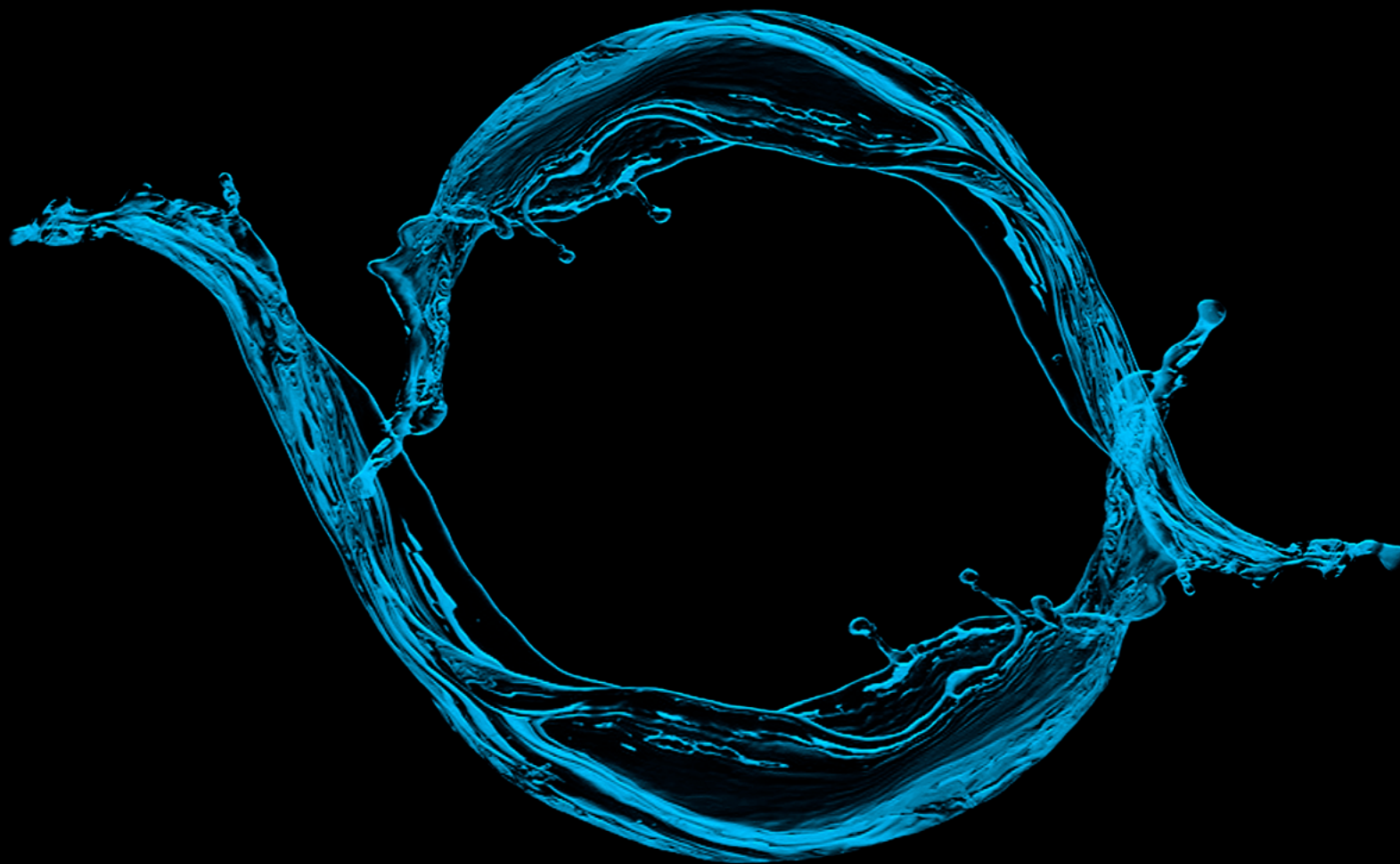


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The price tag of plastic pollution
An economic assessment of river plastic

