The Waste Flow Diagram: Identifying Leakages from Municipal Waste Management Systems

Compendium of Case Studies

Implemented by

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Contents

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Acronyms

API	Application Programming Interface
cap	Capita
DB	Development Bands
DNA	David Newby Associates
Eawag	Swiss Federal Institute of Aquatic Science and Technology
HH	Households
IUCN	International Union for Conservation of Nature
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
ISWA	International Solid Waste Association
kg	Kilogram
kg/person/year	Kilogram per Person per Year
km	Kilometre
LI	Low Income
LMI	Lower Middle Income
MFA	Material Flow Analysis
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
p/km²	Persons per Kilometre Squared
PPC	Plastic Pollution Calculator
RWA	Resources and Waste Advisory Group
SDG	Sustainable Development Goals
SPOT	Spatio-temporal Quantification of Plastic Pollution Origins and Transportation
SWM	Solid Waste Management
t/day	Tonnes per Day
t/year	Tonnes per Year
UMI	Upper Middle Income
UN-Habitat	United Nations Human Settlements Programme
UoL	University of Leeds
WB	World Bank
WaCT	Waste Wise Cities Tool
WFD	Waste Flow Diagram
WWC	Waste Wise Cities
WWF	World Wide Fund For Nature
yr	Year

Overview

The Waste Flow Diagram

The Waste Flow Diagram (WFD) is an open-source toolkit that enables a rapid assessment of a city's municipal solid waste (MSW) flows. It maps and visualises the materials flows within a municipal solid waste management (MSWM) system, and quantifies the amounts, sources and fates of plastic leakage into the environment.

Developed in a collaboration between Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, University of Leeds, Swiss Federal Institute of Aquatic Science and Technology (Eawag) and Wasteaware, the WFD has been applied in over 100 cities around the world by consultants, NGOs, municipal authorities, and development agencies, predominantly in low- and middle-income cities. The data collected and results generated through WFD applications are reported and openly accessible on the WFD Portal.

The application of the WFD has led to a many of results across many different contexts. This compendium summarises and compares the experiences from using the WFD around the world and provides some descriptive statistics on the outcomes.

The WFD:

1. Enables a rapid assessment of the MSWM system;
2. Maps and visualises materials flows;
3. Quantifies the sources and fates of plastic leakage into the environment;
4. Enables alternative scenarios to be forecasted;
5. Allows benchmarking and comparison between cities.

The WFD maps the waste flows using a Material Flow Analysis (MFA) covering all stages of the MSWM system from generation to collection, transport, treatment/recovery, and disposal. The flow analysis also presents possible fates of unmanaged MSW released into the environment. Flows represent possible pathways of material quantified in terms of tonnes per annum, which allows for leakage to be mapped and the sources and plastic pollution hotspots to be identified at every stage of the MSWM system. This allows for informed decision making at the municipal or city level so that bespoke interventions may be implemented to improve the system. Furthermore, various scenarios may be run to assess how a proposed intervention may affect the system and the levels of plastic pollution in the environment, while also quantifying the effectiveness of these interventions once implemented. Lastly, this drives benchmarking and comparison between municipalities and aids in encouraging healthy competition for the improvement of each MSWM system.

The diagram below illustrates how the WFD maps the materials flows across a MSWM system.

MAYA ZAATAR – Environmental Engineer, Wasteaware

"Since my first WFD application in Lebanon in 2021, I have applied the WFD in another 6 cities across the Mediterranean in diverse environments (urban, rural, touristic and agricultural areas), mainly for baselining and capacity building purposes. Applying the WFD is a multifaceted experience which include interviews with a wide range of stakeholders, from informal waste pickers to mayors, to the data collection process an following of collection service vehicles, it is an exercise that gives you a reliable insight on a city's SWM operations and performance."

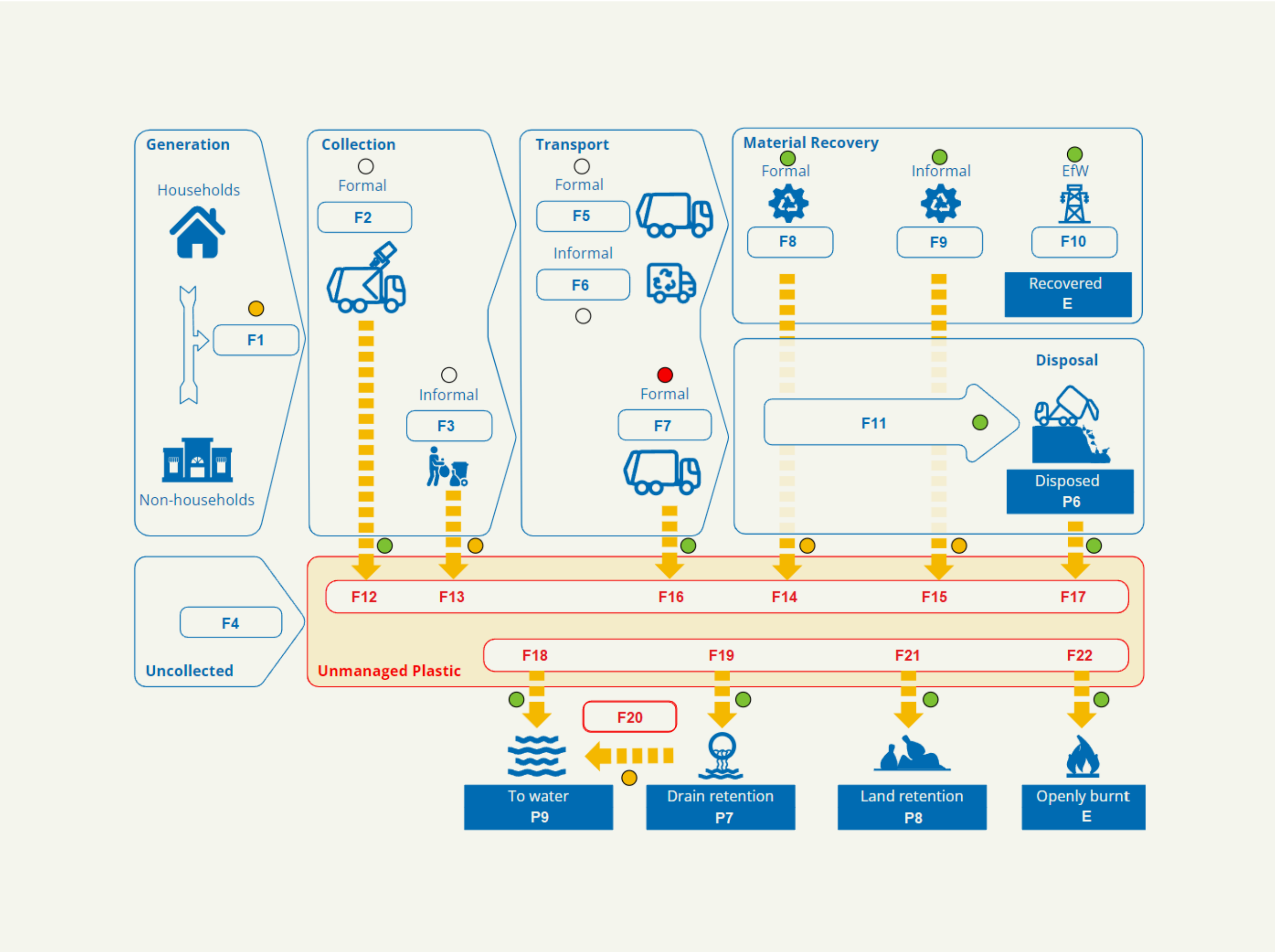

Figure 1

WFD System Map for Municipal Solid Waste and Plastic Flows

The WFD summarises the results of unmanaged plastic waste flows by, including:

- Total amount of unmanaged plastic waste;
- Different sources and contributions to plastic leakage;
- Final fates of plastic pollution in the environment.

The results table also provides a summary of the plastic pollution using alternative units which can be used to help visualise and benchmark the plastic leakages. The WFD outcomes and results can be visualised in different ways.

FLAVIU POP – Waste Management Consultant, GOPA-Infra

"The WFD is a great tool to assess the level of waste leakages into the environment and can be used to set up baselines for projects, evaluate scenarios during project design phases and as a monitoring tool where the progress against the baseline can be tracked over time. I have seen results produced for projects in diverse cities and MSW systems: from megacities with relatively low collection and recovery rates such as Karachi in Pakistan and Lagos in Nigeria, to small cities with relatively high collection and low recovery."

