist Impact estimates

The consequences of wastewater pollution is not limited to the numbers above and is in fact much more disastrous. Our analysis of human health, for example, assesses only the impacts from diarrhoea, considered the most prevalent wastewater-related disease. But there are several others, such as cholera and dysentry, which are caused by pathogens other than *E.coli*. For fisheries, we consider only losses from reduced fish populations and not the impacts from damage to other marine species such as coral reefs or reduced marine tourism.

And our agriculture impact analysis focuses on each country's most highly produced and water-intensive crops, but the overall impacts across all agricultural output is expected to be higher. For agriculture and fisheries, the model only focuses on specific contaminants—salinity and nitrogen respectively. Studying the long list of physical, chemical, biological and radiological contaminants would reveal an ocean of other harms of wastewater.

Wastewater pollution thus impacts countries in many more ways than our model currently considers. This pilot study can serve as a guiding methodology to quantify various wastewater pollution impacts across diverse geographies. In the following sections we take a closer look at its impacts through the prisms of environmental and human health.

Figure 4: Modelled pathways of the economic costs of inaction on wastewater treatment



2. Environmental impacts on ocean and freshwater

Untreated wastewater harms the environment in multiple ways, causing significant damage to ecosystems, water quality and biodiversity. When this wastewater flows into the ocean and rivers, it harms fish directly by introducing toxins, pathogens and physical pollutants, and indirectly by degrading their habitats and food chains. These environmental impacts are not limited to water bodies. When this wastewater is used for irrigation, it contaminates the soil and reduces crop production. This section discusses the quantitative and qualitative impacts on both fisheries and agriculture, highlighting economic losses across the countries covered in the model.

Water bodies

Discharges of untreated wastewater into a country's natural water bodies can increase the concentration of nutrients such as nitrogen and phosphorus. Even secondary treatment primarily reduces organic matter and requires additional treatment steps to considerably remove nutrients. Nutrient accumulation leads to eutrophication—excessive growth of plants and algae—which causes oxygen depletion (hypoxia). These areas are often referred to as dead zones, as they can kill fish, corals and other aquatic life. As highlighted in the introduction, secondary treatment also does not necessarily remove all potentially harmful matter, which is particularly concerning for the environment. In addition, wastewater receiving secondary treatment may still contain microplastics, which are found in pharmaceutical and personal care products and are harmful to wildlife.[6]

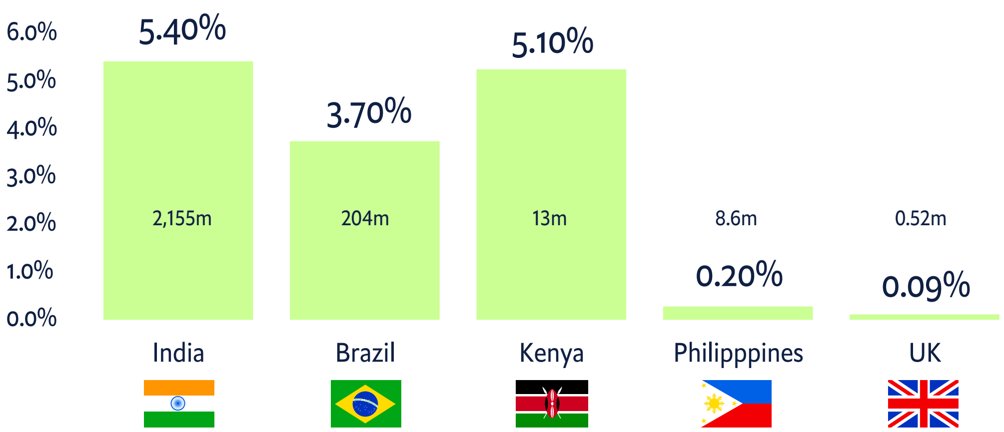
Our model calculates the harmful nitrogen impacts on fisheries from untreated water as well as water that has received secondary treatment*. India's fishery production suffers the most among the five countries we analysed, losing 5.4% of economic value annually, followed by Kenya (5.1%). While Brazil's (3.7%) percentage loss is lower than Kenya, the absolute economic loss in Brazil (US$204m) is much higher. This difference reflects the significant size of the fishing sector in Brazil, with larger volumes of production, extensive marine and freshwater resources, and many dependent on the sector for their livelihoods.

*See appendix for further detail

Both India and Kenya, which see the highest loss in economic activity for fishing, have the lowest levels of wastewater treatment at 21% and 11% respectively. India's fishing industry is heavily reliant on freshwater sources, particularly rivers, many of which are severely polluted. In the Ganga basin, the country's largest river basin, an estimated 12,000 million litres per day (mld) of sewage is generated, yet existing treatment infrastructure can process only around 4,000 mld, leaving a significant volume of untreated wastewater to flow into the river.[7]

While countries such as the UK see a much smaller impact on fishery production in our model, this comes with important caveats. Recent reports suggest that there were more than 600,000 discharges of raw sewage into UK waterways in 2023 alone.[8] Ageing infrastructure and storm overflows also continue to threaten water quality, highlighting that our model, which relies on reported data on wastewater treatment, considerably underestimates the impacts of domestic wastewater and sewage in the UK.

Figure 5: Economic loss in the fisheries sector varies across countries (%)**



**Loss as a percentage of potential sector value
Source: Economist Impact estimates

The Ripple Effects of Wastewater Pollution on Coastal Ecosystems

Apart from harming fish in rivers and ocean, there are multiple additional impacts of wastewater, from harming corals to reducing tourism, that our model doesn't capture. For instance, the effects of eutrophication often take dramatic forms in coastal waters where coral reefs are present. "Coral reefs are very sensitive both to water quality and changes in their exposure to light," explains Will Le Quesne, director of the Centre for Environment, Fisheries and Aquaculture Science. "Declining water quality driven by sewage or other terrestrial runoff brings changes not just in fisheries but also in corals, which is a sensitive habitat."