Contents

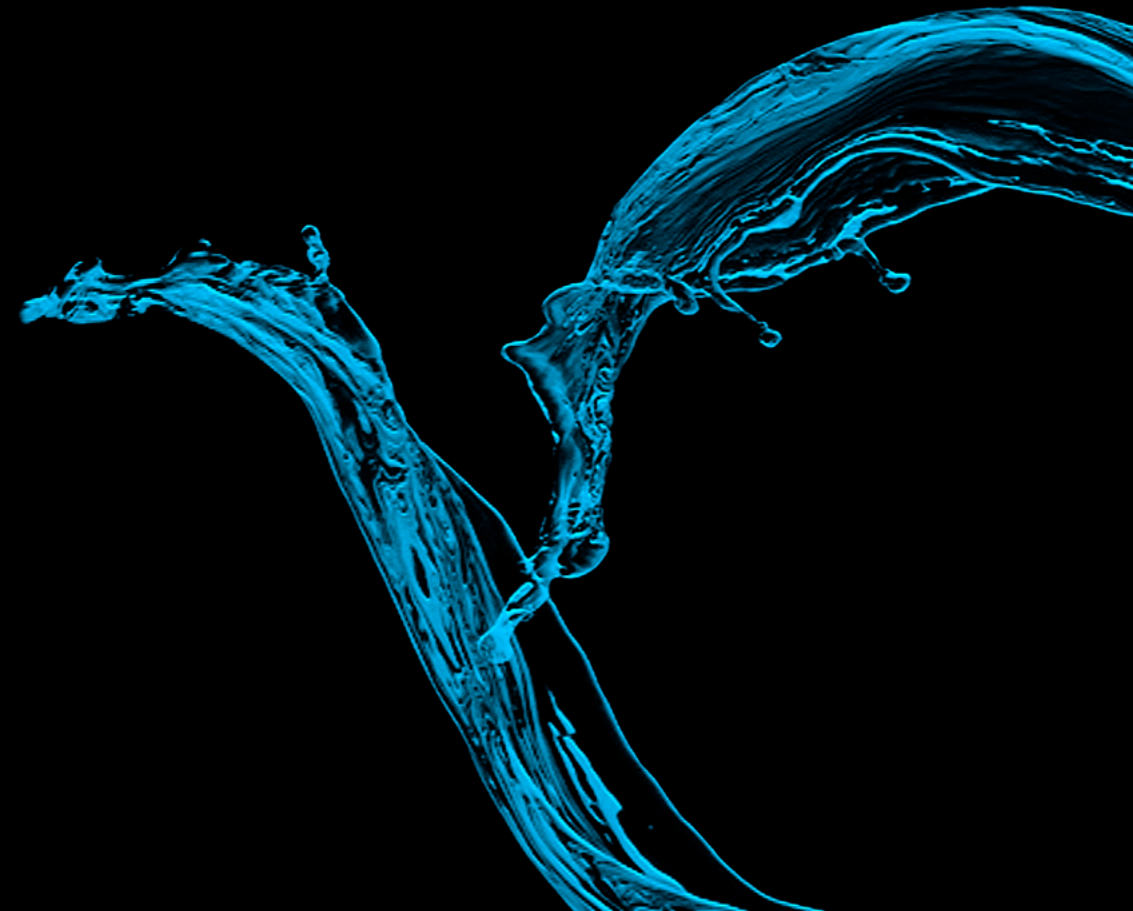
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The price tag of plastic pollution

An economic assessment of river plastic

Marine litter affects key industries such as fisheries, aquaculture, tourism, commercial shipping, and local coastal governments. The economic costs associated with marine litter can be direct (i.e. cleanup activities, and potential loss in economic value) or indirect (i.e. impact on biodiversity and ecosystems).

To date, few studies have addressed the economic costs associated with marine litter. This limits the incentives and ability to address the build-up of marine litter at the source itself, before it enters the oceans. In this paper, we draw attention to the costs emerging from marine plastic pollution, and present a comprehensive assessment model to estimate the costs at a country level, associated with marine plastic litter that flows from land, typically via rivers, into the oceans and ultimately putting a price tag on plastic pollution.



Introduction

It has been estimated that global emission of plastic waste is in the range between 0.8-2.7 million metric tons per year via rivers (study performed by The Ocean Cleanup¹). Mismanaged plastic waste that is discarded, not recycled, incinerated or stored in landfills may drain down rivers and waste water systems ultimately meeting its fate at the sea. Here it slowly weathers and degrades over time into microplastic, accumulates on shorelines, sinks to the seabed or floats on the sea surface of subtropical oceanic gyres. The infamous Great Pacific Garbage Patch, which is the largest reported accumulation zone of floating ocean plastic, is a good example depicting how our thirst for plastic is having consequences on a planetary scale. Plastic is also now recognized as a geological marker of our time for future generations.

Marine plastic debris has far reaching ill-effects that are indicated in an increasing number of publications from various scientific disciplines². Awareness of the harmful impact has led to several initiatives from governments and volunteers aiming to curb the problem of marine plastic pollution. Although the impact of marine debris has been identified and discussed in several reports at national and regional level, there is no local and comparable estimate on the economic loss to coastal communities due to mismanaged plastic waste that flows from land to oceans.