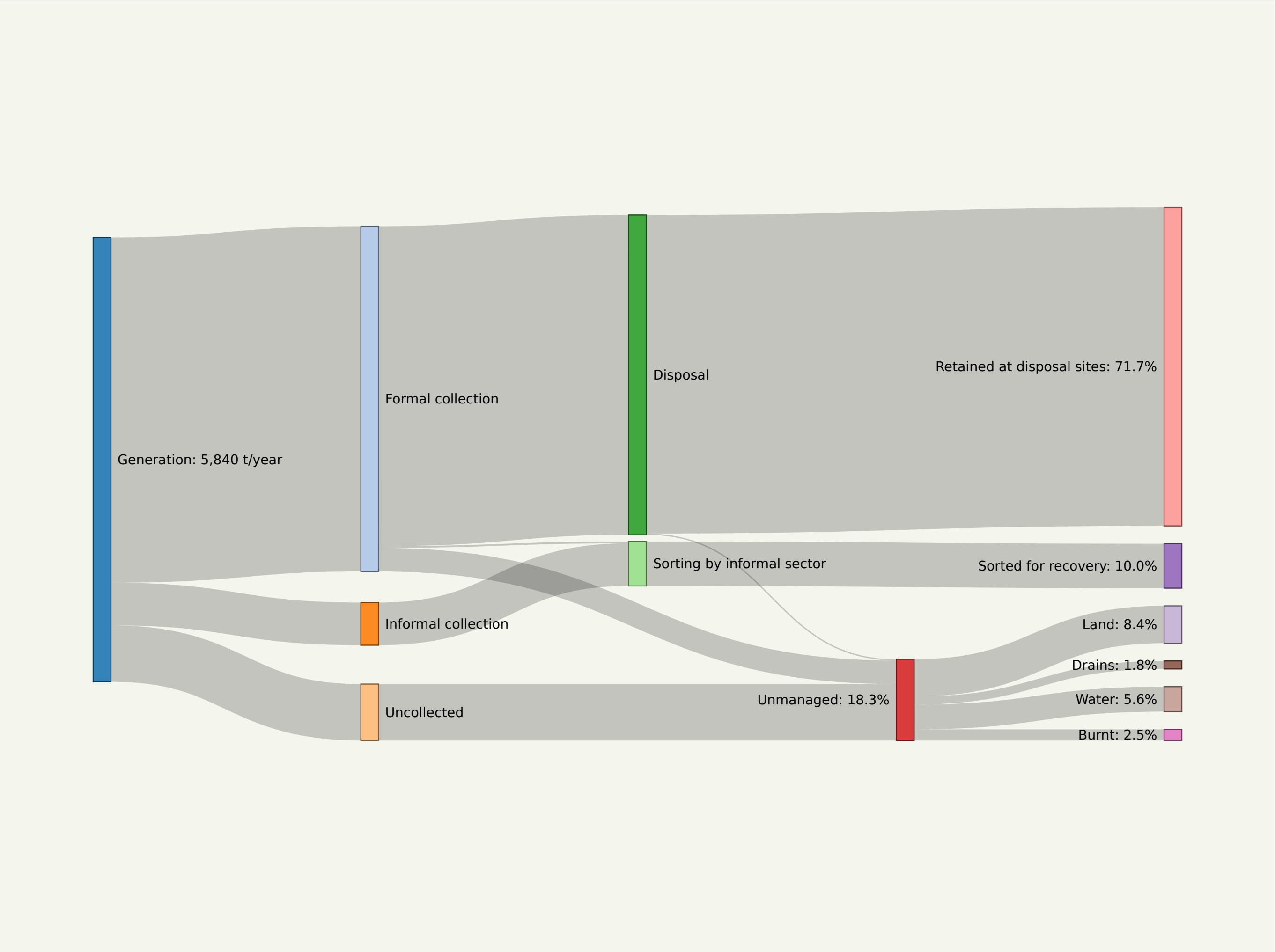

Figure 2

Standardised Sankey Diagram

The WFD estimates the plastic leakage throughout the entire MSWM stages based on leakage potential levels which are selected by the user following an observational assessment. Leakage refers to plastic waste escaping the waste management system and becoming unmanaged. Uncollected plastic waste is also accounted for.

Plastic leakages may occur during all MSWM stages. Sources and influencers of plastic leakage that are included in the WFD are as follows:

- Collection services (collection containers, loading method, primary transportation, multiple handling, transfer);
- Informal value-chain collection (recyclables extraction, transportation);
- Formal sorting (plastic reject rate, disposal of rejects);
- Informal sorting (plastic reject rate, disposal of rejects);
- Transportation (capacity vs load, waste containment, vehicle covering);
- Disposal facilities (environmental hazards, exposure to weather, waste handling, coverage, burning, fencing);
- Storm drains entering waterways (frequency of rainfall/storm events, drain clean-up).

The total plastic leakage from the MSWM system is calculated as the sum of the plastic leakages from each MSWM stage. The WFD tool estimates this by multiplying the leakage percentages by the total amount of plastic flowing through the system at each specific MSWM stage.

A user manual and comprehensive training course is available for learning how to do a WFD assessment, these can be accessed here.

The WFD model determines how much of the uncollected and leaked plastic ends up in each of the following four fates:

1. Openly burnt;
2. Released to land;
3. Released into storm drains;
4. Released into water systems.

For the first three fates (i.e. burning, land, storm drains), the user directly observes the amount of plastic they see in the environment. For the fourth fate (i.e. water systems) the user inputs proxy data for the model to assess the amounts released to water bodies.

The WFD estimates:

How much pollution comes from where? By measuring and estimating the amount of plastic waste that is leaked into the environment for the different stages of the solid waste management system.

Where does this quantity of pollution go? Once the plastic waste is leaked into environment, the question is: where does it go? Here the WFD helps estimate how much of the plastic waste leaked goes into water, into drains, stay on land or is burnt.

How the leakages would change? With improvements in the waste management system or with changing conditions (e.g. population, waste generation or composition, etc.) through a scenario development function.

Limitations of the WFD

The WFD generates a first-level approximation, targeting a level of detail and accuracy that can be achieved through a rapid assessment. There are other tools available, such as the International Solid Waste Association (ISWA) Plastic Pollution Calculator (PPC)[2], which provide a more detailed assessment. The GIZ study Benchmark of Plastic Hotspotting Methodologies provides additional information[3].

The reliability of a WFD assessment depends on a variety of factors including:

- The frame of the initiative under which the WFD has been used, including the level of resources dedicated to the task;
- The quality and reliability of data collection, including whether primary data was freshly collected or if historical secondary data was relied upon;
- The skill and determination of the WFD assessor to reach results that are representative of the MSWM system being studied;

2 https://plasticpollution.leeds.ac.uk/toolkits/calculator/

3 https://www.giz.de/de/downloads/giz2022-en-benchmark-of-plastic-hotspotting-methodologies.pdf

- Whether the WFD tool was adapted from its originally intended use to fit the specific needs of a case study.

The WFD uses in-built factors to estimate leakages and fates of plastics emitted into the environment. These are based on the best available expert assessments. However, it should be recognised that the science of plastic pollution modelling is still in its relative infancy.

Linkage to the Waste Wise Cities Tool (WaCT)

The WFD is seamlessly integrated with the UN-Habitat WaCT[4], being embedded within Step 7 of the WaCT assessment methodology.

Through its close linkage with the WaCT, the WFD is complementary to the SDG Indicator 11.6.1, i.e. the proportion of municipal solid waste collected and managed in controlled facilities out of total municipal waste generated, by cities, and relevant to a wide range of other SDGs including SDG 12 and 14.

The two tools have been developed in parallel to each other thanks to a working partnership between UN-Habitat and GIZ, with support from Wasteaware-RWA, the University of Leeds, Eawag and David Newby Associates (DNA).

The WFD user is enabled to directly input primary data collected through a WaCT assessment, utilising the following key data from the WaCT:

- Proportion of MSW collected – total MSW collected in the city;
- Proportion of MSW managed in controlled facilities - total MSW that is managed in facilities with at least 'basic' control level.

The WFD can still be used as a tool without having previously completed a WaCT assessment. However, it will be necessary to input the key data from other sources.

Synergy with Other Plastic Pollution Estimation Tools

Several plastic pollution assessment tools have been developed over the recent years, each using slightly different methodological approaches. In general, four main approaches can be distinguished based on: transfer coefficients, MFA, statistical / trend analysis or hydrological modelling (World Bank, 2021).

The WFD suits well for a rapid assessment on city level. Other applications which apply the MFA approach are the ISWA Plastic Pollution Calculator (PPC)[5], International Union for Conservation of Nature (IUCN) Hotspotting Tool[6] and the Spatio-temporal Quantification of Plastic Pollution Origins and Transportation (SPOT)[7] model.

The key similarities and differences between these four MFA-based plastic pollution estimation tools are profiled in table 1 below.

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4 https://unhabitat.org/wwc-tool

5 https://plasticpollution.leeds.ac.uk/toolkits/calculator/

6 https://www.iucn.org/news/marine-and-polar/202008/guidelines-target-plastic-pollution-hotspots

7 https://plasticpollution.leeds.ac.uk/toolkits/spot/

	WFD	PPC	IUCN	SPOT
Key objective	Rapid baselining to identify leakages from MSWM systems	Detailed baselining for targeted action planning	Hotspotting for regional action planning	Identifying sources, pathway and accumulation hotspots
Resolution (geographical)	City/municipal	Sub-municipal	National (urban/ rural)	Local to national
Resolution (materials types)	Municipal solid waste (including plastics)	Plastic items	Polymers	Plastics (rigid/flexible)
Resolution (temporal)	Annual	Daily	Annual	Monthly
Basis for leakage methodology	Observational assessments	Conceptual modelling	Transfer coefficients	Conceptual modelling Transfer coefficients
Resources	Low	High	Low	N/A (global analysis regularly updated)
Used for	Understanding MSW and plastic flows	Quantifying plastic flows	Identifying hotspots	Estimating SDG 11.6.1 and plastic emissions in absence of data
	Scoping geographical and sectoral interventions	Determining specific sectoral interventions	Macro-planning of sectoral interventions	Hotspotting over large regions (e.g. National, Regional, Global)
	Understanding and prioritising leakages	Understanding and prioritising leakages		Identifying municipal and river basin accumulations and hotspots.
	Scenario building	Identifying temporal and spatial hotspots		

Table 1

Similarities and Differences between the MFA-based Plastic Pollution Estimation Tools

The WFD requires lower data input and only needs to be conducted annually, takes into account all material types, is the most rapid and cost effective of the above tools, whilst also assessing a MSWM system at the municipal level. However, the other tools may be preferable in certain circumstances, as listed below.