Coastal environments support a variety of biodiversity, which can also sustain tourism. "In areas where you have these kinds of important species, wastewater and other types of pollution can have cascading effects on employment and coastal stability," says Dr Le Quesne. Tourism can be a key contribution of marine ecosystems to the local economies. Failure to protect marine life from wastewater impacts can have substantial economic impacts in countries such as Maldives, Palau and St Barthélemy, where over 40% of the GDP comes from coral reef tourism.[9]

Wastewater pollution in coastal environments highlights the extended harms it causes to ecosystems and ultimately to societies, says Stewart Sarkozy-Banoczy, managing director and CEO of the World Ocean Council and steering committee chair of the Ocean Sewage Alliance. "The impact might be immediate—for example, from a rain or flood induced sewage discharge or infrastructure failure that damages habitat, spurs disease, or closes beaches and tourism operations. It may also take longer, from the time of discharge, for the fisheries or ecosystem effect to develop," he says, "but once it does, it is going to affect everything connected with it, including humans, their activities and their livelihoods. When species like coral go away, everything goes away; when people cannot be in or near the water, health is threatened along with the cost of economic shock. These potential threats only get worse when we are adding climate issues like warming waters that speed those nutrient pollution events."

Overflowing sewage concerns might be underestimating fisheries impact in the UK

In the UK, combined sewer overflows (CSOs) are designed to release untreated wastewater into rivers during periods of heavy rainfall to prevent sewage from backing up into homes. However, these overflows are occurring more frequently, even during dry weather, with some experts and non-government organisations claiming that water utilities often cause such discharges illegally.[10] In 2017 a raw sewage discharge from an emergency overflow killed approximately 5,000 fish in the River Great Ouse, highlighting the detrimental impact on fisheries.[11]

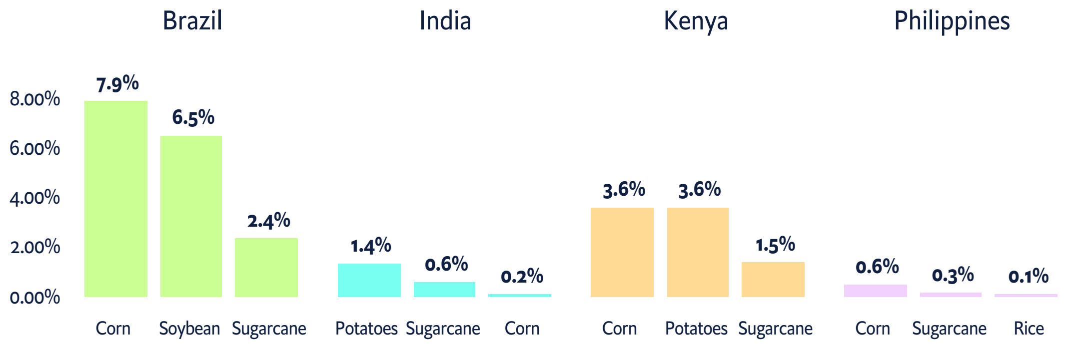
The country's ageing water infrastructure is also not always up to the task of adequately handling excessive water volumes.[12] The wastewater discharge data that our model uses don't take CSOs into account, meaning that the impacts on the ground are much more severe for the UK than those estimated. Recent reports indicate that the number of fish killed due to water pollution has risen sharply, with over 216,000 fish deaths recorded 2023-24, a fivefold increase from the previous year.[13] This increase underscores the escalating threat that sewage pollution poses to aquatic ecosystems.

3. Agriculture impacts on soil salinity and crop yields

Wastewater irrigation in agriculture is a common practice, especially where there is water scarcity. "[It] causes enormous damage in low-income countries in Africa, Asia and Latin America, where its use by farms is widespread," according to Grace Wambui, water and sanitation consultant with Nairobi-based Dev-Afrique Development Advisors.

Around 10% of agricultural land in developing countries is irrigated using raw or partially treated wastewater.[14] And this wastewater often contains heavy metals such as zinc, chromium, manganese and iron, which are toxic to humans. Other wastewater nutrients such as nitrogen may initially increase crop yields compared with freshwater irrigation. But in the longer term, the use of wastewater for such purposes reduces yields due to soil salinisation.[15,16]

Figure 6: Agricultural value loss attributed to inadequately treated wastewater*



* Defined as a proportion of the potential economic value if all wastewater used in irrigation is treated. The analysis covers the water-intensive crops with the largest share of production in each country.

Source: Economist Impact estimates

Our model finds that Brazil's agriculture sector faces the largest losses from irrigation using untreated wastewater, particularly from the reduced yield of its staple corn and soybean crops. Untreated wastewater has a high level of salt content. Some crops, such as soybean, are highly sensitive to soil salinity (the accumulation of salt in soil), meaning that countries where these crops are commonly farmed see exacerbated impacts. Climate change is further intensifying this challenge, as higher temperatures increase water evaporation, leaving behind salts in the soil. Rising sea levels can also lead to saltwater intrusion into freshwater systems and agricultural lands, further raising salinity levels.

Lower soil salinity in India causes relatively less proportional losses, although it loses the highest revenue in absolute terms (US$1.2bn). In the Philippines, while the impact is negligible in comparison to other countries, the use of water intensive crops such as sugarcane and rice drives losses in the sector. In the Philippines, as in the UK, losses are also intensified due to high crop prices, as both these countries are relatively big importers of food products.

Across the board, differences in losses at the country level are driven by the level of treatment of wastewater and whether it is used for irrigation, and losses in crop yields are driven by their sensitivity to soil salinity, which increases with the use of untreated wastewater.

4. Human health and social equity

The effects to human health and societies from failing to treat wastewater adequately are potentially long lasting. Their implications extend far and wide. Waterborne diseases contracted in childhood, for example, can stunt children's growth and cause health complications later in life. They can result in children's extended absenteeism from schools and lower educational outcomes, causing future productivity loss. Children and adults afflicted with waterborne diseases may require hospitalisation, placing a burden on healthcare systems. There are also immediate economic impacts as sickness reduces the productivity of those employed in the workforce.

Diseases associated with untreated wastewater include diarrhoea (caused by the pathogen *E.coli*) and other diseases such as cholera, typhoid and dysentery (caused by other pathogens). According to Grace Wambui, diarrhoeal diseases are the leading causes of childhood deaths in Kenya, and are more prevalent in informal settlements where sanitation is poor.

Our modelling of the economic losses caused by the health impacts from consuming untreated wastewater focuses on diarrhoea, among the most common waterborne diseases.[17] Our research found that the total present annual economic loss from not treating diarrhoea (caused by water contamination) across the five countries in our research range between US$ 14m and US$ 247m.