This paper provides an assessment model to estimate the economic impacts of land sourced marine plastic pollution. Through secondary research, we consolidated worldwide data on marine litter, litter characterization, coastal population density, economic status, and direct

and indirect impact of floating marine litter to develop a comprehensive database and a scalable assessment model to calculate the economic impact associated with marine plastic pollution to coastal communities. By compiling data from existing research literature for Europe, Asia, Africa, Middle East, the Americas and Oceania, we estimate that marine plastic pollution could have resulted in an economic loss of USD 6 to USD 19 billion for 87 coastal countries in 2018. Our conclusion is that beyond obvious ecological arguments, there is a strong economic and financial reason to address the marine plastic pollution challenge. This paper discusses specific features of the assessment model and presents the limitations of existing literature to stimulate further research in this field. Finally, the paper offers a general discussion on analyses derived from the model outcomes, and conclusions.

¹ The study of waste emissions into the ocean is under peer review. <https://theoceancleanup.com/sources>

² Oceanography, Anthropogenic waste management, Real estate valuation (hedonic regression), Human biology, Marine biology

Methodology

The methodology in this study focuses on the economic impact of plastic litter on national economies and uses a sector-based approach to investigate the increased costs for governments and potential loss of economic value for key industries. This approach does not include the quantification of economic costs of degradation of ecosystem goods and services due to marine litter and the findings presented here are therefore likely to significantly underestimate the total economic costs.

The methodology is divided into four elements:

1. determination of the scope of the model,
2. designing the model,
3. data mining and calibration, and
4. model audit.

1. Determination of scope – The model focuses on economic impact in two areas

- costs incurred for cleanup activities and
- potential loss of economic value for established sectors in the Blue Economy³. The economic costs are expressed as annual impact. 87 countries are considered for the impact assessment based on the level of waste density in waterways in the respective country.

2. Designing the model

- Identifying information: an extensive list of indicators and focus sectors were collected from existing literature for five countries out of the 87 countries in scope. The five countries were selected on the basis of waste density in waterways, geographical coverage and economic status.
- Profiling information: the indicators were classified into impact area and focus industry sectors.
- Designing model prototype: multiple evaluation dimensions were designed to assess costs per focus sector. Mathematical formulas were designed to evaluate costs per dimension.

3. Data mining and calibration

- Gathering data: a data mining exercise was conducted to gather model relevant data for indicators identified while designing the prototype model. The database was compiled from information gathered via research papers, regional and local reports, news articles, and global datasets.

- Establishing comparability: information gathered from local and regional literature on certain indicators such as beach cleanups, and costs for intercepting floating debris, was not comparable because different studies followed different procedures of information gathering, differences in frequency of analyses, seasonality and geographic conditions at time of analyses, etc. In order to make the data between countries and regions comparable, the data for such indicators was extrapolated from European studies. Model indicators were extrapolated using local economic parameters like purchase power parity, inflation, currency conversion, and waste outflow from land to ocean relative to the parameters in region of origin for the base literature.
- Rationalizing dimensions: different dimensions to estimate the economic impact in the same focus sector could not be consistently applied to all countries mainly because of issues like insufficient data, and demographic differences between countries. Therefore, dimensions per sector were rationalized to use the ones that were consistently applicable to all countries.

4. Model audit – The model data and output were reviewed by multiple experts in areas such as river research, business and operations, sustainability advisory, data analytics, and audit. The model audit focused on three objectives:

- to determine that input parameters were correctly referenced and interpreted, and reasonably extrapolated
- the output from the model is reasonable and ties back to the actual costs incurred or budgets allocated in countries. The output costs should not appear to be substantially higher when that may not be the case,
- scalability of the database to add more countries and more focus sectors as information on the topic increases in future.

³ All economic activities related to oceans, seas and coasts.

Blue economy covers a wide range of interlinked established and emerging sectors

https://ec.europa.eu/maritimeaffairs/sites/maritimeaffairs/files/docs/publications/what-is-the-blue-economy_en_1.pdf

Model Mechanics

In order to determine a method for assessing the economic impact of marine plastic pollution, we performed secondary research on six socio-economic areas; public health, marine ecosystem, real estate, marine tourism, government, and fisheries & aquaculture. The model discussed in this paper focuses on economic assessment that is quantifiable for 3 areas – marine tourism, government, and fisheries & aquaculture. Figure 1 below visualizes the classification of the six areas by type of assessment.