PPC focuses on the characteristics of a municipality using conceptual modelling to quantify plastic flows for a more detailed baseline with targeted action planning, while using daily assessments. However, due to this frequency and level of detail it requires a high level of resources.

IUCN identifies plastic pollution hotspots through evaluating the plastic value chain from production through to disposal, while also assessing the implications of microplastics and macroplastics through leakage sources. It offers both upstream and downstream interventions for regional action planning and allows benchmarking to be established from the municipal to the country level.

SPOT is a machine learning tool which provides a detailed assessment of plastic leakage on land and in rivers. Though it requires a high level of data input, it is the only tool that offers a global assessment and may be the most useful for hotspotting over large regions.

Applying the WFD in the Field

A WFD fieldwork assessment will entail about 5 core activities.

1. Preparation: to make sure your time on the field is efficient, you need to plan in advance your logistics and the WFD activities such as stakeholder meetings, site visits and coordination with local partners;
2. Interviews: should be conducted with many stakeholders. Seek out people who can give you a good overview of the MSWM operations, and provide data for the WFD excel sheet;
3. Site visits: observing collection systems, and visiting recovery and disposal facilities,
4. including those managed both formally and informally (where relevant);
5. Observations: of each stage of the MSWM system in order to assess the main leakage
6. influencers and investigate where plastic is leaking into the environment;
7. Data recording: taking summary notes of everything you do and see. This helps to create a story line for the WFD and have a comprehensive understanding of the current MSW situation.

The amount of resources needed to carry out a WFD assessment will vary depending on several factors, including the availability of data, size of the assessment area, and complexity of the waste management system. As a rule of thumb, implementing a WFD assessment should take around 7 working days, and a maximum of 7 working days of professional time input, however depending on your situation, you may need to allow around 1-2 months elapsed time for preparations before commencing the assessment.

NITESH CHANDRAKAR – Environmental Policy Resources Efficiency Advisor, Waste Management Expert, Environmentalist – Project Aviral, Haridwar

“Transforming a SWM system in a city like Haridwar, India, that experiences a massive annual tourist influx every year due to its national and cultural importance, is a challenge requiring a complex solution. We wanted to provide a methodology to local officials that can be easily, regularly and inexpensively applied in the city to track progress. Therefore, we selected the WFD which is easy to handle and allows an estimation of waste flows and leakage streams without a large input data basis. The WFD supported us in demonstrating the significance of plastic leakage by illustrating leakage quantities to officials. It helped urban local bodies to plan waste management infrastructure to increase the amount of recyclables entering the formal system, allowing waste management infrastructure to be more economical.”

WFD Case Studies

Case Studies Profiled

Over 100 WFD assessments have been implemented globally. The following overview of case studies displays details of the results for a selection of 50 case studies, as shown in Figure 4. The WFD Portal features the totality of the WFD case studies carried out worldwide.

The 50 case studies selected for presentation in this compendium cover a wide range of realities of solid waste management and cultural practices[8]. In total, the cases fall within 22 different countries. These are predominantly within three of the World Bank income categories (low income (LI), lower-middle income (LMI), upper-middle income (UMI)).

The case study cities have also been classified according to their waste management developmental context using the 'nine Development Bands (DB)' methodology (Whiteman et al., 2021). The DB categorise the status of a city's solid waste management, with WFD cases falling within 6 of these bands.

DB 1 - 4 reflect cities that are in the process of establishing and expanding their waste collection and controlled management systems, whilst DB 5 – 9 reflect cities that have achieved universal collection coverage and controlled management and have more advanced and differentiated waste and resource management systems.

The diversity of case studies profiled demonstrates the capability of the WFD tool in being applied across cities with widely different demographic and socio-economic characteristics (although the WFD was originally developed for cities in low- and middle-income cities). For example, Kep in Cambodia with a population of just 21,000, and Karachi in Pakistan with a population over 24 million. Likewise, the WFD has been implemented in cities both with and without high levels of tourism and/or commercial activity demonstrating its flexibility to a wide range of socio-economic scenarios.

All cities profiled in this Compendium have conducted a WFD survey, typically with the main objective of baselining, understanding and visualising waste flows and plastic leakages from different stages within the MSWM system.

How the WFDs Have Been Undertaken

A selection of WFD case studies are included as an Annex to this Compendium. Detailed results of the case studies presented below can be found in the WFD Portal, in the 'Browse Data' page.

Several city names have been replaced with 'City' or 'Municipality' followed by the country's name in order to respect the data ownership of these cities by anonymising them throughout this publication.

WFDs have been implemented under a range of different initiatives with a variety of different objectives; often as part of initiatives implemented by international development organisations supporting national, regional and city/municipal governments.

8 The 50 case studies shown are those deemed reliable based on expert judgement.

The majority have been prepared by waste management consultants and practitioners, but in some cases, they have been implemented by city/municipal waste managers with training and backstopping support.

WFD is often used as a tool that plugs into an international development project to provide research, context, and evidence around which to gather stakeholders together who are involved in tackling deficiencies in waste management systems, and plastic pollution of the environment.

The WFD itself does not offer the 'solution' to addressing the problem, other tools such as the Wasteaware Benchmark Indicators (Wilson et al., 2015) place more focus on how to identify and address complex waste management systems. However, it does provide a rapid assessment of the deficiencies, and shine a spotlight on the particular sources and fates of plastic pollution emissions from a MSWM system.

Figure 4

Waste Flow Diagram Case Studies Profiled in this Compendium

50 case studies across 23 countries, 3 income levels and 6 development bands

1. Manila, Philippines (LMI – DB4)
2. City, India (LMI – DB4)
3. City, Kenya (LMI – DB2)
4. City, Kenya (LMI – DB3)
5. Fnideq, Morocco (LMI – DB4)
6. Tulum, Mexico (LMI – DB4)
7. Mangalore, India (LMI – DB4)
8. City, India (LMI – DB4)
9. City, India (LMI – DB3)
10. City, China (UMI – DB7)
11. City, Nepal (LMI – DB3)
12. City, Nepal (LMI – DB4)
13. City, Nepal (LMI – DB4)
14. City, Nepal (LMI – DB4)
15. City, Nepal (LMI – DB5)
16. Huế (core), Viet Nam (LMI – DB5)
17. Huế (expanded), Viet Nam (LMI – DB4)
18. Haridwar, India (LMI – DB3)
19. Rishikesh, India (LMI – DB3)
20. Maragogi, Brazil (UMI – DB5)
21. Tamandaré, Brazil (UMI – DB5)
22. Rio Formoso, Brazil (UMI – DB5)
23. Sirinhaém, Brazil (UMI – DB5)
24. São José da Coroa Grande, Brazil (UMI – DB5)
25. Barreiros, Brazil (UMI – DB4)
26. City, Ethiopia (LI – DB3)
27. City, Tanzania (LMI – DB2)
28. Cagayan de Oro, Philippines (LMI – DB4)
29. Municipality, Philippines (LMI – DB4)
30. Shkodër, Albania (UMI – DB3)
31. Ghazir, Lebanon (UMI – DB5)
32. Byblos, Lebanon (UMI – DB4)
33. Tyre, Lebanon (UMI – DB3)
34. Ulcinj, Montenegro (UMI – DB5)
35. Khulna, Bangladesh (LMI – DB3)
36. Karachi, Pakistan (LMI – DB3)
37. Kep, Cambodia (LMI – DB3)
38. Sihanoukville, Cambodia (LMI – DB4)
39. City, Viet Nam (LMI – DB5)
40. City, Viet Nam (LMI – DB4)
41. Municipality, Philippines (LMI – DB4)
42. Legazpi City, Philippines (LMI – DB3)
43. Ormoc, Philippines (LMI – DB3)
44. Bogor, Indonesia (LMI – DB4)
45. Depok, Indonesia (LMI – DB4)
46. Santo Domingo, Dominican Republic (UMI – DB2)
47. City, Malaysia (UMI – DB5)
48. Bukavu, Democratic Republic of the Congo (LI – DB1)
49. Cape Coast, Ghana (LMI – DB3)
50. Harare, Zimbabwe (LMI – DB3)

LI = Low income country LMI = Lower-middle income country UMI = Upper-middle incom country DB = Development band

Note: Due to special data consent requests, some cities presented here have been anonymised.