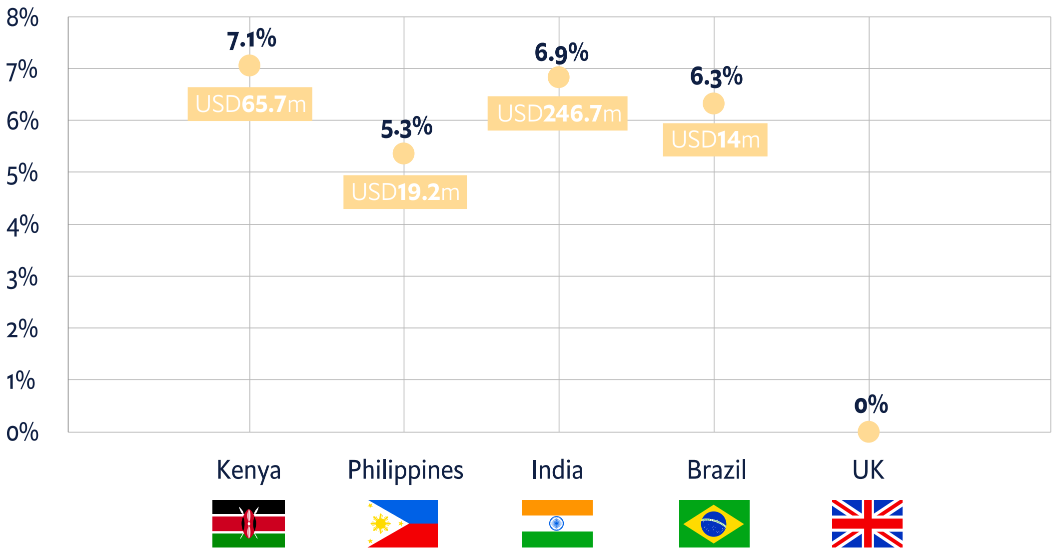
Our economic model estimates both present and future costs:

Present costs	Treatment costs: hospitalisation and other medical expenses incurred for treatment.
	Productivity loss: loss of wages and/or economic output among working-age adults, resulting from workplace absenteeism.
Future costs	Productivity loss: loss of future workforce productivity resulting from present school absenteeism.

Of the countries in our model, the economic losses attributable to this disease—as a result of consuming untreated wastewater—are the greatest in Kenya, where economic losses caused by diarrhoea are higher by 7.1% (Figure 7) than they would be if all wastewater was treated.

India's economic losses from diarrhoea are nearly as substantial, amounting to 6.9%, followed by Brazil and the Philippines where losses amount to 6.3% and 5.3% respectively. When the impacts of cholera, typhoid and other diseases are factored in, the true costs will be clearer.

Figure 7: Expected % increase in economic losses from diarrhoea caused by lack of wastewater treatment*



*Economic losses include treatment costs (hospitalisation and other treatment costs) and productivity losses (loss of wages or economic output among working-age adults)

Source: Economist Impact estimates; UN IGME Child and Adolescent Causes of Death Estimation (CA CODE) project (2024). See: https://data.unicef.org/topic/child-health/diarrhoeal-disease.

The health consequences stemming from untreated wastewater also continue to generate economic losses in years to come. For example, countries across the board face future losses in the form of lost wages due to current school absenteeism.

Inaction translates into inadequate education, a less productive workforce and less prosperous communities. Countries that take action to improve wastewater management today can prevent not only present but also future losses.

India: Pursuing circularity in wastewater management

India's costs due to the diarrhoea burden caused by drinking untreated wastewater losses (6.9%) are second only to that in Kenya.

According to a report the CEEW produced in 2023, the country's treatment capacity increased by 40% between 2014 and 2020.[18] "But we need to increase it much more," says Mr Bassi, noting that installed capacity in most Indian states is below 50% of sewage generation. At the same time, only around 28% of sewage generated in urban centres is actually treated.

However, expanding treatment capacity addresses only part of India's wastewater problem. According to Mr Bassi, wastewater treatment and its reuse must become economically attractive, especially in cities. "The price of freshwater in much of the country is heavily subsidised, and in some places free," he says. With little incentive for end-users to purchase treated wastewater, there is less incentive for water companies to build new treatment plants.

Mr Bassi highlights initiatives currently under way in Chennai, Bengaluru, Gwalior and Thane that seek to address that challenge. The results seen thus far are encouraging, he says, with increased reuse of treated wastewater in irrigation, at industrial sites and for replenishing groundwater tables.[19] "We need more such projects to help make wastewater treatment financially viable," says Mr Bassi.

The social injustice of untreated wastewater

“The burden of poor sanitation and water management falls disproportionately on the poor,” says Ms Wambui. In Africa, she notes, low-income communities are more likely than others to live in areas without sanitation systems or access to clean water. Drawing water from polluted sources, they face heightened exposure to waterborne diseases.

“In Africa, this burden weighs especially heavily on women and girls”, says Ms Wambui. It is mainly women and girls who fetch water for the household and use it for washing and cleaning; and the use of contaminated water during childbirth can cause infections that lead to death and can harm the child’s health.

Given women’s responsibility for finding water resources, “inadequate wastewater treatment increases the time and distance women must travel to find clean water,” says Ms Wambui. “This reduces their opportunities for education and economic participation.” It also contributes to gender-based violence, she adds: “Women and girls are often exposed to sexual violence when accessing distant or unsafe sanitation facilities.”

The income-based inequities of wastewater pollution are readily evident in Brazil’s large cities, says Cristiano Von Steinkirch de Oliveira, environmental engineer at SEMAE Mogi das Cruzes, the water utility serving a municipality adjacent to São Paulo. “Diarrhoea, hepatitis and other diseases are prevalent among migrants and other marginalised communities living in the city outskirts where sanitation infrastructure is sparse, while they are almost non-existent in the more developed central districts,” he says.

It is a similar picture in Indian cities, where in-migration trends are strong. “New migrants end up staying in places that are not connected to the water supply or a sewage system,” says Nitin Bassi. “They are definitely at greater risk of using contaminated water.” And without access to a sewage network, he adds, their waste will end up in a local surface water body, from which it enters the groundwater system or aquifers. “These people are dependent on the same water body and aquifers to meet their own water demand. It is a vicious circle.”

