INTERIM METHODOLOGY

Water Pollution

Environmental Topic Methodology

The International Foundation for Valuing Impacts, Inc. (IFVI) is a section 501(c)(3) public charity dedicated to building and scaling the practice of impact accounting to promote decision-making based on risk, return, and impact.

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Executive Summary

- The Interim Water Pollution Topic Methodology can be used by preparers of impact accounts to measure and value the impact of water pollution on people and the natural environment. The Interim Water Pollution Methodology can also be applied by users of impact information to manage the sustainability-related risks, opportunities, and impacts of an entity and inform decision-making regarding an entity's contribution to sustainability.

- To use this methodology, preparers should:

  - develop a full accounting of water pollution across an entity and its value chain

  - organize water pollution data by pollutant, and location, including whether it is discharged into seawater, freshwater, or unspecified;

  - utilize the impact pathway and value factors developed in this methodology to convert water pollution into impact accounts;

  - present any related impact information with supplemental notes and qualitative commentary necessary to meet the qualitative characteristics of impact information.[1]

- **Section 1** introduces the purpose of the document, outlines key concepts and definitions, and defines the scope for the Methodology. As an interim methodology, the Interim Water Pollution Methodology complements official impact accounting methodologies produced by IFVI in partnership with the Value Balancing Alliance and will be revised as part of the official Due Process Protocol with oversight from the Valuation Technical Practitioner Committee.

- **Section 2** develops the impact pathway for the Methodology, consisting of inputs, activities, outputs, outcomes, and impacts. The main impacts of water pollution include reduced human health, reduced recreational and property value, and impacts from reduced fish stocks.

- **Section 3** establishes the data required from the entity to implement the Methodology. This includes water pollutants produced in kgs by location, organized by whether they are discharged into freshwater, seawater, or unspecified.

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[1] See General Methodology 1: Conceptual Framework for Impact Accounting.

- **Section 4** outlines the approach of the Methodology for measuring and valuing the impacts, focusing on research linking the direct impacts of water pollutants on human health and the broader impacts of eutrophication.

- **Section 5** articulates potential opportunities for further development of the Methodology.

- This Interim Water Pollution Methodology builds on frameworks and protocols published by leading organizations in the impact management ecosystem and sustainability-related disclosures required by governing jurisdictions and international standard setters, including:

    - Capitals Coalition;
    - Ecosystem Service Valuation Database (ESVD);
    - European Sustainability Reporting Standards (ESRS);
    - Global Reporting Initiative (GRI);
    - Intergovernmental Panel on Climate Change (IPCC);
    - National Institute for Public Health and Environment, Netherlands;
    - The Transparent Project;
    - Value Balancing Alliance
    - World Resources Institute (WRI); and
    - World Wide Fund for Nature (WWF).

1 Introduction

1.1 Document purpose

1. The purpose of this document is to outline the Interim Methodology for Water Pollution (henceforth, the Interim Water Pollution Methodology or the Methodology).

2. Interim methodologies have been released by the International Foundation for Valuing Impacts as complements to the official *impact accounting methodology* being developed by the International Foundation for Valuing Impacts and the Value Balance Alliance. The content of the Interim Water Pollution Methodology builds on the General Methodology and is intended for use alongside other Interim, Topic, and Industry-specific Methodologies.

3. The impact accounting methodology measures and values the *impacts* of corporate entities (entities or an entity) in monetary terms for the purposes of preparing impact accounts and generating impact information. The Interim Water Pollution Methodology can be used to inform internal decision-making, investment decisions, and understand the significance of waste impacts of an entity.

4. Interim methodologies have undergone a detailed research and development process but have not gone through the Due Process Protocol or been approved by the Valuation Technical and Practitioner Committee (VTPC). Interim methodologies will be further developed and revised through the Due Process Protocol according to the established annual VTPC work plan.

5. The Interim Water Pollution Methodology can be applied via this document and the Global Value Factors Database. Supporting resources include the Interim Water Pollution Methodology Model and the Model Technical Manual for users interested in understanding and expanding the interim methodology at a more technical level.

6. Preparers of impact accounts should adhere to the Interim Water Pollution Methodology to the fullest extent possible and should disclose any deviations from it when shared with users of impact information.

1.2 Topic description

7. For the purposes of the Methodology, water pollution is defined as the release of substances into surface water, such as lakes, streams, rivers, estuaries, and oceans, or

into subsurface groundwater to the point that the substances interfere with the beneficial use of the water or with the natural functioning of ecosystems.[2]

8. Water pollution is a global issue that is on the rise, despite improvements in some developed countries. It has adverse effects on human well-being and carries a societal cost. Unsafe water kills more people each year than war and all other forms of violence combined.[3] Meanwhile, drinkable water sources are finite: less than 1 percent of the earth's freshwater is actually accessible to humans. Without action, the challenges will only increase by 2050, when global demand for freshwater is expected to be one-third greater than it is now.[4]

9. The impacts of water pollution are primarily local or regional and depend on the physical environment and local demographic exposure. For example, the change in concentration of arsenic following a release depends on the size of the water body and flow rate. The extent of its subsequent impact on people depends on the likelihood that local populations will come into contact with the polluted water.

10. The most significant categories of water pollutants are toxic pollutants, nutrient pollutants, pathogens, and thermal pollution.

11. Toxic pollutants[5] are substances or combinations of substances which after discharge and upon exposure, ingestion, inhalation, or assimilation into any organism result in adverse effects. They include both organic and inorganic substances and have a tendency to bioaccumulate in the food web, persist in the environment, and cause undesirable changes in the natural environment. These pollutants can enter water bodies through industrial discharges, agricultural runoff, and improper waste disposal.

12. Nutrient pollutants, such as nitrogen and phosphorus, can lead to excessive plant and algal growth in a process known as eutrophication. These nutrients, which originate from sources like agricultural fertilizers, sewage, and stormwater runoff, are essential for life. However, in elevated concentrations, they can cause severe algal growth, resulting in a range of negative effects, such as low levels of dissolved oxygen in the

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[2] Britannica (2016). *Water Pollution sources and impacts.*

[3] NRDC (2023). *Natural Resources Defense Council. Water Pollution: Everything You Need to Know*.

[4] UNESCO World Water Assessment Programme (2018). *The United Nations world water development report 2018: nature-based solutions for water.*

[5] Cornell Law School 33 U.S. Code § 1362 – Definitions. *The term "toxic pollutant" means those pollutants, or combinations of pollutants, including disease-causing agents, which after discharge and upon exposure, ingestion, inhalation or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will, on the basis of information available to the Administrator, cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction) or physical deformations, in such organisms or their offspring.*

water. This then leads to hypoxic conditions that can kill fish, crabs, oysters, and other aquatic animals.[6]

13. The impact of eutrophication extends beyond aquatic life. Harmful algal blooms, particularly those caused by cyanobacteria, produce toxins hazardous to human health. Eutrophication also results in secondary impacts such as impaired recreational value and decreased property values. Excessive macrophyte growth due to nutrient enrichment can make water bodies less suitable for recreational use by creating health hazards from toxic blooms, water congestion from vegetative growth, unfavorable appearances, and unpleasant odors. This subsequently affects the potential sale value of local properties.[7] Studies suggest that leisure and residential properties can be devalued by as much as 20% due to consistently poor physical water quality.[8] Additionally, hypoxic conditions resulting from excess algal growth can lead to a decline in fish stocks and the accumulation of toxins in fish, negatively impacting commercial fishing and exacerbating economic losses.

14. Understanding and addressing water pollution is crucial on a global scale. The high-level impacts include not only environmental degradation but also significant economic and health concerns. Measuring these impacts is essential for developing effective strategies to mitigate water pollution.