MSW Generation Rate

Municipal and plastic waste generation varies considerably depending on many factors, but most prominent amongst them is income and socio-economic context. As can be seen in Figure 5, MSW generation rates across the profiled cities vary from between 0.29 kg/cap/day in City, Nepal, to 2.57 kg/cap/day in Tulum, Mexico. Most waste generation rates profiled are less than 1.0 kg/cap/day, with an average of 0.71 kg/cap/day and a median of 0.63 kg/cap/day.

The high MSW generation rate found for Tulum is likely due to the city being a highly touristic location with around 2 million people visiting annually. It is well established that the additional number of people within a city due to tourism, as well as the different activities and types of waste these tourists produce, can lead to significant increases in waste generation (Diaz-Farina et al., 2020; Martins and Cró, 2021). This is supported by the fact that the two other case studies with MSW generation rates above 1.5 kg/cap/day are those of Ulcinj, Montenegro, and Sihanoukville, Cambodia, both of which are characterised by a large number of tourists in comparison to their residential population.

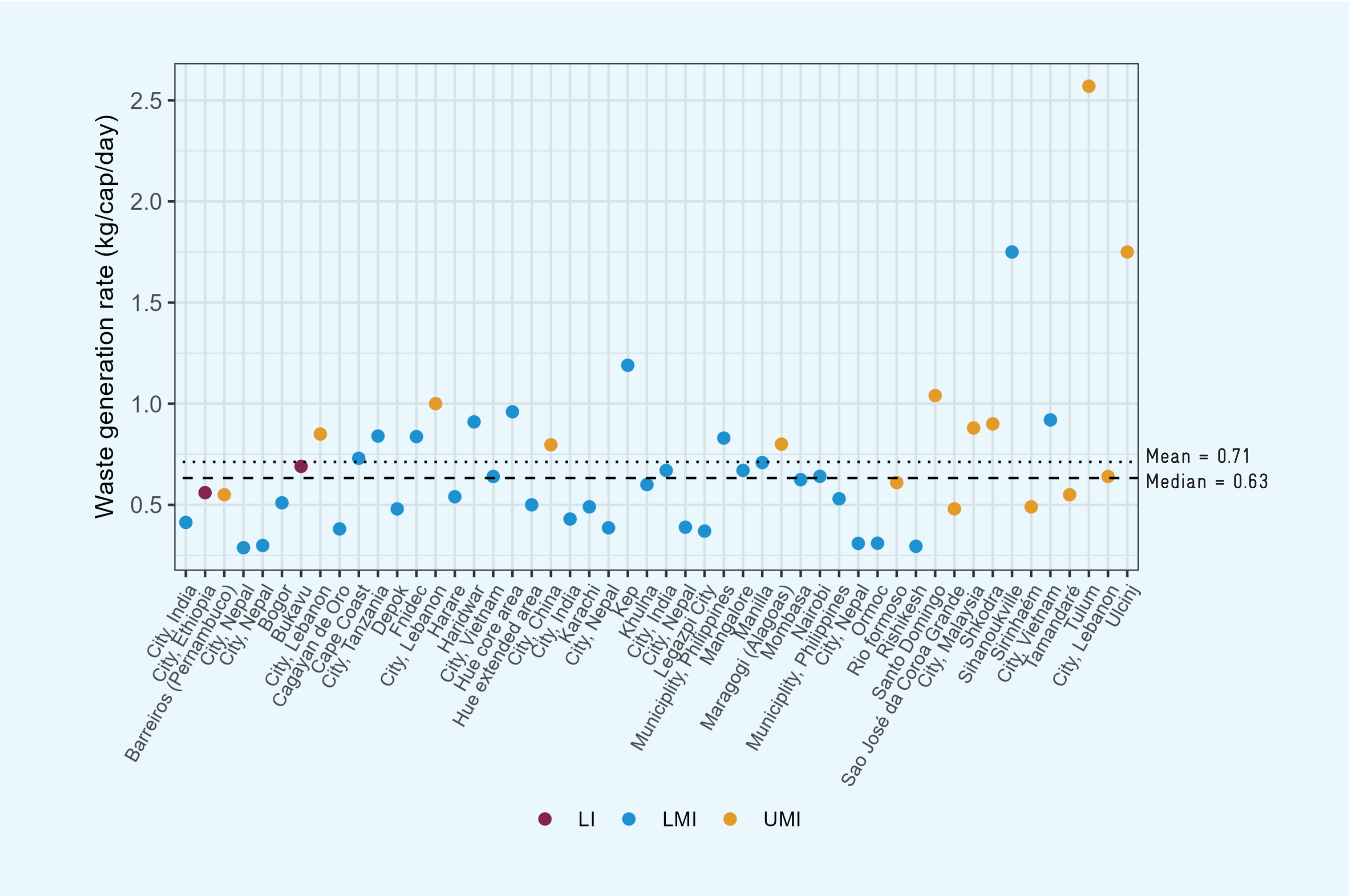


Figure 5

Comparison of MSW Generation Rate

Plastic Waste Generation

The proportion of plastics in the MSW stream varies considerably, depending on the consumption habits and activities in the city. Plastics are believed to make up around 12% of MSW generation globally, with this number not varying drastically in all but the lowest income group (Kaza et al., 2018).

However, measuring plastic waste generation in low- and middle-income countries has traditionally been challenging due to the prominence of the informal waste management, service and value chain. For example, sampling waste composition at the point of disposal can lead to an underestimate of plastic waste generation due to the informal sector having already removed valuable plastic items prior to the sampling location.

This difficulty is largely avoided in the WFD due to a system-wide approach being taken that incorporates waste flows from across the MSWM system, including any activities of the informal sector. Likewise, the WaCT, which is the recommended approach for SWM data collection in the WFD, similarly accounts for the informal sector's activities.

The amount of plastic as a proportion of total MSW generation can be seen in Figure 6. It was found that the amount of plastic is slightly higher than the average outlined by Kaza et al. (2018) as on average 15% of MSW is composed of different types of plastic materials. The range of plastic generation varies from as low as 6% in City, Tanzania; Ulcinj, Montenegro; Bukavu, Democratic Republic of the Congo; and Khulna, Bangladesh, and up to 32% in Sihanoukville, Cambodia. Although City, Ethiopia is a LI country, it was found that its plastic generation was also comparable to many other LMI and UMI cities, with a value of 12%.

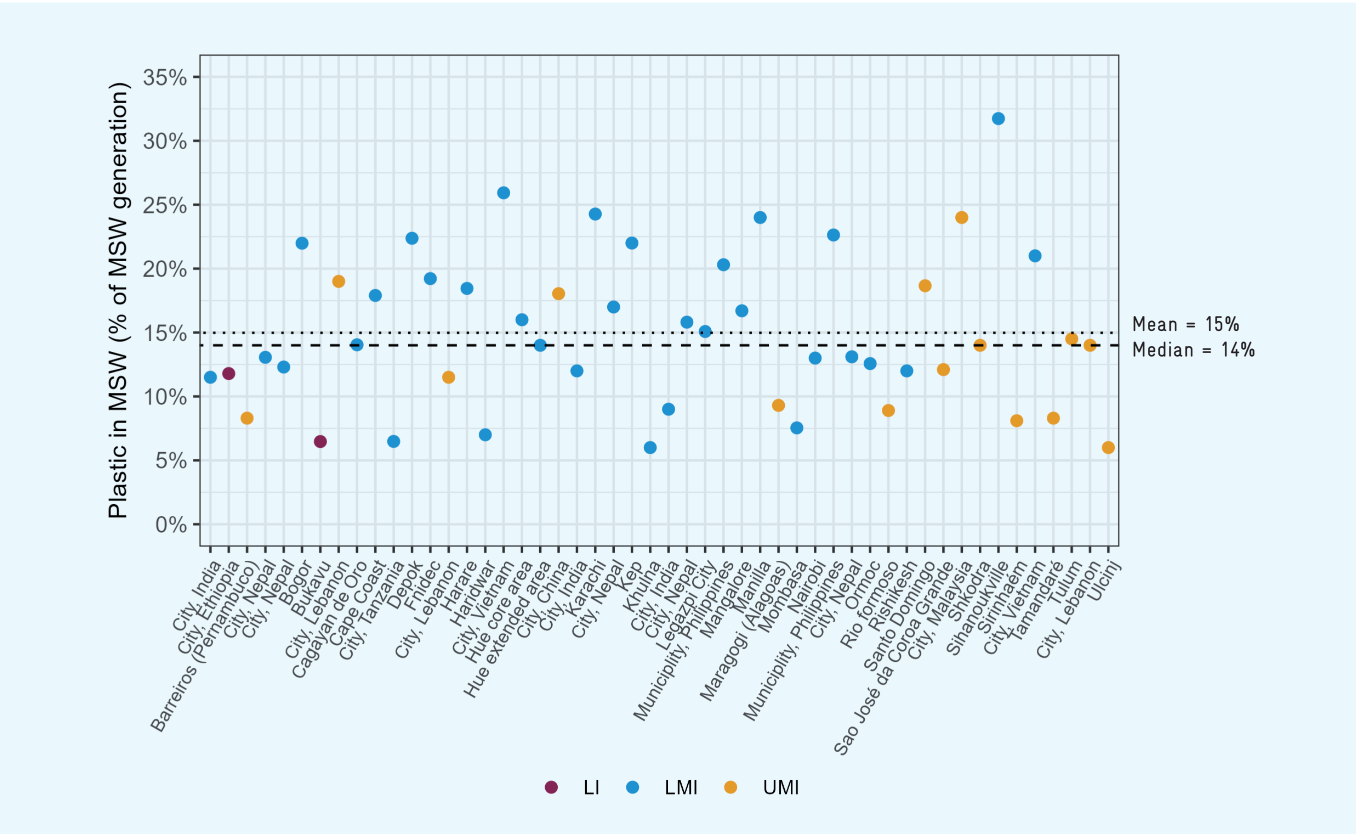


Figure 6

Comparison of plastic waste generation

MSW Collected

Uncollected waste is the biggest contributor to plastic pollution worldwide (Lau et al., 2020). It is estimated that around 2 billion people globally do not have regular and reliable waste collection services, meaning that they are forced to self-manage their waste. This includes openly burning their waste, or dumping it into rivers, storm drains, or the wider environment. As such, the collection coverage is a key indicator of the likely amount of plastic pollution which is also confirmed by the WFD applications.