Another dimension of wastewater inequality is the rural-urban divide in access to sewerage. In developed and less developed countries alike, sewer networks exist mainly in cities and suburban or peri-urban areas. On-site sanitation such as septic tanks predominate in rural areas. While such systems are designed to leach in a controlled way, in poorer countries they are often prone to unintended leakage and the wastewater they hold undergoes no or rudimentary treatment (see below, Kenya: The role of decentralised water treatment facilities). Limited data availability of rural conditions may also hide the real impacts and challenges of wastewater on the ground.

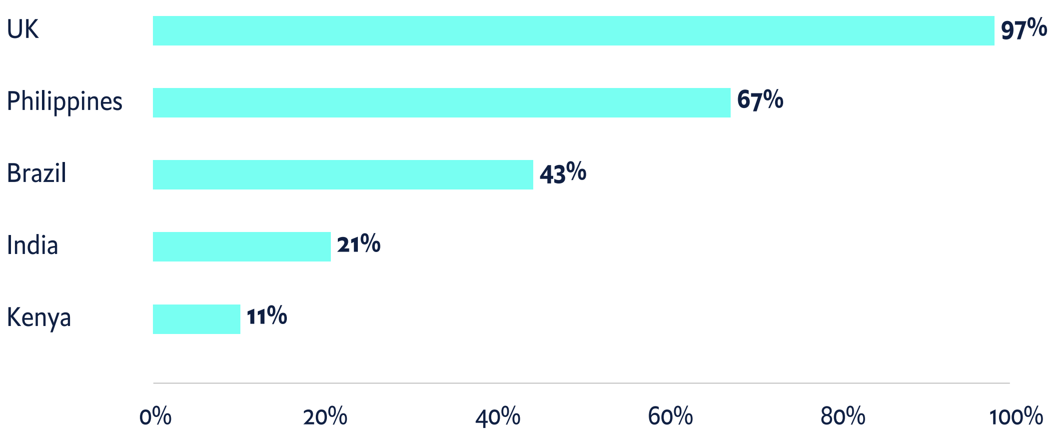
5. Points of progress

A report of this nature necessarily dwells on the weaknesses of wastewater management, particularly in the developing world—non-existent sewerage, scarcity of water treatment facilities, inadequate regulation of sanitation providers and practices, and others. Figure 8 amply testifies to the progress those countries need to make to eradicate the costs of untreated wastewater. While this progress is remarkable, countries need to continue to invest in the maintenance and resilience of their infrastructure to reduce costs consistently in the long-term.

Commendable efforts are under way to achieve that. For example, Brazil's government launched a major reform of the water and sanitation sector in 2020.[20] Among other measures, it established a new federal oversight agency for the sector, mandated the development of standardised water and sanitation guidelines, and opened the sector to private investment. It also set uniform targets for rural and urban sanitation coverage. "This reform was a huge step," says Mr Von Steinkirch de Oliveira, "although its implementation has thus far been very slow."

Mr Von Steinkirch de Oliveira also lauds an initiative being undertaken by the federal ministry of finance to develop a taxonomy that will guide sustainable investments in the country, including in water and sanitation. "This should help open new avenues of financing for improvements to wastewater management," he says.

Figure 8: Proportion of domestic wastewater safely treated, 2022



Source: UN Water, "Progress on Wastewater Treatment (SDG target 6.3)" (data for 2022, the latest year available). See: https://sdg6data.org/en/indicator/6.3.1

In the Philippines, Manila's residents have benefitted from the growth of wastewater treatment facilities in the city. Manila Water has built 40 new treatment plants since 1997, expanding its treatment capacity from 40 million litres per day to 410 million, and it plans to build 12 more plants.[21] By 2037 the utility aims to have connected 100% of households in its region to sewers connected to treatment plants.[22]

India's national and state governments have implemented a raft of new rules in recent years that set specific targets for the use of safely treated wastewater. The Namami Ganga initiative to clean the Ganges River kickstarted this effort in 2014. Now, according to Mr Bassi, about ten states have a formal policy in place for reusing treated wastewater.

The UK, which treats the highest proportion of wastewater, out of the five countries in this research, is going a step further by turning sewage into renewable energy. A standout example is the use of microbes that transform organic wastewater matter into hydrogen energy, significantly reducing the carbon footprint of wastewater treatment plants.

In the past decade, the Kenyan government has made strides in policy development and capacity building aimed at improving wastewater management. This includes the Kenya Environmental Sanitation and Hygiene Policy 2016-2030; the National Water Master Plan for the achievement of universal water and sanitation access by 2030; and the Water Sector Trust Fund, which provides funding to develop water and sanitation services to underserved areas. Where sewerage connections to wastewater treatment plants are currently absent, local utilities have implemented an innovative solution to help plug the gap (see box).

Kenya: The role of decentralised water treatment facilities

In Kenya, treating domestic wastewater is a challenge when only around 16% of the country's population is connected to a sewer.[23] Most communities, representing 84% of the population, are served by on-site sanitation. "The risks associated with on-site facilities in this part of the world are numerous," says Grace Wambui. Groundwater contamination is one of them. On-site septic tanks and latrines are bio-digestors, she explains, which means that they can leak pathogens into the environment. "These facilities are generally unregulated, which greatly increases the risk."

Water utilities in parts of Kenya are implementing decentralized wastewater treatment systems (DEWATS) to compensate for the lack of sewerage and provide viable solutions for increasing their treatment capacity. According to Ms Wambui, such systems are widely used in rural and peri-urban areas. The systems involve multiple stages, including aerobic and anaerobic treatment,[24] and can handle wastewater flows of different scales, from small communities to larger industrial sites. "DEWATS reduce energy costs, as they often require no power and have a long-lasting design," she says. "Additionally, they offer the potential for resource recovery, such as biogas generation from treated sludge."

Financing the installation of such systems is a challenge for most rural and semi-rural utilities, says Ms Wambui. This is where the UBSUP programme—Up-scaling Basic Sanitation for the Urban Poor—comes in. The programme, initially funded by the Bill and Melinda Gates Foundation and the German government and implemented by Kenya's Water Sector Trust Fund, issues grants to utilities to install DEWATS systems. In addition to financing and technical assistance, the programme also supports the training of experts needed to operate and service the systems, as well as of other actors in the local sanitation sector.[25]

Conclusion

This report quantifies the economic, environmental and public health costs associated with failing to address wastewater treatment issues. The findings demonstrate that inaction results in significant financial burdens, including losses in fisheries, increased healthcare expenditure, productivity declines and broader ecosystem degradation. The costs of current practices that allow untreated wastewater to persist are substantial, making clear that the status quo is not a neutral or low-cost option.