15. The Methodology takes a societal perspective rather than a discrete affected stakeholder group by considering the impacts on society, both within the region where water is polluted and globally. By measuring and valuing the impacts on society, water pollution impact accounts can provide guidance to entities to manage and mitigate risks.

16. While the Methodology measures the impacts of an entity on stakeholders, understanding and managing water pollution impacts can also help an entity comply with environmental regulations, reduce the risk of legal action, enhance the entity's reputation, and improve operational efficiency by preventing contamination-related shutdowns and remediation expenses.

1.3 Scope and assumptions

17. The health impacts of toxic pollutants are comprehensively covered in the Methodology. These pollutants include both inorganic substances, such as heavy metals and organic compounds such as Benzene, and Polycyclic aromatic hydrocarbons, which

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[6] National Ocean and Atmospheric Administration. *Ocean Facts. What is Nutrient Pollution?*

[7] Krysel, C., Boyer, E. M.; Parson, C.; Welle, P. (2003). *Lakeshore Property Values and Water Quality: Evidence from Property Sales in the Mississippi Headwaters Region.*

[8] Wood, R. and Handley, J. (1999). Urban waterfront regeneration in the Mersey Basin, North West England.

can persist in the environment, bioaccumulate in the food web, and cause adverse health effects.

18. While there are studies that assess the societal costs of both organic and inorganic pollutants, comprehensive comparative studies that evaluate the relative societal costs of different pollutants and pathways in a way that can fully inform whether impacts are significant. The Methodology aims to cover as many pollutants and pathways as possible, only excluding areas where there is particularly strong evidence of immateriality, insufficient data, or a compelling case on other grounds.

19. The Methodology does not address ecotoxicity due to the preliminary stage of research in this area, and the increasing number of (unknown) chemical stressors and mixture effects present in the environment. The European Commission, for example, has indicated that substantial work is still needed to robustly consider the toxicity effects on biodiversity and consequently on recreation, property values, fish stocks, livestock, agriculture, and other ecosystem services.[9]

20. Thermal pollution, which involves the discharge of water at temperatures different from the ambient water bodies, is also out of scope in the Interim Water Pollution Model. The impacts of thermal pollution are highly localized, and there is no consistent data collected to clearly articulate the causation in an impact pathway. However, it is recognized as an issue for some industries and can be addressed on a case-by-case basis in future methodologies.

21. The Methodology does not address groundwater contamination due to the lack of a suitable model for understanding the relationships between discharges, changes in groundwater quality, and human consequences.

22. The health impacts of pathogens are not considered within the scope of this methodology. This exclusion is based on two reasons: human wastes are less commonly directly linked to corporate activities, and the impacts of consuming water containing harmful pathogens are captured in the Water Consumption Methodology, and therefore the risks of double-counting of impacts would be high.

23. The methodology uses USEtox[10] to model chemical date and exposure of humans to toxic pollutants. USEtox includes a number of simplifying assumptions, as explained

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[9] European Commission-Joint Research Centre (2011) - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) *Handbook- Recommendations for Life Cycle Impact Assessment in the European context*.

[10] Rosenbaum, R.K., Huijbregts, M.A.J., Henderson, A.D., Margni, M., McKone, T.E., van de Meent, D., Hauschild, M.Z., Shaked, S., Li, D.S., Gold, L.S., Jolliet, O., (2011). *USEtox human exposure and toxicity factors for comparative assessment of toxic emissions in life cycle analysis: sensitivity to key chemical properties.* USEtox was developed by

within its documentation. Key assumptions and simplifications include the use of country geophysical parameters for a location (e.g. average temperature, average rain rate, average freshwater depth) and linear dose response functions. This assumes that pollutant concentrations are already above any damage threshold, such that any addition of pollution in the environment causes an impact.

24. The scope and boundaries of the Interim Methodology includes full value chain water pollution. This includes upstream, direct operations, and downstream as defined in General Methodology 1. An entities' own operations should be the same scope used for financial statements to ensure comparability. Value chain water pollution production may be based on models and not directly measured due to the challenges of measuring upstream and downstream water pollution.

25. The Interim Water Pollution Methodology recognizes full responsibility of an entity for its upstream and downstream waste production. Water pollution is attributed to an entity through physical or economic relationships by portioning the inputs or outputs of water pollution and determining the portion that is linked to the entity. The inclusion of value chain water pollution means that double counting will occur if aggregating across entities in the same value chain. However, this will not lead to double counting within an individual entity's impact statement.

1.4 Key concepts and definition

26. For the Methodology, the following terms are defined as follows:

    a. Eutrophication: This refers to the process by which a body of water becomes overly enriched with nutrients, leading to excessive growth of algae and other aquatic plants. This can result in oxygen depletion and harm to aquatic life.[11]

    b. Ecosystem services: The benefits that humans receive from ecosystems, including provisioning, regulating, cultural, and supporting services. The valuation of these services can be impacted by water pollution.

    c. Willingness to pay (WTP): A measure of the amount individuals are willing to pay to avoid negative outcomes, such as health impacts from water pollution. This is used in the valuation of societal costs of emitting excess nutrients to water.

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the Task Force on Toxic Impacts under the United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC) Life Cycle Initiative to include the best elements of available LCA multi-media models.

[11] F. Chislock, E. Doster, A. Zitomer (2013) *Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems.*

d. Disability-adjusted life year (DALY): A measure used to quantify the burden of disease. It represents the total number of years lost due to ill-health, disability, or early death. The value of a DALY is used to put a monetary value on the damage function calculated in DALYs per case.

2 Impact Pathway

2.1 Summary

27. The impact pathway is the analytical framework adopted to identify series of consecutive, causal relationships, ultimately starting at an input for an entity's activities and linking its actions with related changes in people's well-being. It serves as the foundation of the impact accounting methodology.

28. Detailed components of the impact pathway are outlined in subsequent sections, leading to the valuation of an entity's pollution of water in Section 4: *Outcomes, Impacts, Valuation.*