Figure 7 breaks down the MSW collection data for each case study. These are that the waste remains uncollected (and is therefore dumped or openly burnt), is collected by service providers, or is collected by the informal value chain (i.e. waste pickers).

For the majority of case studies, collection by service providers is the dominant management method, accounting for 79% of MSW generation on average. In contrast, uncollected waste accounts for 15% on average and informal value-chain collection for 6% on average.

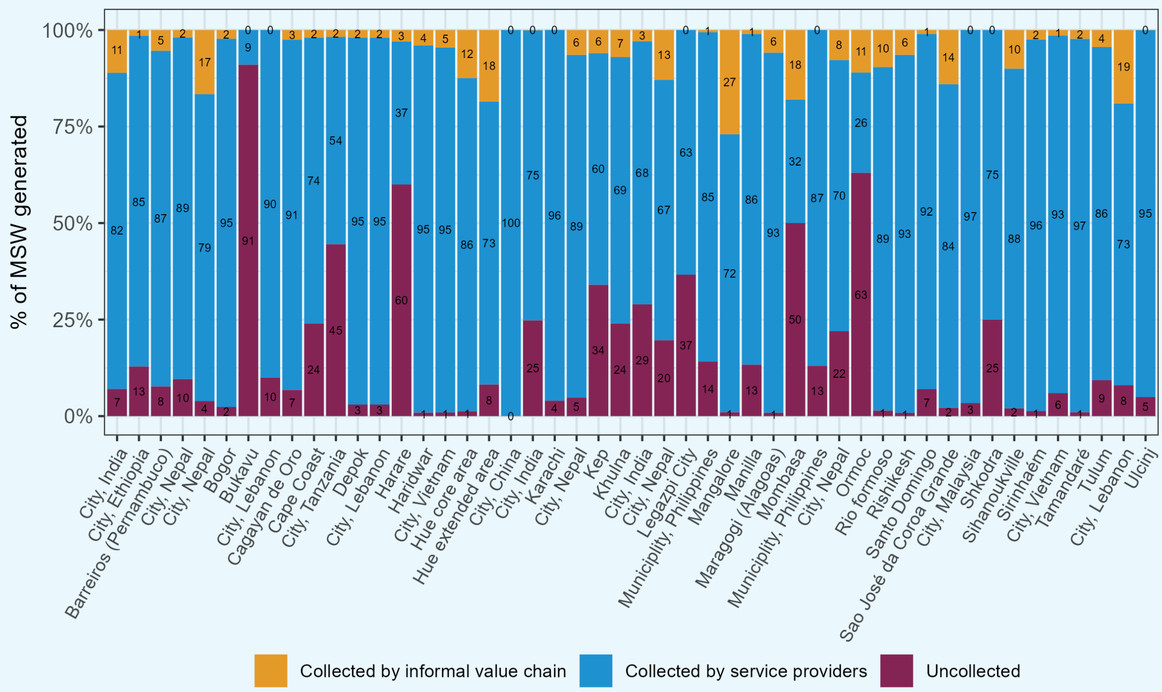


Figure 7

Comparison of waste collection practices

Large variation is seen however between the case studies as would be expected. The city with the highest collection by service providers is City, China achieving 100%, whilst seven other case studies achieve 95% or more. On the other hand, the city with the largest proportion of waste collection by the informal recycling sector is that of Huế (Viet Nam) accounting for 21% of MSW generated. Data included the amount of food waste collected by pig farms and re-used for animal feeds.

Uncollected waste is a critical issue in determining the amount of plastic pollution. Four of the case studies have over 50% of their generated MSW remaining uncollected. These are Bukavu (91%), Ormoc (63%), Harare (60%), and Mombasa (50%). Surprisingly, only one of these cities is within a LI country (Bukavu), with the others being LMI countries. This suggests that collection service coverage is not solely related to income level, but also may depend on other factors.

Collected and Managed in Controlled Facilities

SDG 11.6.1 is defined as the proportion of MSW collected and managed in controlled facilities out of total municipal waste generated. This is calculated via the WaCT and links to the WFD accordingly. The results of SDG 11.6.1 for the profiled case studies can be seen in Figure 8.

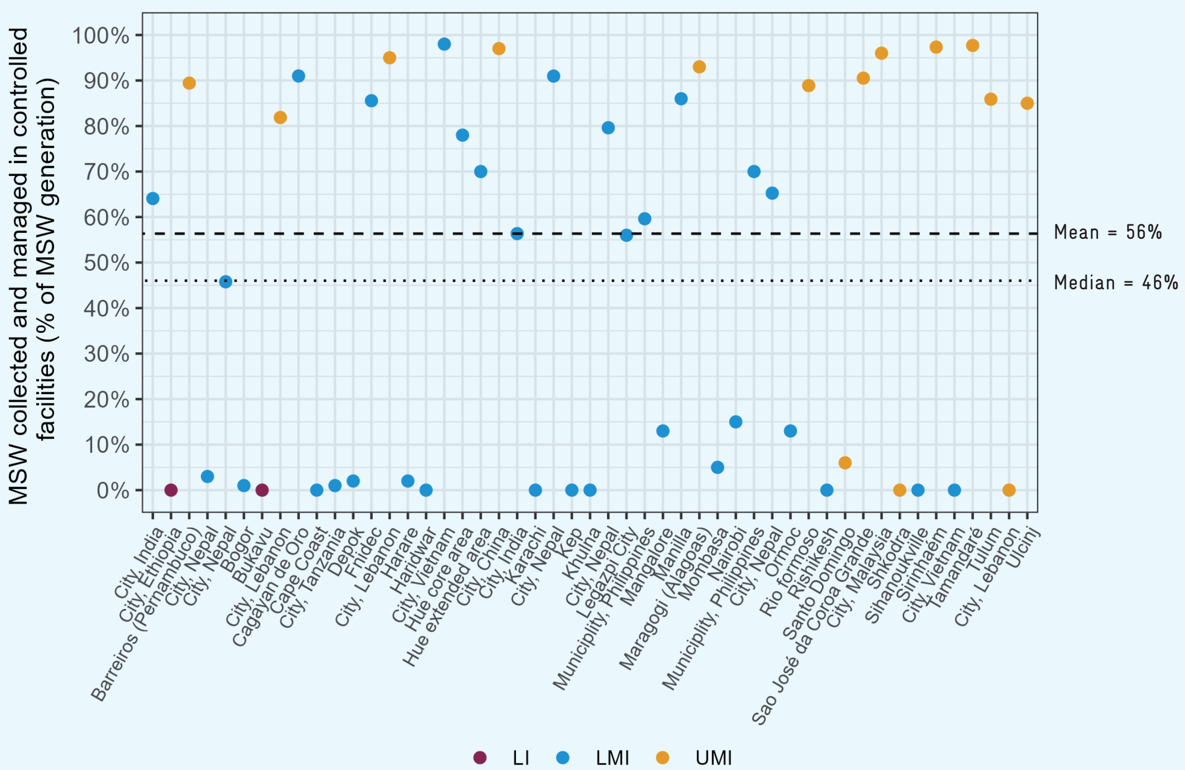


Figure 8

Comparison of MSW collected and managed in controlled facilities

Five of the WFD profiled cities achieve over 95% of their waste being collected and managed in controlled facilities. These are Tamandaré, Brazil (96%), Sirinhaém, Brazil (94%), City, China (97%), Seremban, Malaysia (97%) and Municipality, Lebanon (95%). On the other hand, 20 out of the 50 cities (40%) had less than 5% of the MSW being collected and managed in controlled facilities. This is due to the cities having incomplete collection coverage and/or a high incidence of uncontrolled disposal.

The average level of controlled management is 56% whereas the median was 46% across the case study cities. These statistics do not adequately reflect the largely bimodal distribution of results, in that the results tend to be either close to zero or approaching 100. In fact, 78% of results were either above 80% or below 10%.

Intuitively this bimodality makes sense as cities, when establishing their waste management system, usually first prioritise waste collection and then controlled disposal only after this. As such, a city which has achieved widespread collection and decides to then invest in controlled disposal will typically have controlled management approaching 100%. On the other hand, a city that is still struggling with collection service coverage is unlikely to have invested in (or sustained) controlled disposal, therefore according to the WaCT methodology the level of control remains close to zero.