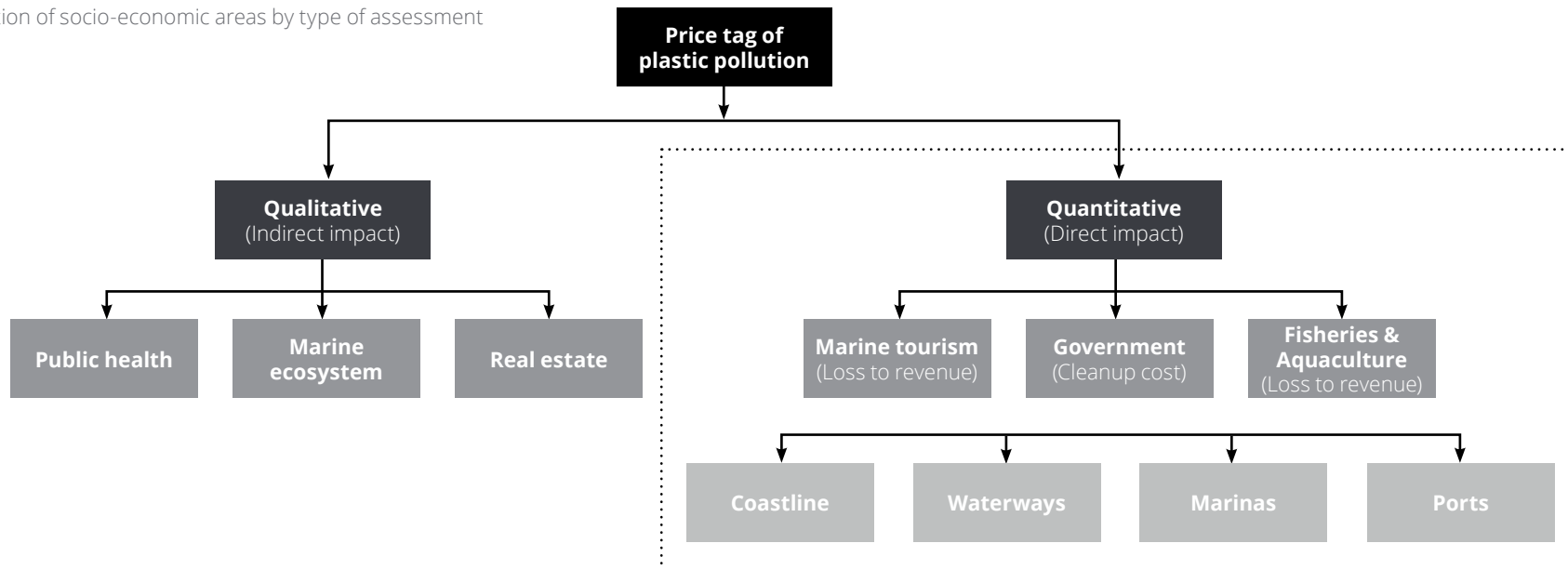
Costs of marine plastic pollution are broadly classified as indirect costs and direct costs.

Indirect costs: these costs can be viewed in terms of economic value together with the long-term impact to biological ecosystem which is assessed qualitatively and is more severe than the financial implications. The harmful impact to ecosystems has become evident from numerous reports about marine animals getting injured and strangled by discarded fishing gear, risk of extinction for species of marine

animals and birds from ingestion of plastic debris, and a panoply of health concerns for humans. Marine pollution also results in loss of aesthetic value of the environment which has an economic cost in form of decreased real estate value of waterfront housing and deterrence of tourists from polluted beaches.

Based on literature review, we concluded that although indirect costs can be quantified with several assumptions, the estimates are not always comparable between countries

Figure 1. Classification of socio-economic areas by type of assessment



or even within a country. Furthermore, despite sufficient awareness on the ecological impact, existing information about the affected population is not collected on a regular frequency nor following a consistent methodology. Therefore, the economic costs associated with public health, marine ecosystem and real estate are not included in the quantitative part of the model.

Direct costs: these are economic costs arising directly from damage to an industry or costs linked to an activity. Direct costs are measured on a periodic basis, are comparable and can be quantified. Such costs imply the short term and immediate financial impact to society. In this study, we focused on quantifying direct costs and developed an assessment model to estimate costs arising from cleaning stranded or floating plastic from inhabited coastline, rivers, ports and marinas, and the potential loss in economic value to marine tourism, fisheries & aquaculture.

The model used to quantify direct costs is based on ~3,500 data points sourced via secondary research. Secondly, indicators such as waste density and waste outflow from rivers per country are based on research and insights from The Ocean Cleanup. The model can be extended as further information is made available from research in other economic sectors.

Cleanup costs

As one of the significant actors in waste management, local municipalities and governments play an instrumental role in setting up waste management infrastructure and investing in waste collection and treatment value chains. As a result, a variable but often significant percentage of the fiscal budget in most countries is reserved for the aforementioned activities.