The first crucial step for countries is to invest in upgrading their infrastructure that can effectively collect, treat and safely dispose of wastewater. While these improvements require upfront capital, the costs of not doing this are high, as highlighted in our study. Moreover, making investments into improving infrastructure today could provide numerous long-term benefits—ranging from healthier populations and more resilient ecosystems to enhanced economic productivity. Governments have an opportunity to shift from reactive spending on the consequences of poor sanitation to proactive investment that can have economic, environmental and societal benefits.

"We have a variety of solutions to reduce or eliminate wastewater pollution," says the World Bank's Mr Damania. "There is no reason whatsoever to have children and people falling sick from [wastewater and from its] destruction of our oceans, rivers and lakes. In many ways, the circumstances are right for us to be able to resolve the wastewater problem now."

Expanding treatment capacity is the main remedy but, says Nitin Bassi, senior programme lead for sustainable water at the Council on Energy, Environment and Water (CEEW), "we need to improve both water quality and usable quantity of water. If more wastewater can be captured, treated and reused, it will reduce the pressure on our freshwater resources." As countries improve their treatment capacity, they must also integrate sustainable water management practices to ensure that wastewater is effectively reused.

Countries investing in improved wastewater treatment can also go a step further to unlock additional benefits through circularity. For instance, sludge removed from wastewater can be repurposed into organic fertilisers that prevent soil erosion and support plant growth. It can also be used to produce biogas, a renewable energy source. Several countries included in this study, such as the UK, Brazil and India, are already demonstrating the potential of these solutions. By adopting similar approaches, governments can turn wastewater from a growing environmental challenge into a valuable resource for sustainable development.

Appendix: Methodology note

Economic model: definitions and pathways

This economic modelling exercise quantifies the economic costs of inaction from **failing to treat domestic wastewater safely**. Costs are estimated by assessing the environmental (on fisheries in water bodies and crops in agriculture) and health impacts (on humans) through three pathways:

1. Fisheries: the economic value lost from depleted fish stocks due to sewage contaminants in the water.

2. Agriculture: the economic value of crops lost as a result of soil contamination from irrigation using untreated wastewater.

3. Health: economic losses from diarrhoea, including lost wages and medical expenses.

Our analysis gives a conservative estimate of the overall economic cost of inaction on wastewater treatment. For example, in assessing the impact of untreated wastewater on fisheries, the model doesn't include areas such as tourism (coastal contamination and reduced biodiversity can make areas less attractive to tourists). The agricultural impacts exclude increased food import expenses due to reduced crop yields and the broader effects on ecosystems. Finally, the health pathway focuses only on the morbidity-related impacts of diarrhoea, excluding its effects on mortality as well as the burden of other waterborne diseases that arise from consuming contaminated water.

Our model focuses on domestic wastewater. The starting point to calculate the costs of inaction is the share of water that is not safely treated.

- Definition of domestic wastewater: wastewater comes in various forms and this model focuses on domestic wastewater, which the UN defines as "effluent consisting of blackwater (excreta, urine and faecal sludge) and greywater (kitchen and bathing wastewater)."[26] There are other forms of wastewater that our model doesn't include such as industrial wastewater, which comes from sources such as factories and manufacturing plants.

- Definition of safely treated wastewater: the model uses the "proportion of safely treated domestic wastewater flow" data points from UN Water. UN Water defines this data point as "the proportion of wastewater flows from households that are treated and discharged in compliance with national and local standards (or in the absence of such data, treated by secondary or higher processes)."

Primary treated wastewater (which filters out many large contaminants) can still be harmful to human and environmental health. Wastewater that undergoes further forms of treatment, such as secondary and tertiary (where biological and chemical processes are used to remove contaminants), is considered safely treated under the UN definition and for the purposes of this analysis.[27]

This dataset covers different types of treatment systems including onsite (those near the source such as septic tanks, which are more common in rural areas) and offsite sanitation (such as sewer systems connected to households), which allows us to account for urban and rural experiences.

Country selection

The analysis focuses on five countries—Brazil, India, Kenya, the Philippines and the UK—which were selected based on the following criteria:

- **Wide regional representation:** selected countries demonstrate the global scale of wastewater discharge costs. We therefore include one Latin American country (Brazil), two Asian countries (India and the Philippines), one African country (Kenya) and one European country (the UK).

- **Data availability:** part of our selection process included countries with relevant data availability. Although few countries had full data availability across all datasets, the selected sample had relatively better data. Missing data are supplemented with data from individual papers in addition to our primary datasets.

- **Treatment rates:** our selection of countries accounts for a wide range of wastewater treatment rates. The maximum safe treatment, according to our definition, is 97% (the UK) and our minimum is 11% (Kenya). By accounting for this range in treatment rates, we aim to better understand the impacts of differing wastewater treatment levels.

Detailed methodology and assumptions

a. Agriculture

Agriculture pathway in a nutshell

- The use of untreated wastewater for irrigation can have negative impacts on the output of farms due to increased levels of contaminants.
- Soil electrical conductivity (ECe) of saturated paste extract, a measure used to assess soil salinity, is increased when irrigation by wastewater is performed.
- When soil ECe increases above crop-specific thresholds, crop output is reduced.
- The cost of inaction is estimated as the difference in yields between current practices compared with an ideal scenario in which all wastewater used for irrigating agricultural land is treated.

The agriculture pathway estimates the effect of untreated wastewater used for irrigation on crop yield across five countries. The presence of dissolved salts in untreated wastewater used for irrigation can decrease crop yields.The analysis estimates the losses in yields of the three crops (per country) with the largest total production that are sensitive to soil salinity for each country. If all crops in each country were included, the total cost of inaction would likely be much higher.

Baseline versus ideal scenario

Cost of inaction: we measure this as the difference between agricultural output in the ideal and baseline scenarios:

- **Baseline scenario:** the baseline scenario models the crop output based on current wastewater irrigation practices.
- **Ideal scenario:** the estimated output of three crops if all wastewater used for irrigation receives adequate treatment.