29. The impact pathway for water pollution is as follows:

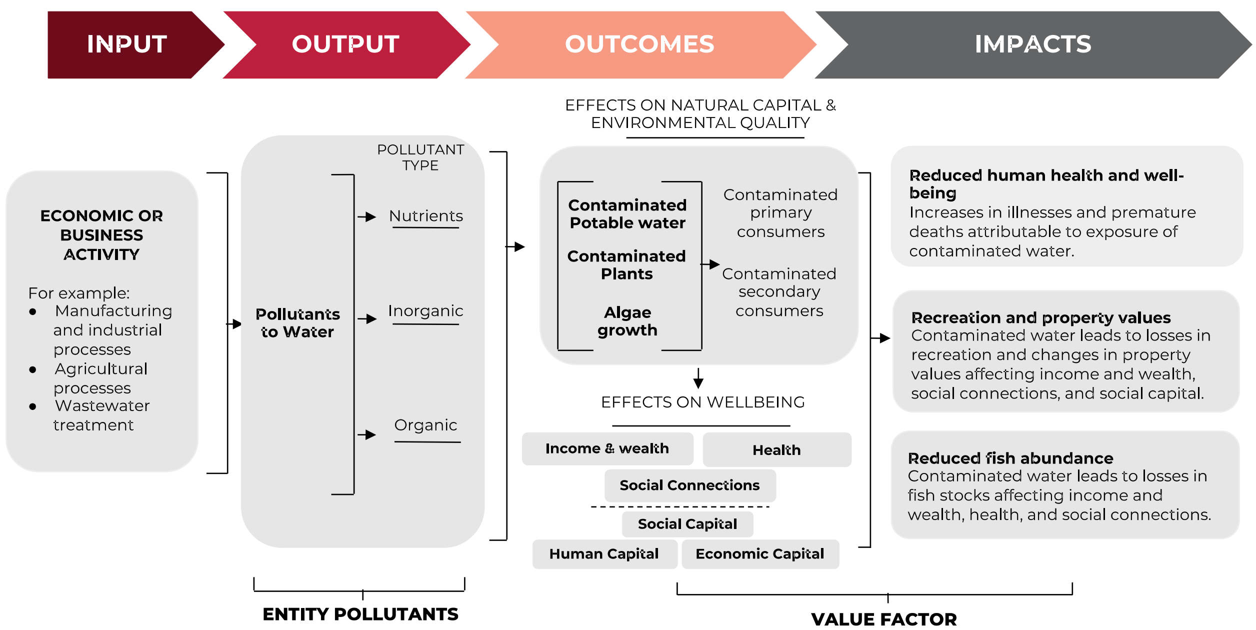

Figure 1: Water Pollution impact pathway

2.2 Description and notes

30. The primary inputs for the water pollution impact pathway are the corporate activities that generate water pollution including industrial processes, agricultural activities, and wastewater treatment. For instance, industrial processes may release heavy metals and chemical compounds into water bodies, while agricultural activities contribute nutrients such as nitrogen and phosphorus through runoff. Wastewater treatment plants, although designed to clean water, may still discharge pollutants if the treatment is not fully effective.

31. The output from these corporate activities can be categorized into various types of pollutants. These include inorganic pollutants (e.g., heavy metals like arsenic and mercury), organic pollutants (e.g., chemical compounds), and nutrients (e.g., nitrogen and phosphorus).

32. The disposal and accumulation of these pollutants have consequent impacts on environmental quality and natural capital. These include contamination of potable water, plants, and livestock; eutrophication due to excess nutrients; and bioaccumulation of pollutants in the food web. The likelihood of these impacts being realized is greatly influenced by the type and concentration of pollutants discharged.

33. The consequential changes to the physical environment drive impacts that reduce the well-being of people and the condition of the natural environment. Categories of well-being affected include income and wealth, health, social connections, social capital, human capital, and economic capital. These primarily fall in two categories in the Interim Water Pollution Methodology:

    a. Human health impacts: Toxic pollutants discharged into water systems can persist in the environment, bioaccumulate in the food web, and cause adverse health effects ranging from acute illnesses, such as gastrointestinal diseases, chronic conditions such as cancer, and neurological disorders, and DALYs lost.

    b. Impacts to Recreation, Property Values, Fish Stocks, Livestock, Agriculture, and Ecosystem Services. Nutrient pollutants discharged to water systems in excess resulting in eutrophication can impair recreational opportunities such as swimming, fishing, and boating. This loss in recreation not only affects the well-being of individuals but also has economic implications for communities that rely on tourism and recreational activities. Properties located near water bodies with severe algal growth often experience a decline in value. This is attributable to the reduced aesthetic and recreational value of the water, as well as potential health risks associated with living near contaminated water sources. Hypoxic conditions in water bodies as a result of eutrophication can lead to a decline in fish stocks, affecting both commercial and subsistence fishing. Moreover, toxins can accumulate in fish, making them unsafe for consumption and reducing their market value. This has direct economic impacts on the fishing industry and communities that depend on fishing for their livelihood.

3 Impact Driver Measurements

34. Impact drivers consider inputs and outputs and reflect the data needs expected of a preparer to provide an impact account for water pollution. The section below outlines the specific data needed along with how these data align with various respective reporting standards.

35. Data requirements for the Interim Water Pollution Methodology are aligned with and expand upon water pollution related sustainability reporting standards, which primarily capture quantities of water discharged to particular water sources and specific water pollutants of concern.

3.1 Data requirements

36. The Interim Water Pollution Methodology requires the total kilograms of each pollutant released to freshwater or seawater as presented in Appendix E and featured in the Global Value Factor Database. These measures should be separated by country, as shown in Table 1. If it is not known whether a pollutant is released to freshwater or to seawater, an 'unspecified' value factor can be used.

37. Companies will need to select the water pollutant that are relevant to their business, including their direct operations and full upstream and downstream value chain.

Data input		Country	Country 2	Country 3
Water Pollution in Own Operations				
Pollutant mass released to water (kg)	Freshwater			
	Seawater			
	Unspecified			
Water Pollution in Upstream Value Chain				
Pollutant mass released to water (kg)	Freshwater			
	Seawater			
	Unspecified			
Water Pollution in Downstream Value Chain				
	Freshwater			

Pollutant mass released to water (kg)	Seawater			
	Unspecified			

Table 1: Water pollution data requirements

38. Due to the exhaustive nature of water pollutants included in the Methodology, not all are listed in the chart above. A full list is available in Appendix E and the Global Value Factors Database.

39. The data requirements of the Water Pollution Topic Methodology aligns with and expands upon disclosure requirements established by relevant standard setters including European Sustainability Reporting Standards E2: Pollution and the Global Reporting Initiative 303: Water and Effluents 2018. Additional alignment may exist with other regional or topic specific reporting standards as well.

Metric	ESRS	GRI
Water Pollution – own operations	Expands upon E2-4, paragraph 26 and 28, page 108	Expands upon Disclosure 303-4 (a) and (d)
Water Pollution – value chain	Expands upon E2-4, paragraph 26 and 28, page 108	Expands upon Disclosure 303 -4 (a) and (d)
Location of waste production	Expands E2-4, paragraph 26 and 28, page 108 Expands upon E2-4, paragraph AR 22, page 112	Expands upon Disclosure 303-4 (a) and (d)
Water Type Polluted	Aligns with E2-4, paragraph 26 and 28, page 108 Expands upon E2-4, paragraph AR 22, page 112 Table 2 – Terms defined in the ESRS, Annex II, page 23 and 28	Expands upon Disclosure 303 -4 (a) and (d)

Table 2: Alignment with reporting standards[12]

[12] Categories of alignment include (1) fully aligned: data from reporting can be used as is for preparation of impact accounts; (2) expands upon: data from reporting conceptually aligns with the impact accounting methodology, but additional detail, context, or presentation is necessary for an accurate accounting of impact; or (3) independent: Data needed for the preparation of impact accounts are not covered by the reporting standards and would require separate data collection and analysis.

3.2 Data sources, gaps, and uncertainty

40. Preparers should strive to measure water pollution impacts in a manner that is complete, neutral, and free from error. This includes faithfully representing water pollution from all parts of the value chain.

41. In practice, obtaining full value chain water pollution data may be challenging for entities, particularly from upstream or downstream in the value chain. Barriers such as cost, accounting methods, or availability of data may limit preparers from measuring, in their entirety, water pollution impacts.

42. To determine the impacts of waste, total mass of water pollutants, split by compound, destination (seawater vs freshwater vs unspecified), and by location (at least country-level). These can be estimated directly, using data reported by the entity, or indirectly through techniques such as Life-cycle Assessment or Environmentally Extended Input-Output Modelling. Where a direct approach is taken, water pollution data should be apportioned to seawater vs freshwater using actual data where available. Otherwise, general trends at a country or sub-national level can be used.

43. To determine water pollution, knowledge of water pollutant type, discharge quantities and pollutant concentration is necessary. Water discharge data is often more difficult to obtain as water utilities often do not monitor it. If an entity is not directly measuring discharge, it will need to be estimated from secondary data.

44. The metric data required are the masses of each pollutant emitted to water from a given source location in a given year. Measurement of discharges to water is best undertaken on-site using direct in-line measurement. However, aside from large, regulated facilities in developed countries, this is rarely a practical data source, and instead the drivers of pollution to water can be measured to estimate discharges indirectly.