Unmanaged Plastic Waste

Figure 9 shows the amount of unmanaged plastic waste (total plastic leakage into the environment including openly burnt plastic) by case study. This largely correlates with the proportion of uncollected waste found in Figure 7. This is because all uncollected waste is assumed to be released into the environment or openly burnt, therefore directly contributing to the amount of unmanaged plastic waste.

There is a strong relationship between plastic pollution and uncollected waste, as uncollected waste is typically the largest single source of plastic pollution in cities with low-medium collection service coverage (which is most of these profiled case studies).

JOYCE KLU – Waste Management Consultant, RWA Group

"The WFD tool has been critical in achieving the highest standards of quantitative outputs, particularly in assignments that focus on plastic pollution and marine litter. Quantifying the amount of plastic waste ending up in water bodies was paramount but would have been complicated or even impossible without the WFD tool. The ability to visualise the masses of plastic waste causing water pollution helped decision-makers in these locations to make informed data-driven decisions and strategies to minimise marine litter."

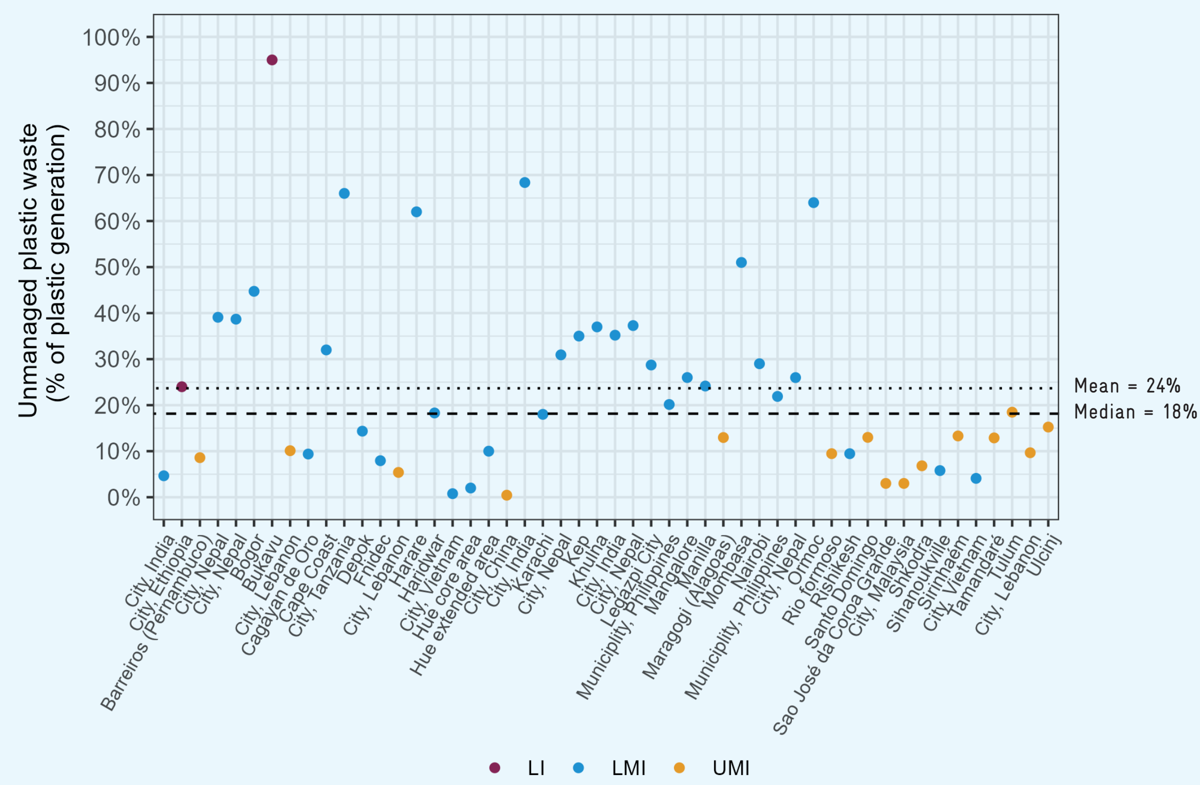


Figure 9

Comparison of unmanaged plastic waste

On average 24% of all plastic waste generated becomes unmanaged plastic waste in the environment across the case studies profiled. It should be noted that unmanaged waste within the WFD is defined as the summation of both uncollected waste and waste that leaks out from the solid waste management system, whether intentionally or not, as well as illegally dumped waste in the environment.

This differs from the widely used mismanaged waste definition in that it excludes waste that is collected but disposed of in uncontrolled disposal sites. Instead unmanaged plastic waste focuses on the plastic waste that is more dispersed in the environment and much more likely of becoming mobile and therefore potentially becoming marine litter.

The city with the highest proportion of unmanaged waste is Bukavu, whereby 94% of plastic waste generated is believed to become unmanaged in the environment. This very high value is due to its low collection coverage of just 7%, meaning 93% of waste remains uncollected and subsequently burnt or dumped into the environment. In contrast, City, China has the lowest proportion of unmanaged plastic waste with only 0.4% of generated plastic waste estimated as leaking into the environment due to its complete collection coverage, and well-functioning MSWM system.

The amount of unmanaged plastic waste in a city can also be shown via a different metric; the amount of unmanaged plastic waste in kilograms per capita per year. This has the advantage over the previously shown metric of unmanaged plastic waste (i.e. when expressed as a proportion of plastic waste generation) in that it also accounts for the overall amount of plastic waste being generated.

For example, a city with a high amount of plastic waste being generated compared to other cities, but only a small proportion of this being unmanaged, would rank worse on a kilogram per capita basis to reflect that there is still a large absolute amount entering the environment. In contrast, a city with a large proportion of unmanaged plastic waste as a proportion of generation but with very little actual generation, would rank better on a per capita basis, as a lower overall quantity is being released into the environment. Additionally, as the metric uses mass as a basis, the amount emitted is easier to conceptualise, particularly when converted to the number of items it represents, or as shown visually in Figure 10c. These metrics are crucial to allow comparison of how well a city performs on plastic pollution prevention compared to other cities.

A grouping or indicator-based approach has also proven effective in communicating performance levels. Such an approach can be used to present the outcomes of a WFD assessment in 'emission bands' in terms of kilograms per person per year of plastic emissions.

The orange area in Figure 10a shows the density of underlying data (i.e. where most data lays). The underlying data points are shown by the light grey dots, whilst five emission bands A-E are shown by the coloured bands in Figure 10b.

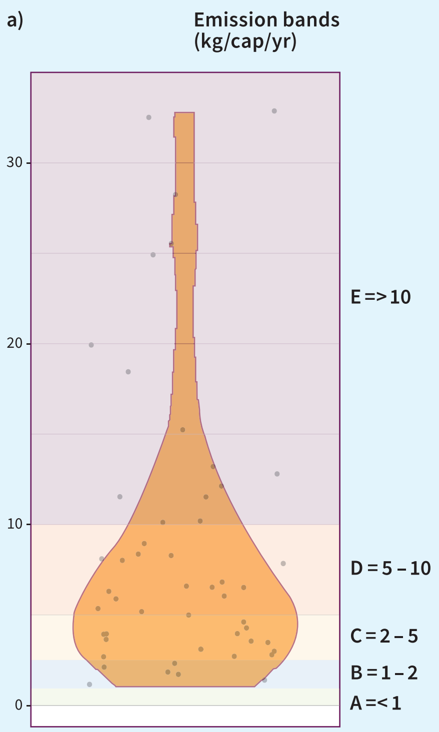
Emission bands are provisionally set on the basis of the 50 case studies and will be updated later when a broader spread of WFDs are available.

Table 2 shows how the plastic pollution emission bands apply to the 50 case studies profiled here. The results on a kilogram per capita per year basis differ considerably when compared as a percentage of plastic waste generation. For example, touristic locations such as Tulum and Sihanoukville fall into Band E despite their relatively well-functioning waste management systems due to them having high plastic waste generation and low population. Small absolute emissions therefore count for a lot on a per capita basis.

SHOUKRY HUSSEIN – Institutional Development and Capacity Building Consultant

"Application of WFD contributed to drawing conclusions and making recommendations to improve the solid waste management system in two Egyptian governorates. The WFD methodology allowed the municipal officials to identify and evaluate collection, transportation, treatment, and disposal processes, in addition to understanding where plastic leaks occur and how they can be reduced."

a)



c)

E	Municipality, Philippines Manilla Tulum* City, India	Mangalore City, Tanzania Kep, Cambodia Sihanoukville, Cambodia*	Bogor Santo Domingo Bukavu Cape Coast	Harare
D	Mombasa, Kenya Nairobi, Kenya City, India City, Nepal	City, Nepal City, Nepal City, Nepal City, Ethiopia	Municipality, Philippines Municipality, Lebanon Ulcinj* Karachi	Legazpi City Ormoc Depok
C	Fnideq City, Nepal Huế (extended area) Haridwar	Maragogi(Alagoas) Tamandaré Shkodër Municipality, Lebanon	Municipality, Lebanon Khulna City, Vietnam City, Malaysia	São José da Coroa Grande
B	Huế (core area) Rishikesh Rio Formoso Sirinhaém	Barreiros (Pernambuco) Cagayan de Oro		
A	City, India City, China City, Vietnam			

b)

Figure 10

a) Violin Plot of Unmanaged Plastic Waste and Plastic Pollution Emission Bands including Number of Case Studies in each,

b) Visual Representation of 1kg Plastic Waste,

c) Case Studies According to the Emission Bands.