Although volunteering cleanup activities led by NGOs, concerned citizens, and businesses are increasingly evident across regions, such activities are rather sporadic, and it is difficult to correctly identify costs associated with such activities. Government sanctioned cleanup activities are more systematic and have a dedicated budget for the activity. We therefore model the government as the primary orchestrator for cleanup activities and hence the associated costs. As the scope of this study is limited to coastal countries, four cleanup areas have been identified namely; coastlines, waterways, marinas and ports.

Coastlines – An assessment of potential cleanup costs is made for the length of coastline that is inhabited by more than 300 people per square kilometer and a distance of one kilometer from the coastline⁴. The cost of cleanup is identified from European studies and extrapolated to all countries based on the relative purchase power parity, waste outflow from land into ocean, inflation and currency conversion to US dollars. The overall cost estimate is attributed to plastic by using a secondary research based ratio of the average

volume of plastic debris in overall waste collected from beaches⁵.

Waterways – Similar to coastlines, the potential cleanup costs are estimated for the length of waterways that are inhabited by more than 300 people per square kilometer at a distance of one kilometer from the shore of waterways⁴. The cost of cleanup is identified from European studies and extrapolated to all countries based on the relative purchase power parity, waste density in waterways, inflation and currency conversion to US dollars. The overall cost estimate is attributed to plastic by using a secondary research based ratio of the average volume of plastic debris in overall floating waste in waterways⁵.

Port and marina – The potential cleanup costs are estimated by identifying costs to intercept floating marine debris in ports and marinas from European studies and extrapolating the costs to all countries in scope based on same methodology as followed for coastline cleanup. The ports and marinas are identified from global datasets and a plastic to waste ratio in waterways is used to assess the costs.

It is important to note that any revenue generated from the collected waste is not included in the scope of the model. This exclusion has been made to manage the complexity of the model. This ensures consistency of data irrespective of different maturity levels in the waste management chains for the countries in scope.

Loss in economic value of Fisheries and Aquaculture

The presence of micro-plastics and debris in the water bodies has adverse effects on the marine biodiversity. Not only does this impact the local ecosystems and food chain, but it also harms the fishery reserves, which are the main source of sustenance for the fisheries sector. The degradation of water quality, furthermore, compounds the problem by creating unfavorable conditions for aquaculture. Fish larvae have high mortality rates and are sensitive to water quality and nutrient feed. Any impact on the survival rates can result in significant economic losses to the farmers. A single loss of harvest can bring farmers to bankruptcy due to higher investment requirements and informal farming practices.

In the model, the loss in economic value is modelled by analyzing the fisheries and aquaculture revenue of a country and allocating a loss percentage in the range of 0.3 to 5% (Takehama 1990, Ten Brink et al 2009). Similar to potential loss of economic value for tourism, an uncertainty range is considered instead of a fixed value to ensure the exploratory nature of the model and account for regional and national differences.

⁴ It is assumed that coastlines which are polluted but not inhabited will not be cleaned up

⁵ Waste characterization from Waste Atlas and Ocean Conservancy 2017, 2018

Additionally, a factor for the plastic to waste ratio is considered for all zones to account for the plastic debris in the overall waste.

The loss of revenue, for fisheries & aquaculture, results from the inaction towards management and collection of floating plastic debris.

Loss in economic value of Marine Tourism

The aesthetic value of the environment is greatly affected by mismanaged waste. Stranded debris can also cause injuries and long-term health concerns to humans. The combination of unpleasant experience together with health and safety risks can result in a snowball effect of reduced tourism activity and loss of livelihood for businesses associated with tourism. Although the nature of these impacts is both ecological and economic, the reliance of coastal nations on marine tourism deems it an important sector of the overall economic impact.

Loss in economic value is modelled by analyzing the marine tourism revenue of a country and allocating a percentage of potential loss attributed to plastic pollution. Due to the uncertain nature of the loss percentage, being influenced by the waste management maturity of a country, an uncertainty range between 0.3 to 3% (Takehama 1990, Ten Brink et al 2009⁶) is considered, instead of a fixed value. This ensures the exploratory nature of the model and accounts for differences among the countries.

For the countries where the economic value from marine tourism is unavailable, the overall tourism revenue is considered with a tourism coastal factor ratio identified from OECD studies (OECD 2016). Additionally, a factor for the plastic to waste ratio is considered for all countries to account for the plastic debris in the overall waste.

⁶ As losses to marine tourism in specific are considered, the percentage loss of economic value to tourism is set at 3% instead of 5% to be on the conservative side of estimating costs



Tradeoffs and assumptions

This paper discusses the economic costs of land sourced marine plastic pollution. The uncertainties in the model dynamics occur from the following tradeoffs and assumptions: Input data points are based on secondary research – research papers, reports, news articles, global databases.