45. Preparers should prioritize approaches that:[13]

    a. directly measure waste produced over those that estimate waste production based on calculations from activity data,

    b. utilize primary data from specific activities within a company value chain over secondary data, and

    c. consider sources of data that are of the highest quality possible.

46. High quality data sources should consider:[14]

    a. technological representativeness. Does the data match the technology used?

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[13] Language adapted to water consumption from the Greenhouse Gas Protocol. (2011). Corporate value chain (scope 3) accounting and reporting standard.

[14] Language adapted to water consumption from the Greenhouse Gas Protocol. (2011). Corporate value chain (scope 3) accounting and reporting standard.

b. temporal representativeness. Does the data represent the actual time or age of the activity?

c. geographical representativeness. Does the data reflect geographic considerations of the activity?

d. completeness. Is the data statistically representative of the activity?

e. reliability. Are the data sets or sources dependable?

47. Various estimation techniques can be used to determine water pollution. While a variety of techniques exist, those recommended for water pollution analysis include life cycle analysis (LCA) and environmentally extended input-output (EEIO) tables. Both approaches have developed frameworks for determining water pollution but may differ in levels of data specificity or considerations depending on the context of application.

48. Uncertainty will arise when quantifying water pollution. Preparers should report qualitative uncertainty and, when possible, quantitative uncertainty. These may include but are not limited to propagated measured uncertainty, pedigree matrices, sensitivity analyses, or probability distributions. Reporting uncertainty and other results may be done in accordance with the Value Notes guidance produced by the Value Commission of the Capitals Coalition.[15]

[15] https://capitalscoalition.org/project/the-value-commission/

4 Outcomes, Impacts and Valuation

49. The impacts that result from water pollution affect the environmental quality dimension of well-being and the well-being resource of natural capital. These are linked to the well-being of people through their effects on health, income and wealth, social connections, as well as social, human, and economic capital.

50. The impact pathway in this statement has been developed using a value factor that collapses the impact measurement and valuation stages into a summary value that is location-specific for each category of impact. The value factors, available in the GVFD can then be multiplied directly by entity-specific waste production consumption using the equations in section 4.1. The measurement and valuation approaches are expanded upon in sections 4.2 and 4.3 and Appendix B.

4.1 How to calculate impacts

51. To determine the monetized health and eutrophication impacts of water pollutants (WP $\text{Value}_{\text{Total}}$), entities should apply the following valuation formula:

$$\textbf{WP Value}_{\textbf{Total}} = \sum\left(EUT\ Impact_p + HEALTH\ Impact_{pl}\right) \quad \text{(Eq. 1)}$$

for all pollutants in all countries

$$EUT\ Impact_p = Pollution_p * VF_{p\ EUT} \text{ for each country} \quad \text{(Eq. 2)}$$

$$HEALTH\ Impact_{pl} = Pollution_{pl} * VF_{pl\ HEALTH} \text{ for each country} \quad \text{(Eq. 3)}$$

52. The variables for the equations are as follows:

$VF_{pl\ HEALTH}$	The value factor for health for each water pollutant and the location type where the pollution occurred. These values are distinct for each country where pollution occurs. The value factor should be obtained for each country from the Global Value Factors Database.
$VF_{p\ EUT}$	The value factor for eutrophication for each water pollutant. These values are distinct for each country where pollution occurs. The value factor should be obtained for each country from the Global Value Factors Database.
$Pollution_p$ $Pollution_{pl}$	The kilograms of water pollution released organized by the pollutant, location type, and country of release. For eutrophication impacts location is not needed.
p	Type of pollutant (e.g. phosphorus or lead).

l	Location type where water pollutant is released (freshwater, seawater, or unspecified). This consideration only applies to health impacts.

53. The water pollution impact calculation is described below.

    a. Equations 2 - 3 calculate the monetary value of impacts for each of the components of the water pollution impact pathway, eutrophication and health impacts. These are organized based on the type of pollutant, location type (only for health) and country and are presented as part of the Global Value Factors Database. The value factor for each can be multiplied by the water pollution value for that pollutant and country. These equations should be calculated separately for each of the categories provided.

    b. After determining each impact, the total water pollution impact can be determined by summing the two impacts for each air pollutant, location type, and country.

54. The methodology presented here is intended for use with global water pollution data organized by the country of pollution. Where highly localized valuations are required, a more locally focused approach should be applied.

55. Upstream value chain, downstream value chain, and own operations of water pollution should always be considered separately to increase transparency, comparability, and decision-usefulness. Additional levels of detail may be useful such as an assessment of water pollution impact regionally, nationally, or within specific value chain categories

4.2 Outcomes and impacts

56. For each impact, the approaches used to link water pollution to outcomes and impacts are described below. Additional methodological details are in Appendix B.

57. Human health impacts from toxic pollutants in water are significant and multifaceted. To estimate the societal impact of toxic pollutants on human health, specific pollutants that cause health issues are identified, such as heavy metals, pesticides, and industrial chemicals. Next, the incidence of health conditions attributable to these pollutants is estimated, including cancer, neurological disorders, and respiratory issues.

58. Outcomes and impacts related to excessive nutrients and their influence on recreation, property values, and fish stocks are combined in the monetary valuation calculation below.

4.3 Monetary valuation

59. Monetary valuation uses value factors to estimate the relative importance, worth, or usefulness of changes in well-being indicators in monetary terms. The monetary valuation approach and value factors are developed individually for each impact. Each approach is described briefly below with additional methodological details in Appendix B.

60. Regarding human health, the Interim Water Pollution Methodology applies economic studies on the value of statistical life (VSL) to estimate the financial burden of these health conditions. Specifically, the VSL is obtained from an OECD meta-analysis, with a single value used globally such that mortality is valued the same regardless of location. The VSL used is $4,889,008 in 2023 USD. The societal cost is calculated by multiplying the incidence of health conditions by the associated medical and economic costs, thereby providing a monetary value representing the societal impact of toxic pollutants on human health.

61. The equation to determine the value factor of health impacts is shown below:

$$Value\ Factor_{c1.fw,mw,z} = Characterization\ factor_{c1,fw,z} \times DALYs_z \times DALY\ value_{c1} +$$

$$Characterization\ factor_{c1,mw,z} \times DALYs_z \times DALY\ value_{c1}$$

$Characterization\ factor_{c1,fw,z}$	The number of disease incidences per kilogram of substance released to freshwater of a substance in a given country
$Characterization\ factor_{c1,mw,z}$	The number of disease incidences per kilogram of substance released to marine water of a substance in a given country
$DALYs_z$	The number of DALY associated with the critical cancer and non-cancer effects of the substance
$DALY\ value_{c1}$	The PPP adjusted value a DALY in monetary terms

62. Valuation of impacts caused by excessive nutrients including decreased recreation, property values, and fish stocks is done by a welfare-based approach to calculate generic damage values. The methodology is adapted from Ahlroth (2009)[16] who uses WTP to estimate damage values per kg of N or P. This approach makes best use of the

[16] Ahlroth, S. (2009). Developing a weighting set based on monetary damage estimates. Method and case studies. US AB : Stockholm.

somewhat limited literature on valuation of eutrophication impacts. Calculation of other countries value factors is done using Benefit Transfer.

63. Conducting primary research on WTP is expensive and time-consuming, particularly at the global scale. A more time and cost-effective alternative to primary valuation studies, widely used in policy, is benefit transfer. This involves applying estimates of WTP from existing studies to different, but sufficiently similar contexts. These values are adjusted to account for the differences in context. The breadth of applicability of benefit transfer generally rises in line with the sophistication of the adjustment technique.

64. In the context of a globally applicable methodology, there is only limited primary research on WTP values across cities and countries and those studies which do exist often use inconsistent approaches. Benefit transfer can help overcome this lack of consistent primary work by providing a single value or set of values which can be applied and adjusted consistently to different geographical and socioeconomic contexts.