* These cities have a high number of tourists in comparison to their residential population. As such, they tend to produce higher amounts waste than other cities. Even though many of them have relatively well functioning solid waste management systems, with only a few percentage points leaking, they are still found to fall into the higher emission bands. This is due to a combination of their higher overall waste generation, and the fact that the per capita rate calculated here only includes residential population.

Plastic Leakage Sources

It is crucial to understand the sources where plastic leakages originate in order to prevent plastic pollution. The WFD toolkit allows this assessment across seven different potential sources. The contribution of each of these sources as a proportion of the total amount of plastic that becomes unmanaged in a location is seen in Figure 11.

Figure 11

Comparison of unmanaged plastic waste sources

Across all case studies, leakage due to uncollected waste, leakage from collection services and leakage from disposal sites typical rank highest in terms of their contribution to unmanaged plastic waste.

This leakage is a symptom of deficiencies within the MSWM system with the amount of leakage dependent on where plastic is in the system, highlighting that there is poor management in the areas where values are highest.

The contribution from uncollected waste is not surprising. Likewise, leakage from collection services is also unsurprisingly high due to inter-linkages between the waste storage and collection services across often large and diverse cities. On the other hand, the fact that leakage from disposal sites is comparably high in many case studies is perhaps more surprising.

Typically, it would be expected that as waste is aggregated from collection through to disposal, the chance of it escaping into the environment reduces due to much of the waste becoming surrounded by other waste and therefore not so easily exposed to the elements. Perhaps one of the main reasons for the relatively high incidence of leakage from disposal sites is that they are often located in low-lying, flood prone land, or within or adjacent to streams and rivers.

Leakage from sorting activities, transportation and informal value-chain collection typically account for only small contribution to unmanaged waste, therefore are unlikely to be key intervention points for reducing plastic pollution.

Unmanaged Plastic Fates

Unmanaged plastic waste in the environment may end up in different locations, termed in the WFD as 'fates'. For example, uncollected plastic waste may be openly burnt by residents as a form of disposal, or dumped directly onto land, into storm drains, or into waterways. Any plastic on land may also subsequently become mobile and transfer to waterways or storm drains. Likewise, plastic waste in storm drains may be flushed to rivers during periods of heavy rain or periodically removed by city cleaners.

Within the WFD, observational based methods are used to allocate the fates of unmanaged plastic waste. For example, the amount of uncollected waste that is openly burnt is dependent on how much evidence there is for open burning in areas that lack waste collection services. In certain cases, such as the movement of diffuse plastic waste to water, it is difficult to see any evidence of plastic transfer to water simply due to the water carrying the plastic away. In these situations, proxies are used as an estimate of plastic waste transfer to water related to the distance of waterways and whether there are any barriers, (e.g. vegetation) likely to stop this transfer.

The proportion of unmanaged plastic waste by fate for each case study is shown in Figure 12. The majority of unmanaged waste enters water or is retained on land. Taking averages across the case studies shows the water fate accounts for 40% of unmanaged plastic waste, on average, whereas retained on land accounts for 49%, on average. Alternatively, 8% of unmanaged plastic waste, on average, is openly burnt, whereas cleaning from storm drains is 3%.

The estimated amounts of openly burnt waste is surprisingly low given that much of the unmanaged plastic waste is believed to have come from uncollected waste (Figure 11) and that this is typically associated with high levels of open burning (Wiedinmyer et al., 2014). It is possible that the observational-based assessments used in the WFD struggle to find clear evidence of open burning. This may be due to burn sites occurring on private land (e.g. in peoples gardens), or the same site being used for multiple burnings, therefore giving little indication of the frequency of burning.

Caution is advised in drawing conclusions from these averages as significant variation in the actual values is seen across case studies. For example, Tulum has the lowest amounts of unmanaged plastic entering water as a proportion of all unmanaged plastic at just 5%, whereas Huế (expanded area) has the largest percentage at 75%. Likewise, in Hue (expanded area), Municipalities in Lebanon and City, Nepal; no evidence of open burning was found despite some of these having relatively high amounts of uncollected waste. Whereas for comparison, the majority of Kep's unmanaged waste was openly burnt at 45%.

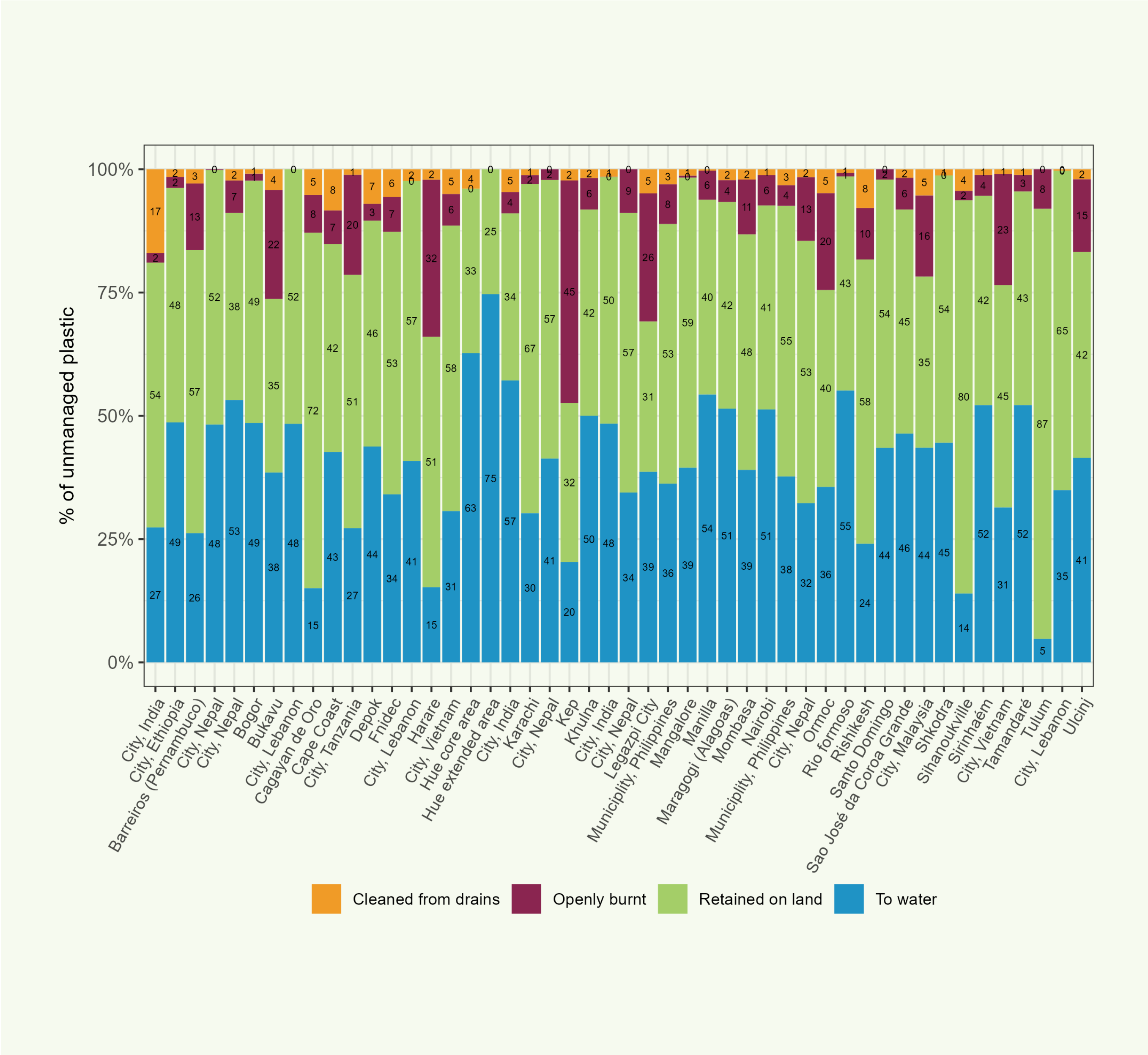


Figure 12

Comparison of Unmanaged Plastic Fates

ALUANE SILVA FERREIRA–- Biologist, Secretary of Environment and Animal Cause of Porto Seguro

“The implementation of the WFD in Porto Seguro was a great opportunity to learn more about the tool while allowing a more refined analysis, especially in relation to the identification of plastic leakage into the environment. Through data collection and analysis, we were able to identify these leaks from discards on the beach, in rivers, wastelands, and landfills. The study alerted us to the amount of plastic that is destined to the disposal site (controlled landfill) and leakage into the environment, which causes great environmental impact to both marine and terrestrial life.”