Approach

As a starting point, this analysis uses the proportions of treated and untreated wastewater used in irrigation for each country. Next, we assess the impact of wastewater irrigation on soil electrical conductivity (ECe) levels. Finally, we estimate the impact of higher soil ECe on agricultural yield.[28]

1. **Establishing baseline levels of irrigation with untreated wastewater:** we use AQUASTAT data to determine this. In its absence, we use treatment data from UN Water. In doing so, we implicitly assume that the use of treated wastewater in irrigation is equivalent to the overall rate of wastewater treatment in the country.

2. **Estimating the impact of wastewater irrigation on soil salinity and electrical conductivity (ECe):**
   We estimate the ECe changes to land irrigated with untreated and treated wastewater. We estimate different ECe levels using a weighted average based on the shares of treated and untreated wastewater irrigation from AQUASTAT (if available). Assuming untreated wastewater raises ECe by 2.66, we adjust each country's average soil ECe to estimate levels for irrigation with 100% untreated and 100% treated wastewater, providing a range around the observed average. If field ECe measurements are not available, other forms of conductivity measurements such as electrical conductivity (EC) or apparent electrical conductivity (ECa)[29] are used to help estimate the ECe values. ECe values can be estimated by EC values via the equation:

   ECe = EC * 6.5[30]

   ECe values can be estimated by ECa values via the equation:

   ECe = ECa*3.37[31]

   This model uses average ECe values for each country, which are based on varied measurements across sub-regions within every country.

3. **Estimating yield loss from changes in soil ECe:** we then estimate the impacts of changes in soil ECe on crop yields per country for the ideal scenario (where all wastewater is treated). These ideal yields are then compared to baseline yields given from current data.

   a. **Cropland affected by wastewater irrigation:** we estimate the crop-specific total hectares irrigated with untreated and treated wastewater based on current production levels from the Food and Agricultural Organization (FAO)[32] and yields from Our World in Data.[33]

We assume that 10% of the total production of crops in developing countries use wastewater for irrigation.[34] We use total production and yield data for three crops for each country to estimate the total area and volume of crops affected by wastewater irrigation.

b. **Yield loss:** the impact of the change in soil ECe on yield can be described by the following equation:[35]

$$Y = 100 - b\,(ECe - a)$$

Where Y = the yield loss; a = the crop-specific salinity threshold expressed in deciSiemens per meter; b = the yield reduction slope; and ECe = the electrical conductivity of the soil.[36] The values for a and b are taken from research published by the United States Department of Agriculture. We apply this equation to each of the three major crops found from the FAO to estimate specific yield losses.[37] We use this equation to calculate the difference between yields for both the baseline and ideal scenarios.

4. **Estimating the production loss and cost of inaction:** we estimate the cost of inaction by calculating the change between total production in the baseline scenario (calculated using actual data) and the ideal scenario (where all wastewater is treated):

   - Production loss (kg): we calculate this by finding the difference between yields from treated and untreated wastewater and apply it to the current total crop production. The gap between the baseline and ideal scenarios is reflective of the production loss.
   - Cost of inaction (US dollars): We calculate the economic loss by applying the price for each crop from the agricultural trading platform Selina Wamucii[38] to the total production loss.

Limitations and data requirements:

- **Lack of ECe data:** ECe values are necessary, as the relationship between ECe and yield loss is empirically defined, unlike other conductivity measurements. Many countries do not report ECe soil levels, which measure soil salinity. There is no comprehensive database containing ECe levels so individual studies are used to estimate soil ECe levels for each country. ECe testing is often done in a laboratory and not in a field, so data on ECe is not as common as other measurements such as EC.
- **Lack of wastewater irrigation reporting:** there is very little reporting on the use of both treated and untreated wastewater for irrigating crops. In the absence of data, we assume that 10% of crops grown in developing countries are irrigated with wastewater.[39]
- **Lack of data on the use of untreated wastewater in irrigation:** of the countries studied, only India reports data on the share of land irrigated with treated and untreated wastewater. For other countries, we assume that the proportion of treated and untreated wastewater used for irrigation is aligned with the country's wastewater treatment rate. For example, if a country treats 60% of its wastewater, we assume that 60% of its agricultural land is irrigated with treated wastewater, while the remainder is irrigated with untreated wastewater.

b. Fisheries pathway

Fisheries pathway in a nutshell

- The discharge of untreated or inadequately treated wastewater into a country's watersheds increases nitrogen concentrations.
- Excessive nitrogen causes eutrophication, where nutrient overloading fosters algal blooms. These, in turn, deplete oxygen in water bodies, causing hypoxia (low oxygen levels).
- Hypoxia kills fish, which diminishes their populations.
- Diminished fish populations lead to loss of economic value in the fishing sector. This model estimates these economic losses from loss of fish populations to calculate the costs of inaction in the fisheries sector.

A major pollutant in domestic wastewater is nitrogen. This pathway estimates the loss to a country's economy and environment as a result of reduced fish populations from nitrogen discharge. The model estimates losses by comparing the ideal scenario where all nitrogen from wastewater doesn't enter water bodies to a baseline scenario where nitrogen enters into the water as a result of current wastewater treatment practices

Expanding the definition of safely treated water to estimate the impact on fisheries: in assessing the impact of wastewater on fisheries, the model incorporates the nitrogen discharged from more advanced forms such as secondary and tertiary treatment. The current definitions surrounding 'safe' treatment primarily focus on human health rather than marine biodiversity health (such as fisheries). Our model includes nitrogen discharges from advanced forms of treatments, which fail to fully remove nitrogen from wastewater and can still cause harm to fisheries.

Baseline versus ideal scenario

Cost of inaction: we measure the cost of inaction as the difference between the economic value of fisheries for the baseline and ideal scenarios.

- **Baseline scenario:** the current economic value of fisheries for each country, based on current wastewater practices, estimated using fish landing data.
- **Ideal scenario:** the potential economic value of fisheries per country if 100% of wastewater receives treatment removing all nitrogen from wastewater.

Approach

1. **Estimating watershed volumes and discharge locations:** this model estimates the change in nitrogen concentration in water bodies due to wastewater discharges. To do this, we must estimate the total volume of a country's watershed (including both freshwater and marine sources) and the proportion of wastewater discharged into these watersheds.
    a. **Total volume of watershed:** AQUASTAT or country-specific data sources are used for estimates for the total freshwater volume for each country. Marine watersheds are calculated to be 50 square kilometres from the coastline and assumed to have a depth of 100 metres.

b. **Proportion of wastewater discharged:** the proportion of wastewater discharged into freshwater and marine water bodies is determined using the HydroWASTE database.[40] Wastewater treatment plants within 10 kilometres of the coast are assumed to discharge into marine water bodies and the rest into freshwater.