The costs are limited to cleanup of stranded or floating plastic litter along coastlines and in waterways respectively.

In order to have comparable costs relating to cleanup activities, costs are extrapolated from European studies. Country specific economic parameters and plastic waste outflow are considered for extrapolation.

Literature review points out that plastic debris is found stranded on remote beaches. However, we assume that local municipalities would have a budget for beach or river cleanup only if the coastline is inhabited. This model considers coastline length that is inhabited by more than 300 people within 1 kilometer from the coastline.

Waste generated in a country could end up as debris on the beaches or river coastlines of another country mainly because of

downstream flow of mismanaged waste in rivers that flow cross-country, ocean currents, and waste trade between countries. The model discussed in this paper is based on estimates of waste density in rivers in each country in scope and the outflow of waste from the respective rivers into sea. Therefore, the model does not take into account cross country plastic waste movements which could be a topic to explore and add to the model dynamics in future.

The model does not factor in political scenarios and geographic catastrophes. For example: tourism could be affected by political discontent, or geographic catastrophes like tsunamis, cyclones etc.

Cleanup activities could reduce contamination levels which would result in lowering the loss of economic value in key economic sectors. However, as this study deals with annual economic loss, this dilemma is not factored into calculations.

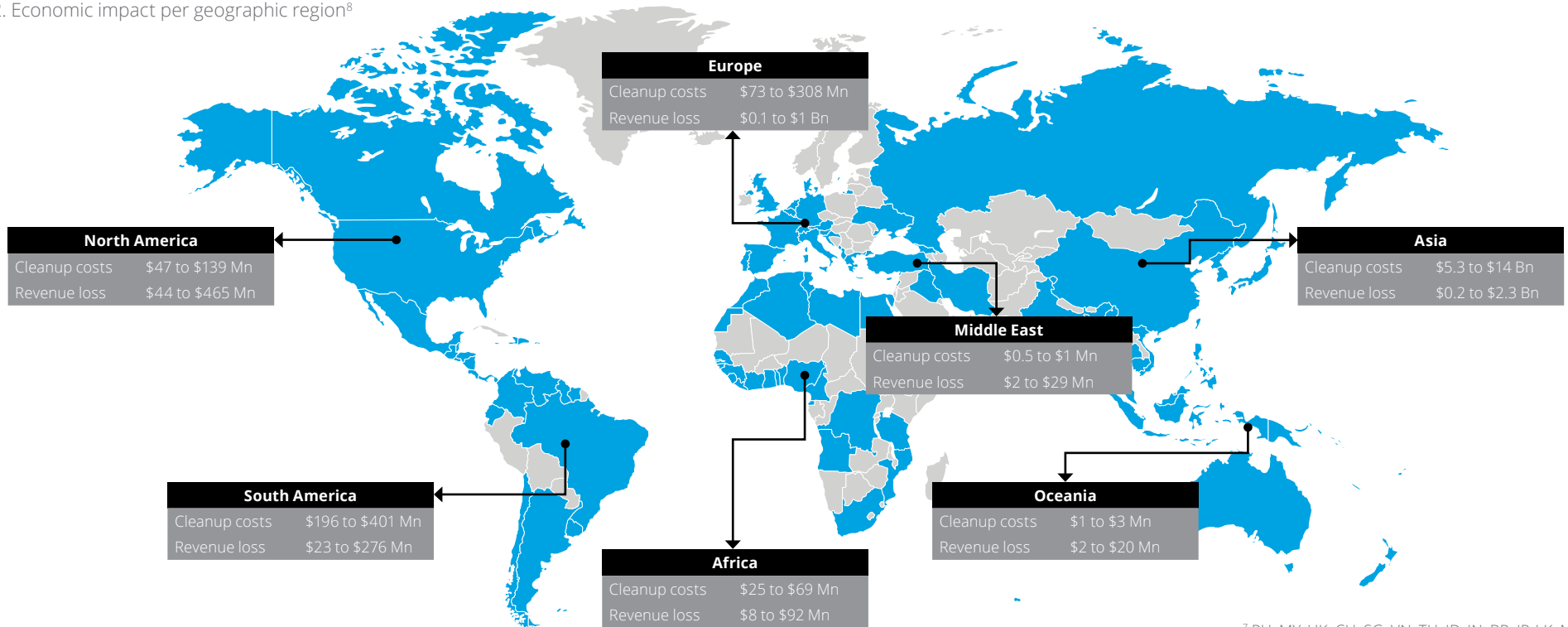


Discussion

Based on the waste density in rivers, it is identified that 19 Asian countries⁷ account for 82% of global plastic waste flowing from land

into oceans. The economic impact of marine plastic pollution in these countries constitutes 86% of the global costs estimated in this study.