65. In this methodology, Ahlroth's base values are used and adjusted to account for income. In the longer term, a more sophisticated benefit transfer function could be developed to allow adjustments for local contexts and preferences. However, insufficient primary data on the characteristics of participants in the underlying studies was available to support this approach. If the valuation approach is to be applied at a more focused geographical area it may however be possible to find or collect such data.

66. The equation to determine the value factor of eutrophication impacts is shown below:

$$Value\ Factor_{c1.fw,mw,N,P} = Eutrophication\ Potential_{c1,fw,P} \times WTP_{c1,fw,P} +$$

$$Eutrophication\ Potential_{c1,mw,N} \times WTP_{c1,mw,N} +$$

$$Eutrophication\ Potential_{c1,mw,P} \times WTP_{c1,mw,P}$$

$Eutrophication\ Potential_{c1,fw,P}$	The eutrophication potential of phosphorus released to freshwater in a given country
$Eutrophication\ Potential_{c1,mw,P}$	The eutrophication potential of phosphorus released to marine water in a given country
$Eutrophication\ Potential_{c1,mw,N}$	The eutrophication potential of Nitrogen released to marine water in a given country
$WTP_{c1,fw,P}$	PPP adjusted willingness to pay for one kg of phosphorus in freshwater in any given country
$WTP_{c1,mw,N}$	PPP adjusted willingness to pay for one kg of nitrogen in marine water in any given country

$WTP_{c1,mw,P}$	PPP adjusted willingness to pay for one kg of phosphorus in marine water in any given country

5 Future Development

67. The Interim Water Pollution Methodology represents the current state of knowledge on understanding water pollution impacts and builds upon decades of rigorous scientific work. But some opportunities for improvement exist including enhancing water pollution data accounting across the value chain and further development of the valuation of impacts.

68. Opportunities to further advance water pollution impact accounting include:

    a. Incorporating emerging pollutants: Expanding the scope of pollutants considered in the methodology to include emerging contaminants such as microplastics, and personal care products, which are increasingly recognized as significant environmental threats.

    b. Improvement on the quality and granularity of primary data where possible to avoid overreliance on secondary data/methodologies.

    c. Conducting targeted research to fill existing data gaps, particularly in areas such as groundwater contamination, thermal pollution, and ecotoxicity. This will help create a more comprehensive water pollution model and improve the accuracy of impact assessments.

    d. Research and data collection efforts to better understand the impacts of water pollution on groundwater quality. This includes developing approaches to assess the relationships between pollutant discharges, changes in groundwater quality, and human health consequences.

69. Further revisions based on these opportunities, among others, will be considered as the methodology is further developed and revised through the Due Process Protocol according to the established annual VTPC work plan.

Appendix A: Glossary

Term	Definition	Source[17]
Benefit transfer	Using existing willingness to pay (WTP) estimates from one context to value similar benefits or costs in another context. This method is often used when primary valuation studies are not feasible. Also known as value transfer.	ISO 14008:2019
Transfer function	A mathematical function used for benefit transfer. While different transfer functions exist, many are a function of the average income in the original context relative to the estimated context and the income elasticity of WTP. Average income can be estimated as gross national income (GNI) per capita using purchasing power parity (PPP) exchange rates (rates of currency conversion that equalize the purchasing power of different currencies). The income elasticity of WTP is the responsiveness of WTP with respect to changes in income.	Organisation for Economic Co-operation and Development (OECD)
Water pollution	The release of substances into surface water or subsurface groundwater to the point that the substances interfere with beneficial use of the water or with the natural functioning of ecosystems.	Britannica
Disability-adjusted life year (DALY)	One DALY represents the loss of the equivalent of one year of full health. DALYs for a disease or health condition are the sum of the years of life lost to due to premature mortality (YLLs) and	World Health Organization

[17] Some definitions are adapted from the original source.

	the years lived with a disability (YLDs) due to prevalent cases of the disease or health condition in a population.	
Direct in-line measurement	A method for measuring effluent discharges to water directly at the site of emission. This is considered the best practice for obtaining accurate data on water pollutants.	N/A
Eutrophication	The process by which nutrient pollutants discharged to water systems in excess result in algal blooms, hypoxic conditions, and subsequent impairment of recreational opportunities and decline in fish stocks.	National Oceanic and Atmospheric Administration (NOAA)
Eutrophication potential	Defined as the potential of a substance or process to over-fertilize the water bodies, resulting in increased growth of biomass, expressed in phosphates equivalents.[18]	Jouhara et al. (2018)
Impact pathway	The series of consecutive, causal relationships, ultimately starting at an input for an entity's activities and linking its actions with related changes in people's well-being.	ISO 14008:2019 (GM1)
Value of a statistical life (VSL)	The amount individuals would be willing to pay or to accept to experience small changes in mortality risk, which is then aggregated to estimate the monetary value of a reduction in mortality risk of 100%.	U.S. Environmental Protection Agency U.S. Department of Transportation
Primary data	Data collected by the entity or an external party specifically for the purpose in which it is used.	General Methodology 2

[18] H. Jouhara, D. Brough (2018): *The aluminium industry: A review on state-of-the-art technologies, environmental impacts and possibilities for waste heat recovery.*

Secondary data	Data originally collected and published for a different purpose. Secondary data sources include	General Methodology 2
Life cycle analysis (LCA)	A technique to assess environmental impacts associated with all the stages of a product's life from cradle to grave.	Capitals Coalition
Limiting nutrient theory[19]	Posits that the growth of organisms, such as algae in aquatic systems, is limited by the nutrient that is in the shortest supply relative to the needs of the organisms. In freshwater systems, phosphorus is often the limiting nutrient, while in marine systems, nitrogen is frequently the limiting nutrient. This theory is used to assess the eutrophication potential of water bodies.[20]	Howarth & Marino (2006) Poikane et al. (2022)
Environmentally extended input-output (EEIO) tables	An analytical framework that uses tables to incorporate environmental data into economic input-output models, allowing for the assessment of the environmental impacts of economic activities.	UNEP

[19] Howarth, R. & Marino, R. (2006). *Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems: evolving views over three decades*. Limnol. Oceanogr., 51, 364–376.

[20] Poikane, S., Kelly, M. G., Várbíró, G., Borics, G., Erős, T., Hellsten, S., Kolada, A., Lukács, B. A., Lyche Solheim, A., Pahissa López, J., Willby, N. J., Wolfram, G., & Phillips, G. (2022). *Estimating nutrient thresholds for eutrophication management: Novel insights from understudied lake types.*

Appendix B: Methodological Details

B1. The Interim Water Pollution Model incorporates the societal impacts associated with all water pollution that can be attributed to a company's operations, potentially covering multiple geographies across expansive global supply chains. The valuation approach first identifies the specific pollutants released into water bodies and quantifies their concentrations. It then estimates the environmental outcomes, such as reduced water quality and bioaccumulation of pollutants, and traces the share of water pollution for which the company is responsible. The model subsequently assesses the extent of impacts on human health, recreation, property values, fish stocks, livestock, agriculture, and other ecosystem services. Finally, the societal impacts of water pollution are quantified and converted into monetary terms, providing a comprehensive estimate of the societal costs. There are two main valuation modules within the Interim Water Pollution Methodology: 1) Toxic pollutants valuation module and 2) Nutrient valuation module.

Toxic pollutants valuation module

B2. This section covers the valuation of human health impacts from toxic pollutants emitted to water. The valuation module for toxic pollutants traces the pollutant from release to ingestion to induced health harms and ultimately values those health harms. Pollutants can enter humans via a number of pathways including direct ingestion (e.g., drinking), indirect ingestion (e.g., via bioaccumulation in fish) and direct inhalation (of evaporated pollutants that were initially emitted to water). Once ingested (or inhaled), the health harms depend on the individual pollutant and its dose. Those health harms are assigned a value using published data on what individuals would pay to avoid those harms, ultimately reaching a total societal cost of water pollution.