2. **Estimating nitrogen discharges from domestic wastewater:** this model estimates the amount of nitrogen discharged from wastewater by using per country data for total wastewater discharged and nitrogen concentrations in treated and untreated wastewater.

   a. **Total volume of untreated wastewater, cubic meters:** we use data on the volume of domestic wastewater and proportion of treatment to estimate the volume of domestic wastewater that is unsafely treated.

   b. **Nitrogen concentrations, milligrams per litre:** we use nitrogen discharge data, current nitrogen concentrations and total watershed volume data to calculate total nitrogen discharge from domestic wastewater into water bodies. We use data on the current concentration of nitrogen (primarily from gemStat,[41] supplemented by country-specific sources to fill data gaps) as our baseline values.

   c. **Nitrogen discharge from secondary and tertiary treatments:** advanced forms of wastewater treatment do not remove 100% of nitrogen. We assume that safely treated wastewater (wastewater receiving secondary or tertiary treatment) retains, on average, 45% of its original nitrogen concentration, owing to research in the available literature.[42]

   We assume that untreated wastewater contains 40 milligrams of nitrogen per litre while safely treated wastewater contains 18 milligrams per litre.[43]

3. **Calculating nitrogen concentrations if all wastewater is treated:** to estimate the potential reduction in nitrogen concentration levels in an ideal scenario where all wastewater is treated, we first calculate the difference in total nitrogen discharge between the baseline and ideal scenarios. We then recalculate the concentration levels as a share of the total watershed for both marine and freshwater bodies.

4. **Potentially disappeared fraction (PDF) of species calculations:** we apply changes in nitrogen concentrations between baseline and ideal scenarios to find differences in the PDF of species. PDF equations estimate the species richness of an ecosystem at certain nitrogen concentrations.[44] By using this calculation, we implicitly assume that changes in the number of species are directly proportional to changes in the volume of fish. PDF equations are calculated by counting the number of species that can survive at different levels of specific nitrogen concentrations in an ecoregion.[45] PDF curves are estimated as:

$$PDF = \frac{1}{1 + \exp \frac{a - \log_{10} C_n}{b}}$$

where a and b are empirical coefficients, a indicates the nitrogen concentration at which 50% of the species have disappeared, and b can be interpreted as the slope of the species sensitivity to increases in nitrogen. C_n (milligrams per litre) is the nitrogen concentration. The following steps specify the detailed calculations for PDF values:

a. **Value of a country's fisheries:** the baseline value is calculated using fish landing data from country-specific sources to estimate the current value of a country's freshwater and marine fisheries. Fish landing data, used as a proxy for the total fishery value, consists of the total volume (in kilograms) of fish catches for the country. These data do not account for the total value of a country's fisheries as fish that are not caught by fishing are not included in fish landing data, thus our model does not include the total value of fisheries impacted in water bodies.

b. **Maximum potential value of fisheries:** we calculate the value of fisheries for PDF value (a value of zero) where no species are harmed by nitrogen concentrations.

c. **Value of fisheries in the ideal scenario with no nitrogen discharges from wastewater:** we calculate the value of the ideal scenario by applying the ideal PDF value (no nitrogen from wastewater but can include nitrogen from other sources) to the maximum potential value (no nitrogen from any sources) of fisheries. This value can be understood as the value of fisheries if all nitrogen from wastewater is removed before discharge. It includes nitrogen from other sources such as agricultural runoff or pollution.

d. **Economic value lost (measured in US dollars and as a percentage):** we calculate the change in value from the difference in the baseline scenario to the ideal scenario for fisheries in freshwater and marine watersheds.

Limitations and data requirements

- **Nitrogen concentration data:** although gemStat provides freshwater nitrogen concentration data for some countries, there are consistent gaps in this dataset. We supplement data from supporting studies and literature to estimate the nitrogen concentrations of water bodies.

- **Value of fisheries:** this model uses fish landings as a proxy to calculate the economic value of fisheries. However, the total economic value of fisheries is likely to be much higher.

- **Marine or freshwater discharge locations and distribution:** the distribution of treated wastewater discharges between freshwater and marine environments relies on the proximity of marine water bodies to wastewater treatment plants, which may simplify actual discharge patterns. We assume that the ratio of untreated wastewater discharges into marine and freshwater sources is the same as the ratio of discharges from the wastewater treatment plants.

- **Depth of marine water bodies:** a uniform depth of 100 metres[46] is assumed for coastal marine areas to simplify the analysis, which likely inaccurately estimates the scale of the marine watershed and the nitrogen concentration.

- **Impact of species richness on total species biomass:** this model uses PDF curves to estimate the impacts of wastewater discharge on fish species populations. PDF equations estimate the species richness of an ecosystem at certain nitrogen concentrations. By doing so, we assume biomass loss is directly proportional to the species diversity loss of a fishery. The model also uses estimates from the largest ecoregion and assumes that it provides the most accurate representation of the impacts of wastewater discharges in the country as a whole.

c. Health pathway

Health pathway in a nutshell

- Pathogens in untreated domestic wastewater mix with inland water. When this water is used directly for human consumption, it can cause infectious diseases such as waterborne illnesses.
- Infected individuals incur treatment and/or hospitalisation expenses.
- Among the working age population, increased morbidity leads to workplace absenteeism, causing loss of economic output and productivity.
- Among school-aged children, increased morbidity leads to school absenteeism, which impacts future income earning potential

Background

Wastewater that has not been put through secondary treatment contains high levels of pathogens such as bacteria, virus, protozoa and helminths. When untreated wastewater is released into water bodies, such as lakes and rivers, it leads to the contamination of drinking water sources, raising the possibility of waterborne illnesses.

Under the health pathway, we study the impacts on human health and subsequent economic impacts resulting from the use of potable water contaminated with domestic sewage and wastewater. The consumption of contaminated water for drinking and other household purposes leads to a range of waterborne illnesses. The pathway calculates the annual economic loss resulting from ***diarrhoea***, which is among the most common waterborne illnesses. Nearly 95% of diarrhoeal cases are mild and do not require hospitalisations[47] but they do lead to lost wages and economic output resulting from workplace absenteeism. Five percent of diarrhoeal cases are either moderate or severe, and therefore lead to direct costs from hospitalisation in addition to lost wages and economic output.