Figure 2. Economic impact per geographic region⁸



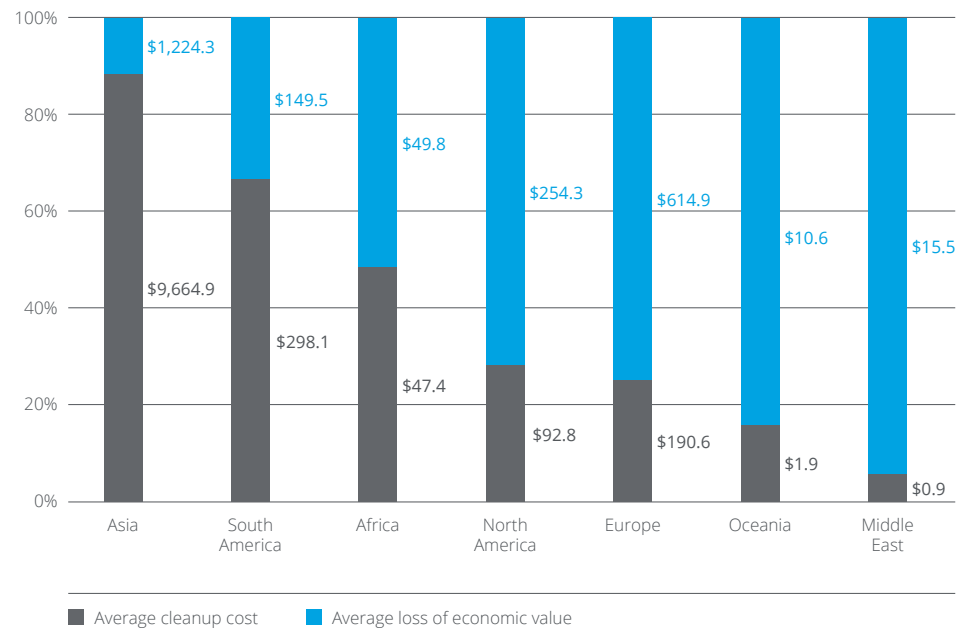
⁷ PH, MY, HK, CH, SG, VN, TH, ID, IN, BR, JP, LK, MM, KO, TW, BG, KH, PR, TL

⁸ The countries in scope are highlighted in blue. Look up <https://theoceancleanup.com/rivers/> for a dynamic visualization of the economic costs

The graph illustrates region-wise segregation of costs into cleanup and loss of economic value in marine tourism, and fisheries & aquaculture. As per the cost estimates from the assessment model, cleanup activities would constitute 82% of the overall economic impact globally.

The following comparative analyses of per capita costs per region indicates that Asia has significantly higher than average costs for cleanup per capita most likely caused by high emissions of waste into the ocean and the population density near coastal areas. Europe and North America are expected to have the highest average loss to economic value from marine tourism, fisheries & aquaculture while cleanup costs are significantly lower than global average.

Figure 3. An overview of the cost components in 2018 by region, values in USD million



Value in USD per capita

Region	Cleanup cost	Loss to economic value	Total economic impact
Asia	2.51	0.32	2.83
Europe	0.29	0.94	1.22
North America	0.24	0.65	0.89
Latin America	0.54	0.27	0.81
Oceania	0.06	0.32	0.37
Middle East	0.01	0.12	0.13
Africa	0.06	0.06	0.12
Global avg.	1.61	0.36	1.97

Conclusion

Marine plastic litter is a complex problem to address, both in terms of prevention and cleanup, which exerts significant economic costs to coastal communities and marine industries such as fisheries & aquaculture, tourism (some of which also contribute significantly to marine litter) (Marine Anthropogenic Litter 2015). While knowledge of marine pollution issues has expanded, the existing literature and research still lacks rigorous assessment of the impact, and potential solutions to the issue. Thus, further research will be required to determine the financial costs associated with socio-economic sectors such as public health, marine ecosystem etc.

Overall, marine plastic litter tends to affect national economies in two main ways: either by directly impacting their core economic sectors or through the need to remove litter, which requires additional resources and expenditure. For many local and central governments, however, it is difficult to find the resources and funds necessary to support the level of service provision required to ensure that land based

water sources are free of litter. This study takes a comprehensive assessment in estimating economic impacts of land sourced marine plastic litter that can be viewed at a global level but can also be zoomed into and compared between countries. We believe that the model presented in this paper can be used as a tool for evaluating potential solutions for prevention or interception of floating plastic debris in land-based water sources that can lead to reductions in waste entering the marine environment.