B3. In order to evaluate the impacts of water pollution on people, a pollutant's movement through the environment is modeled, along with humans' exposure to the pollutant, and the human health outcomes. The output of this model is the pollutant-specific 'characterization factor' which gives the number of health harms per unit of pollutant emitted. This modeling draws on a body of work known as LCA multimedia modeling. The model for the calculation of characterization factors is USEtox. [21]Among model options, it offers the largest substance coverage with more than 1,250 substances and reflects more up to date knowledge and data on effect factors than other approaches comparing multimedia models. It was specifically designed to determine the fate,

[21] Rosenbaum, R.K., Huijbregts, M.A.J., Henderson, A.D., Margni, M., McKone, T.E., van de Meent, D., Hauschild, M.Z., Shaked, S., Li, D.S., Gold, L.S., Jolliet, O., (2011). USEtox human exposure and toxicity factors for comparative assessment of toxic emissions in life cycle analysis: sensitivity to key chemical properties. The International Journal of Life Cycle Assessment 16, 710-727.

exposure and effects of toxic substances. Additionally, it has the ability to consider spatial differences with the addition of country specific parameters. USEtox has been adopted for regulatory assessments, for example the European Union's EUSES in 2004 and for persistence screening calculations as recommended by bodies such as the OECD.[22]

B4. A Bioaccumulation Factor (BAF) represents the extent to which a substance accumulates in an organism relative to its concentration in the environment. In the context of water pollution, BAF is used to estimate the concentration of pollutants in fish and other aquatic organisms. When measurements are available in the literature, these are used; otherwise, models like the Arnot and Gobas (2003) model[23] in the Estimation Programs Interface (EPI) Suite are used to estimate the BAF for non-dissociating substances.

B5. This type of model is already widely used in Life Cycle Impact Assessment (LCIA) and is recommended by the UNEP and the SETAC.[24] It was developed by a team of researchers from the Task Force on Toxic Impacts under the UNEP-SETAC Life Cycle Initiative to include the best elements of other LCA models.

B6. This methodology is built on the USEtox model in two relevant ways: increasing geographic specificity using country-level data from GLOBACK and limiting the model to only addressing emissions to water (to avoid double-counting with our other valuation methodologies e.g., air pollution). These modifications do not change any of the underlying calculations of the model.

B7. In USEtox, substances that have a potential to increase human disease have a characterization factor (CF). In LCIA, the mass of each chemical emitted is multiplied by a CF to provide the impact indicators. CFs are obtained with characterization models – in this case USEtox – which represent the mechanism of a cause–effect chain starting from an emission followed by environmental fate, human exposure, and the resulting effect on the exposed population. The CF in the USEtox model includes a fate factor (FF), an exposure factor (XF) and an effect factor (EF) (Equation 1):

$$CF = FF \times XF \times EF$$

[22] Klasmeier, J., Matthies, M., MacLeod, M., Fenner, K., Scheringer, M., Stroebe, M., Le Gall, A.C., McKone, T., van de Meent, D., Wania, F. (2006) Application of multimedia models for screening assessment of long-range transport potential and overall persistence, Environ. Sci. Technol. 40, 53–60.

[23] Arnot, J.A., Gobas, F.A.P.C. (2003). *A generic QSAR for Assessing the Bioaccumulation Potential of Organic Chemicals in Aquatic Food-webs.* QSAR Comb. Sci. 22: 337-345.

[24] Pennington, D.W., Margni, M., Amman, C., Jolliet, O., (2005). Spatial versus non-spatial multimedia fate and exposure modeling: insights for Western Europe. Environ. Sci. Technol. 39 (4), 1119–1128.

a) The fate factor describes the amount of contaminant in air, water and soil (termed environmental compartments) available for eventual intake by humans. It is calculated based on the substance's mobility and persistence in the environment. It assesses the residence time of a substance in water, considering processes like adsorption, sedimentation, volatilization, degradation, and advective transport.

b) The exposure factor describes the contaminant intake of the human population due to the mass of substance in the environment considering direct ingestion, direct inhalation, and indirect ingestion through bio-concentration in animal tissues. Essentially it is a substance's likelihood to interact with a receptor; it calculates the number of people exposed and the extent of their exposure. The scope of this methodology is ingestion (direct and indirect) and direct inhalation, as dermal contact is currently not covered by the USEtox model.

c) The effect factor describes determines the quantitative relationship between the dose of a substance received and the incidence of adverse health effects in the exposed population. It reflects the change in lifetime disease probability due to changes in lifetime intake of a pollutant. It is based on a linear dose response function. Although there are a variety of approaches to modeling dose-response, the linear model has been deemed most appropriate for the Interim Methodology.

Assumptions	**Comment on purpose and reasonableness**
Simplified fate and exposure modeling using the USEtox parameters at a country level	Geophysical data are defined at a country level, but are able to be defined locally where exact emission source location is known. It is therefore a necessity to simplify geophysical conditions. USEtox was developed by the Task Force on Toxic Impacts under the UNEP-SETAC Life Cycle Initiative to include the best elements of available LCA multi-media models.
Steady state conditions when calculating substance fate	This modeling technique is well established in the literature.
A linear dose response function is assumed when determining ED50[25]	A linear function assumes that emission concentrations are already above any damage threshold, such that any addition of pollution in the environment causes an impact. Determining whether

[25] Effective Dose 50 (ED50): A standard measure used in toxicology to represent the dose of a substance that produces a therapeutic or toxic effect in 50% of the population.

	pollutants are below any damage threshold requires data on ambient concentration and biogenic emissions data which are not globally available. Linear functions are therefore the standard in academic and government analysis.

B8. To value the health harms and reach the societal impact of water pollution, the severity of these harms using Disability-Adjusted Life Years (DALYs is approximated). Monetary values are then applied to these DALY totals based on willingness to pay (WTP) estimates to provide comprehensiveness in the valuation. DALYs, commonly used by health economists and policymakers, help compare the cost-effectiveness of investments but typically do not value the welfare loss associated with a DALY. Lvovsky[26] developed a methodology to derive the value of a DALY from the Value of a Statistical Life (VSL) and the number of DALYs lost, which has been applied in various policy contexts, including the EU's REACH policy. Due to limited data, direct estimates of the value of negative health cases via WTP are not feasible, making DALYs a necessary interim step.

Nutrient valuation module

B9. This section covers the valuation of societal costs of emitting excess nutrients to water. The valuation module for nutrients estimates the eutrophication potential of nutrients in fresh and marine water and then estimates the value based on published data on what individuals would pay to avoid those harms.

B10. The eutrophication potential of excessive nutrients released into the watercourse is calculated. Only P for emissions to freshwater, and both N and P for marine water, due to the limiting nutrient theory, are considered. Limiting nutrient theory can be summarized as follows:

a) In different environments algal growth is limited by different nutrients. If more of the limiting nutrient is introduced into the system, this will promote an increase in growth. However, an introduction of other, nonlimiting, nutrients will have no effect on growth.

b) In freshwater, P is often considered the limiting nutrient. When salinity increases, N contributions to eutrophication increase. In temporal zones N is probably the major cause of eutrophication in most coastal systems; however, P

[26] Lvovsky, K., Hughes, G., Maddisonl, D., Ostro, B., Pearce, D. (2000). Environmental Costs of Fossil Fuels. World Bank Environment Department Papers No. 78, Pollution Management Series.

can limit primary production in other systems. Therefore, both N and P are considered to contribute to eutrophication in marine waters.

c) In application to impact assessment, most models adopt these general rules, acknowledging that it is a simplification as other nutrients can be limiting in specific conditions.