The health pathway calculates the annual economic loss resulting from diarrhoea as the difference of healthcare costs between ideal and baseline scenarios:

- **Baseline scenario** represents the estimated annual healthcare and productivity costs resulting from diarrhoea due to the consumption of unsafe water at the current level of wastewater treatment.
- **Ideal scenario** uses the assumption that all the wastewater released in the country passes at least secondary treatment. Calculations are made for estimated treatment costs and lost productivity resulting from diarrhoea under the assumption that all wastewater is treated.

Approach

We focus on one pathogen, Escherichia coli (E. coli), which is commonly found in sewage and domestic wastewater. Untreated domestic wastewater has very high concentrations of Fecal coliform and total coliform (E. coli is a sub-group of these), which are known to cause diarrhoea. Outlined below is a step-by-step approach to calculating the economic losses.

1. **Estimating domestic wastewater levels:**

    - Under the baseline scenario, the percentage of wastewater treatment prevalent in a country is obtained from Sustainable Development Goals data.[48]

    - Under the ideal scenario, we assume that all wastewater generated in the country is treated.

2. **Estimating pathogen concentration levels**

    - We assume an average level of total pathogen concentration in untreated wastewater, based on estimates from literature.[49] For secondary treatment, we assume a 96% decline in pathogen concentration, based on literature estimates.[50]

    - Based on the prevalent wastewater treatment sources in each country, (data from UN Water), we then use a weighted average approach to calculate pathogen concentration levels in the baseline and ideal scenario. The ideal scenario assumes that all wastewater generated in the country receives at least secondary treatment.

3. **Estimating population infected:** the UNICEF/JMP database is used to estimate the number of people accessing water from unimproved sources. Under both baseline and ideal scenarios, we expect the population exposed to contaminated water to remain the same, as we assume no change in the infrastructure in place for water delivery. While the population exposed remains the same, we expect a change in the level of water contamination that the population is exposed to under the ideal scenario, as a result of higher levels of wastewater treatment, which leads to lower pathogen concentration.

4. **Probability of infection:** Probability of infection: for the population exposed, we calculate the probability of infection with the E.coli pathogen. The probability of infection is calculated using a beta-poisson dose- response model, which describes the relationship between the dose of the pathogen ingested and the response it generates—in this case, infection symptoms. The higher the probability, the higher the disease burden. The Dose response function is as follows:

    Probability of infection = $1 - (1 + d/\beta)^{-\alpha}$

    +Where d is the mean ingested dose of the pathogens,measured in the number of organisms per 100 ml. $\alpha$and $\alpha$are slope parameters of the beta distribution.For this model,we use α= 0.145 and α= 7.589.[51]

5. **Estimating disease prevalence and morbidity by age-group:** we estimate the prevalence of diarrhoea for different age groups, using the total infected population and the country's age structure. Using estimates from the literature, we calculate the percentage of the population likely to suffer from mild, moderate and severe symptoms in each age group.

6. **Estimating immediate losses (due to sickness and workplace absenteeism):** we calculate the losses resulting from sickness due to diarrhoea caused by the consumption of contaminated water. The losses are a sum of treatment costs and productivity losses due to workplace absenteeism:

    - **Total treatment costs:** Using estimates of average treatment and hospitalisation expenses for each country, obtained through a literature review, we estimate costs (in US dollars) for both the baseline (incidence of diarrhoea based on current wastewater practices) and the ideal scenario (incidence of diarrhoea where no contamination results from untreated wastewater but might be a result of other sources) for infected people seeking treatment.

The difference between the baseline scenario and ideal scenario is the treatment costs averted—that is, the costs that could be prevented by reducing the pathogen load in surface water from treatment of wastewater.

- **Total productivity loss:** for the working-age population, contracting waterborne illnesses leads to workplace absenteeism. Using estimates of the number of sick days for moderate and severe symptoms, combined with the likely number of episodes expected to occur in a year, we generate estimates of the number of work days missed due to sickness from diarrhoea. We assume symptoms of moderate diarrhoea persist for around six days and severe cases last for nearly eight days. Each person is expected to contract at least three episodes in a year.[52] We use a country's average wage rate to calculate the loss of wages incurred due to missed workdays. This gives us the productivity loss (measured in US dollars) attributable to workplace absenteeism for a year.

  The difference between productivity loss under the baseline scenario and ideal scenario is the wage loss that was prevented as a result of reducing the pathogen load in contaminated water for the exposed population.

7. **Estimating long-term losses (due to school absenteeism)**

   - For children of school age, multiple episodes of diarrhoea leads to school absenteeism, which manifests as losses to their future income earning potential when they enter the labour force.
   - **School days lost:** using data on the infected population by age group and morbidity rates from calculations made in the previous step, we calculate the total number of children missing school due to suffering from moderate and severe symptoms of diarrhoea.[53] This is converted into a percentage of the school year lost using estimates of the average length of a school year in the respective country.
   - **Loss of potential future income:** for children of school age, each episode of diarrhoea lasts anywhere from 4-8 days, depending on the severity of symptoms. A child who experiences three episodes of diarrhoea in a year could be absent for up to 10% of the school year. This can impact future income earning potential.[54] Literature suggests that losing 1/3rd of the school year reduces future income potential by 3%. Using data on the average length of the school year and the income loss associated with missing school, we calculate the decline in future income potential for each day of school missed for all infected children, for all diarrhoea episodes in a year, measured in US dollars.

Limitations

- **Limited impact measures:** in the present form, we focus on measuring only the morbidity impacts of waterborne illnesses and do not include the mortality impacts. While a small share of severe diarrhoea cases result in death, these can have long-term impacts such as the loss of productive capacity of the economy.
- **Limited disease measures:** the scope of our analysis is currently limited to just diarrhoea and we do not account for the impacts from other waterborne illnesses arising from contaminated drinking water.

End notes

1 The WHO defines safely managed sanitation services as "improved sanitation facilities that are not shared with other households" and "where excreta are safely disposed of in situ or transported and treated offsite". (Sewerage and wastewater treatment are thus components of safely managed sanitation services.) WHO Global Health Observatory. See: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/population-using-safely-managed-sanitation-services-(-)

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