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Authors



Vincent Viool, Director

Monitor Deloitte
Mobile: +31612677088
Work: +31882888736
E-mail: vviool@deloitte.nl



Abhishek Gupta, Manager

Risk Advisory
Mobile: +31683807016
Work: +31882880685
E-mail: abhigupta@deloitte.nl



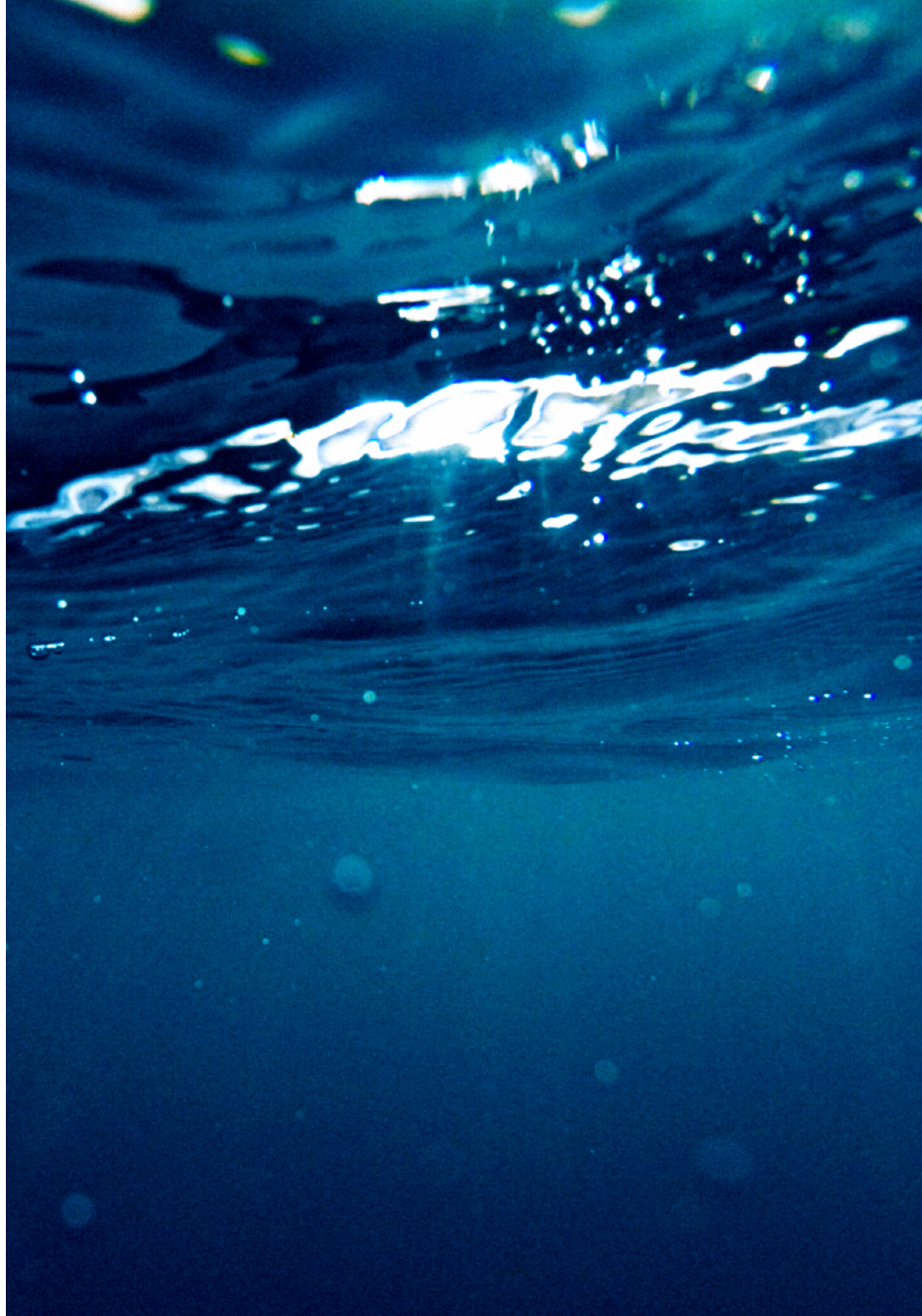
Laurens Petten, Partner

Monitor Deloitte
Work: +31882881901
E-mail: lpetten@deloitte.nl



Jorg Schalekamp, Partner

Consulting-Technology
Work: +31882887217
E-mail: jschalekamp@deloitte.nl



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