B11. For both marine water and freshwater, eutrophication potential of P and N is modelled using the respective LC Impact Characterization Factors. Leading approaches wherever possible including those of the ISO handbook on Life Cycle Assessment.

B12. The characterization factor calculated by the LC Impact, is a product of FF, EF and XF, and includes the impacts in the area of protection 'Ecosystem quality' caused by the emission of phosphorus (P) into the freshwater and into the soil compartment. A higher characterization factor means a more severe impact on aquatic life.[27] For marine water, the LC Impact marine eutrophication model adopts a spatially differentiated approach, using the Large Marine Ecosystems (LME) biogeographical classification system, which divides coastal regions into 66 spatial units. This can then be used to determine the spatial differentiation of eutrophication potential of both P and N.

B13. Excessive nutrients lead to various negative consequences, such as reduced recreational opportunities, lower property values, and decreased fish populations. To estimate the general damage values associated with these impacts, a welfare-based approach is adopted. This approach is derived from Ahlroth (2009), who employs Willingness to Pay (WTP) to determine damage values per kilogram of nitrogen (N) or phosphorus (P). This method effectively leverages the limited available literature on the valuation of eutrophication impacts. Benefit Transfer is then used to apply these published values to other countries.

B14. *Valuing eutrophication in freshwater*: Ahlroth presents an approach to use WTP estimates for reduced eutrophication impacts to calculate a generic damage value per kg of P released to freshwater in Sweden. Studies in other parts of the world are currently limited. The benefit transfer approach presented below is based on Ahlroth's values but could be applied to other source data where available. In applying values from a benefit transfer approach, such as this, it is important to consider the applicability of these values to other areas.

B15. Ahlroth analyzed existing valuation studies that estimated the value of improving water quality in a lake or watercourse. The author constructed a generic damage value per kg of P in Sweden, using a structural benefit transfer of eight studies to calculate total WTP

[27] LC Impact (2021): *Freshwater eutrophication.*

and annual deposition amount. The underlying studies were similar in design and valued a quality change. Respondents were presented with different water quality scenarios, described using a water quality ladder. The ladder presented incremental improvements in water quality based on the water's suitability for drinking, bathing, irrigation, recreational fishing and boating.[28] Respondents provided their WTP to move between the scenarios. An average WTP per unit of emission was calculated based on the reduction in nutrient loading necessary to move between water quality scenarios.

B16. Ahlroth assumes a constant marginal WTP. To transfer this value from Sweden to other countries, the WTP values is adjusted by PPP.[29]

B17. *Valuing eutrophication in marine water.* The approach to valuing marine water nutrients is similar to that for freshwater nutrients. For coastal areas, Ahlroth analyzed existing valuation studies that estimated the value of improving water quality in marine water. As per the approach taken for freshwater, Ahlroth calculates a per kg WTP value for phosphorus and nitrogen, using a structural benefit transfer method.

B18. To transfer values from Sweden to other countries, WTP values are adjusted by PPP. Ahlroth constructed generic damage values for phosphorus, nitrogen, ammonia, and nitrogen oxide (NOx). The scope of the Interim Water Pollution Methodology does not cover emissions to air that lead to eutrophication; therefore, only the generic damage values for phosphorus and nitrogen were modeled. However, the aerial eutrophication emissions are likely to be trivial, based on general research on the amount of eutrophying nutrients emitted to air versus water.

[28] Norwegian State Pollution Control Agency, 1989. Vannkvalitetskriterier for ferskvann. (Water quality criteria for freshwater). Holtan H., Ed. SFT-rapport TA-630.

[29] In the future, transfer functions that consider more local data e.g. socio-economic characteristics, physical environmental conditions, cultural factors could be considered.

Appendix C: Value Accountability Framework – Value Factors

This Appendix presents the Water Pollution Topic Methodology summarized in the form of the Transparency Report proposed by the Value Commission of the Capitals Coalition. Minor adaptations have been made to the report structure to align with the impact accounting methodology.

<table>
<tr><th colspan="3">Transparency Report – Value factors</th></tr>
<tr><td colspan="3">Title and version #: Interim Water Pollution Topic Methodology Value Factors, Version 1

Developed by: International Foundation for Valuing Impacts

Published and updated date: October 2024</td></tr>
<tr><td colspan="3">Unit: The impact in dollars per kilogram of pollutant, into freshwater, marine water, or unspecified, per country.</td></tr>
<tr><td colspan="3">Linkages to other value factors: This value factor is a complement to the public good, independent, impact accounting methodology developed by IFVI in partnership with the Value Balancing Alliance and can be combined or complemented with value factors from other topic methodologies.</td></tr>
<tr><td colspan="3">SCOPE OF VALUE FACTOR</td></tr>
<tr><td>Impact pathway scope</td><td colspan="2">1. The scope of the value factor includes organic, inorganic and nutrient pollutants emitted to freshwater and marine water within the entities' full value chain.

2. The value factor captures (1) impacts to human health from exposure to water pollution, and (2) impacts on environmental quality from eutrophication from nitrogen and phosphorus. This covers emission of water pollutants to both seawater and freshwater.

3. More detail about the impact pathway scope can be found in Section 1.4: Scope and Assumptions.

4. Application of the methodology by an entity is based on a materiality assessment as outlined by General Methodology 1: Conceptual Framework for Impact Accounting.</td></tr>
<tr><td></td><td>ESTIMATING CHANGES IN WELL-BEING</td><td>ESTIMATING MONETARY VALUE</td></tr>
<tr><td>Approach and specificity</td><td>5. The potential impacts of effluents on human health are modeled based on the</td><td>8. The severity of health impacts are assessed using Disability Adjusted Life Years (DALYs) and valued</td></tr>
</table>

	chemical fate as the pollutant travels through different media (water, soil, air, food products), and the likelihood of human exposure. 6. Dose-response functions describe the likelihood of different health impacts occurring given a specified level of exposure. Chemical and impact specific functions estimate health outcomes for populations exposed to pollutants. 7. The eutrophication impacts are determined using the eutrophication potential of Phosphorus and Nitrogen in Freshwater and Marine Water respectively	using the Organization for Economic Co-operation and Development (OECD) methodology for valuing changes in health and life. 9. To determine the cost of eutrophication to society, values based on estimations of WTP are used. 10. These eutrophication damage values are based on structural benefit transfer from contingent valuation studies.
Data inputs	11. Country-specific data is sourced from the World Bank, GLOBACK Database (University of Leiden), and LC Impact. Substance-specific data is sourced from USEtox. 12. For further data sets see Appendix B: Methodological Details along with the primary literature sources cited in each.	
VIEWS OF AFFECTED STAKEHOLDERS		
Representation of stakeholders	13. As an interim methodology, these value factors have yet to undergo the Due Process Protocol of the official methodology, which includes additional stakeholder engagement and public comment.	
ETHICAL DECISIONS IN ESTIMATING SOCIETAL IMPACT		
Equity weightings and income adjustments	14. The health impacts of water pollution use a global DALY value to ensure equity in consideration of impacts regardless of their location.	
Accounting for future impacts	15. N/A	

Other ethical considerations	16.	N/A
	SENSITIVITY	
Sensitivity to key variables	17.	Sensitivity analysis was carried out for a number of variables (Access to improved water, Dose-response coefficients, DALYs per disease type, VSL/Value of a DALY, Eutrophication characterization factors, societal cost per tonne of phosphorus and nitrogen in freshwater and marine water|), for 3 countries (United States, China and Nigeria). For full results see Table 2.

Table 3: Sensitivity analysis

		Arsenic			Mercury		
Variable (Health Impacts)	**Flex**	**US (% change)**	**China (%change)**	**Nigeria(% change)**	**US (% change)**	**China (%change)**	**Nigeria(% change)**
Access to improved water	10%	0%	-0.16%	-0.631%	0%	-0.013%	-0.132%
Dose-response coefficients	10%	-10%	-10%	-10%	-10%	-10%	-10%
DALYs per disease type	10%	10%	10%	10%	10%	10%	10%
Value of a DALY	10%	10%	10%	10%	10%	10%	10%
Value of a DALY (Income Adjustment)	Adjustment of the value of changes in health outcomes for national income (vs base case of no adjustment)	9%	23%	21%	16%	23%	21%

		Phosphorus			Nitrogen		

Variable (Health Impacts)	**Flex**	**US (% change)**	**China (%change)**	**Nigeria(% change)**	**US (% change)**	**China (%change)**	**Nigeria(% change)**
Eutrophication Characterization Factors	10%	10%	10%	10%	10%	10%	10%
Societal cost per metric ton of phosphorus in freshwater	10%	10%	10%	10%	10%	10%	10%
Societal cost per metric ton of nitrate in marine water	10%	10%	10%	10%	10%	10%	10%

Appendix D: Data Sources in the Interim Water Pollution Methodology

Data	Source[30]	Year
Advanced economy	IMF WEO	2023
Value of a DALY	OECD	2023
Birth rate (per 1000)	World Bank	N/A
National improved water access	World Bank	2022
Coastal population	SEDAC	2010
Continental scale area land	GLOBACK	2010
Continental scale area sea	GLOBACK	2010
Continental scale areafrac freshwater	GLOBACK	2010
Continental scale areafrac nat soil	GLOBACK	2010
Continental scale areafrac agr soil	GLOBACK	2010
Continental scale areafrac other soil	GLOBACK	2010
Continental scale temp	GLOBACK	2010
Continental scale surface wind speed	GLOBACK	2010
Continental scale wind speed over mixing height	GLOBACK	2010
Continental scale rain rate	GLOBACK	2010

[30] Sources are hyperlinked for your reference.

Continental scale depth fresh water	GLOBACK	2010
Continental scale fraction fresh water discharge	USEtox2.13	2023
Continental scale fraction run off	USEtox2.13	2023
Continental scale fraction infiltration	USEtox2.13	2023
Continental scale soil erosion	USEtox2.13	2023
Continental scale irrigation	GLOBACK	2010
Global scale area land	USEtox2.13	2023
Global scale area sea	USEtox2.13	2023
Global scale areafrac freshwater	USEtox2.13	2023
Global scale areafrac nat soil	USEtox2.13	2023
Global scale areafrac agr soil	USEtox2.13	2023
Global scale areafrac other soil	USEtox2.13	2023
Global scale temp	USEtox2.13	2023
Global scale surface wind speed	USEtox2.13	2023
Global scale rain rate	USEtox2.13	2023
Global scale depth fresh water	USEtox2.13	2023
Global scale fraction fresh water discharge	USEtox2.13	2023
Global scale fraction run off	USEtox2.13	2023
Global scale fraction infiltration	USEtox2.13	2023

Global scale soil erosion	USEtox2.13	2023
Global scale irrigation	USEtox2.13	2023
Urban scale area land	USEtox2.13	2023
Urban scale areafrac unpaved area	USEtox2.13	2023
Urban scale areafrac paved area	USEtox2.13	2023
Exposure human breathing rate	GLOBACK	2010
Exposure water ingestion rate	GLOBACK	2010
Above-ground produce world	USEtox2.13	2023
Above-ground produce continent	GLOBACK	2010
Below-ground produce world	USEtox2.13	2023
Below-ground produce continent	GLOBACK	2010
Meat intake world	USEtox2.13	2023
Meat intake continent	GLOBACK	2010
Dairy products intake world	USEtox2.13	2023
Dairy products intake continent	GLOBACK	2010
Fish freshwater world	USEtox2.13	2023
Fish freshwater continent	GLOBACK	2010
Fish coastal marine water world	USEtox2.13	2023
Fish coastal marine water continent	GLOBACK	2010

World population	World Bank	N/A
Helme's fate factors	Spatially explicit fate factors of phosphorous emissions to freshwater at the global scale	2012
CF for P emissions to freshwater	LC Impact FW Eutrophication	2019
CF for direct N emission to marine system	LC Impact MW Eutrophication	2019

Appendix E: List of Water Pollutants

Impact pathway	Pollutant
Eutrophication	Nitrogen
	Phosphorus
Human health	Antimony – Sb(III) and Sb(V)
	Arsenic – As (III) and As(V)
	Cadmium – Cd (II)
	Chromium – Cr(III) and Cr(VI)
	Copper – Cu(II)
	Lead – Pb(II)
	Mercury – Hg(II)
	Nickel – Ni(II)
	PAHs
	Zinc – Zn(II)
	Silver – Ag(I)
	Barium – Ba(II)
	Beryllium – Be(II)
	Cobalt – Co(II)
	Molybdenum – Mo(VI)
	Selenium – Se(IV)

	Thallium – Tl(I)
	Vanadium – V(V)
	1,2-dichlorobenzene
	1,2-dichloroethane
	1,2-DIMETHYL-5-NITRO-1H-IMIDAZOLE
	1,3-Dichloropropene
	1,4-dichlorobenzene
	2-(2,4-dichlorophenoxy)acetic acid
	2,4,6-trichlorophenol
	2-CHLOROPHENOL
	3-Methylcholanthrene
	4-CHLOROANILINE
	7,12-Dimethylbenz(a)anthracene
	Acenapthene
	ACEPHATE
	ACETAMIDE, N-(4-HYDROXYPHENYL)
	Albuterol
	Aldicarb
	Aniline
	Anthracene

	ANTIPYRINE
	Atrazine
	Benzene
	Benzidine
	benzo[a]pyrene
	Bezafibrate
	butyl benzyl phthalate
	Carbamazepine
	Chlorobenzene
	Chloropyrifos
	Chlorothalonil
	CYANAZINE
	CYPERMETHRIN
	DEF
	di-(2-ethylhexyl)-phthalate (DEHP)
	Diazinon
	Dibenz(a,h)anthracene
	Dicamba
	dichloromethane/methylenechloride (CH2Cl2)
	Diclofenac

	Dicrotophos
	Ethephon
	fluoranthene
	Fluorene
	Fluvastatin
	FUROSEMIDE
	Gemfibrozil
	GLUFOSINATE-AMMONIUM
	Glyphosate
	INDOMETHACIN
	Iopromide
	Malathion
	Mancozeb
	Methyl Bromide
	Metolachlor
	Metoprolol
	METRONIDAZOLE
	Naled
	NALIDIXIC ACID
	Naphthalene

	OXOLINIC ACID
	Paraquat
	Parathion-methyl
	Pendimethalin
	pentachlorophenol
	Phorate
	Propanil
	Pyrene
	Pyrene, 1-nitro-
	Sulfamethoxazole
	Terbutaline
	tetrachloroethylene
	THIABENDAZOLE
	TRI-2-CHLOROETHYL PHOSPHATE
	Trichloroethylene
	Trifluralin
	TRIMETHOPRIM
	Tris (2,3-dibromopropyl) phosphate
	trrichloromethane/chloroform (CHCl3)
	Warfarin

	Analgesics
	anesthetics & NSAIDs
	Anthelminthics
	Antibiotics
	Anticoagulants
	Antihyperlipidemic agents
	Beta-agonists
	Beta-blockers
	Contrast agents
	Diuretics
	Psychiatric drugs
	Pesticides

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