Application Support

Learning to apply the WFD

Experience in applying the WFD is gained through practice. Based on lessons from two years of field experience a comprehensive application support and training package was developed. These materials will help you to get started:

- A user manual accompanying the WFD tool can be accessed here;
- Two general videos for decision makers: a) Intro explaining the WFD approach, key function and data requirements here and b) Application using the example of a dumpsite, explaining how the WFD quantifies plastic leakage and determines its fate in the environment for decision maker here;
- Three video courses for learning how to do a WFD can be accessed here;
- Train the trainer course for consultants that implement WFDs (available in resources section here).

See more info in the Annex B – Training programme

WFD 2.0: The Online Portal

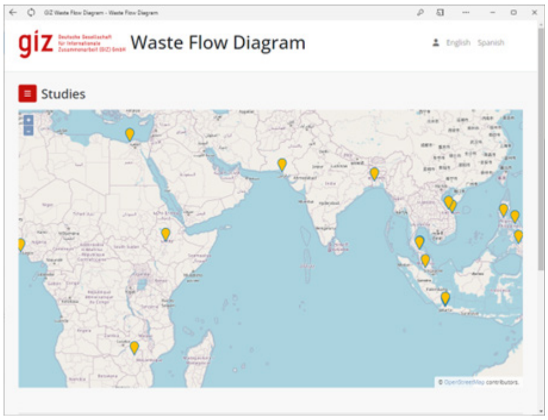
To ease WFD assessments, present data and to promote data sharing a dedicated WFD data portal was developed. The portal adheres to open-source standards and principles while ensuring highest data security standards. It features full WFD computations as well as graphic generator for the Waste Flow and Sankey diagrams. It further includes general information about the WFD, a case studies repository, tutorial videos and training material. A forum allows peer-to-peer exchange and support each other.

At launch setup the WFD portal includes integration with the WaCT data portal. This enables users to link to the data portals and to determine availability of the necessary input data for WFD, and therewith contributes to stakeholder and methodological harmonization. Linkage to other databases in envisioned in the future.

The data portal includes:

1. A publicly available repository of WFD study data for studies that have been validated by the WFD team and designated public by the respective study teams. An online data entry and data management application for study teams to enter and update data for subsequent validation by the WFD team; this functionality is available via a user registration and log-In system;
2. The ability to model “scenarios” and predict plastic leakage and fates; this functionality is available via a user registration and log-In system;
3. Downloadable resources for data collection and data upload to the data portal;
4. Access to training content;
5. An Application Programming Interface (API) which may be used by third party applications to query the repository or submit data to it.
   https://wfd.rwm.global/homepage/

wfd.rwm.global



http://wfd-data.rwm.global

BRUNO ABE SABER – Environmental Analyst, Ministry of the Environment of Brazil

"In a country of continental dimensions like Brazil, the availability of tools such as the WFD – affordable and easy to understand and apply by local decision-makers – is very important. The conclusions of the WFD application in six municipalities of the Brazilian coast allowed us to identify the most cost-effective measures according to each location's conditions to improve solid waste management systems and, consequently, reduce plastic leakage into the environment."

Summary

Key Points:

1. The Waste Flow Diagram (WFD) is a rapid assessment tool for mapping the flows of waste in a Municipal Solid Waste Management (MSWM) system at the city or municipality level; and estimating the quantities of plastic pollution sources and fates;
2. The WFD is a proven engagement tool that is suitable for many purposes, including baselining, benchmarking, monitoring, and scaling to national leakage assessment. It helps tracking progress of waste management interventions, while being easy to handle, not requiring a detailed professional background to manage and being cost-efficient in its application;
3. Predominantly, the WFD has been used during baseline assessments as part of wider MSWM projects and initiatives;
4. It is recommended to undertake a WFD assessment in tandem with a WaCT assessment;
5. The WFD further allows the generation of up to three scenarios to assist in planning interventions and visualising the outcomes from those interventions;
6. Other plastic emission modelling tools, such as the University of Leeds developed SPOT model or ISWA Plastic Pollution Calculator, amongst others, can be used to extend the assessment into more granular detail;
7. Conducting a series of WFDs will provide valuable primary data to feed into municipal waste management plans and national plastic pollution inventories. Experience in applying the WFD is gained through practice. A comprehensive suite of learning materials to help you get started is available here;
8. For those wishing to use the WFD in their development programmes, some capacity building and data curation support will be helpful in ensuring the quality of the assessment;
9. You access the WFD portal here as a source for the most updated WFD tool, and for the latest advice and supporting materials.

Ten Lessons Learned so far

1. Timing

Conduct the WFD at the same time as implementing other baseline MSWM assessments, such as the Waste Wise Cities Tool (WaCT). This brings synergy, concentrates the resources, and helps ensure higher quality results.

Conducting a WFD assessment in parallel with assessments of collection and recovery/recycling systems is particularly useful as it provides more reliable information on the quantity of materials recovered, and the nature of the collection and recovery systems in terms of the split between formal and informal sector activities.

2. Define System Boundaries and Use Clustering Waste Management Approaches

Clearly defining the boundaries of the study area is important and should encompass all Municipal Solid Waste (MSW) activities, from generation, collection, transfer, recovery and disposal. Observations need to be harvested from all major waste management facilities in the study area, so the outer boundary of the study area needs to include the recovery and disposal facilities in use by the city/municipality.

The clustering approach is a useful when a city has diverse MSWM systems operating within the selected system boundary. Clustering refers to dividing the study area in different areas, based on their particularities and studying these clusters differently, using the scenario analysis option of the WFD tool. It offers more precise information, but also requires more resources.

3. Photologs and Geo-Coordinates

It is helpful to document the WFD assessment, taking photographs of the observed evidence at each of the assessment stages. This allows visualisation and cross-checking assumptions at a later stage, boosts the overall quality and representativeness of the assessment, and enables extended verification.

It is also helpful to capture geo-coordinates whilst taking pictures in pollution hotspots and during observational assessments of determining pollution levels per fate, to be able to further analyse the photo documentation at a later stage and not misinterpret data.

4. Data Consistency

Planning and conducting the survey sequentially in each of the MSWM stages lowers the risk of confusion and data input errors.

The WFD tool allows for data input check through the check cells which are highlighting errors, e.g. If the users may have a higher amount of waste being collected and disposed/sorted for recovery than the amount being generated, it will provide an error in the data sheet and in flow diagram due to imbalanced input and output flows.

Prior to your field survey, you should gather information from existing sources to understand the local context. This typically includes – population, per capita generation of waste and its composition, amounts of MSW recovered, amount of disposed waste and its composition and the amount of recyclable extracted from disposal sites. Collecting representative data from informal sector recovery activities is often challenging.

5. Quality Assurance

The WFD is a data-driven tool, and reliability and accuracy of data sets are a critical factor in assuring a representative survey.

The WFD tool, including the online tools, have been designed to help you spot data errors and inconsistencies. Check the latest version of the WFD tool on the online portal, and also look at the frequently asked questions.

A quality assurance framework is provided in Annex C to this Compendium as a guide to the type of parameters inherent in WFD quality.

6. Data Ownership

Data ownership should be clarified at the beginning of a case study and consent for publication must be requested. It is possible that some cities/municipalities may feel uncomfortable sharing their WFD assessment outcomes. Initially, data entered directly onto, or uploaded to, the data portal is private. The study team can flag the study as "public" if authorised to do so. The assessment results are then publicly visible and shareable if the study has also been flagged as "valid" by the WFD portal administration. Care should be taken to ensure that permission has been granted before flagging data as public. Control remains with the study team.

7. Littering

The WFD does not capture plastic pollution emissions from littering (incorrect disposed waste). In situations where there is universal waste collection service coverage, and high standards of control on leakages throughout the MSWM system, the WFD will not accurately pick up plastic leakages. Instead, other more detailed and system-sensitive tools need to be used for such locations.

8. Contextualising the Outcomes

The WFD provides a snapshot and indicative assessment of plastic leakages from MSWM systems. The results depend on observational assessment performed in the field. The leakages are not actually measured, rather they are approximated based on factors attributed to leakage potentials. Therefore, comparisons should only be taken as indicative.

9. Upscaling

The WFD is performed at a system level, with the results being reflective of the situation within that system boundary. It is possible to upscale the results from multiple smaller systems into a broader picture of plastic pollution emissions from a larger MSWM system.

To do this, you can profile several different MSWM systems in a country or region that are representative and assign proxies to make a broad estimate of wider emissions. The results from this 'bottom-up' approach can be compared with the results from other tools that rely on macro-modelling of plastic pollution emission models at a national or regional level.

10. Asking for Help

The WFD is a tool that is designed for use by expert assessors. Expertise can only be gained over time through conducting more WFD assessments. As results come in from WFD assessments around the world, updates will be posted on the WFD hosting portal.

EZRA OSORIO – Design Engineer, AMH Philippines

"It was the first time our team used the WFD tool for the solid waste management (SWM) baseline project in one of the highly urbanised cities in the Philippines. The tool might seem complicated to apply for the study, but with the user manual and the training and guidance from the experts who have developed the tool, the experience as a user became smooth for our team to obtain and generate quality and reliable data."

Annexes

Annex A - WFD Case Studies

The following case studies have been selected due to the diversity of arrangements that they offer. Their differing demographic and socio-economic variables which include – population, location, size, rural or urban areas, and collection rates were used to highlight how the WFD can be translated to a range of cities, all with their own unique characteristics.

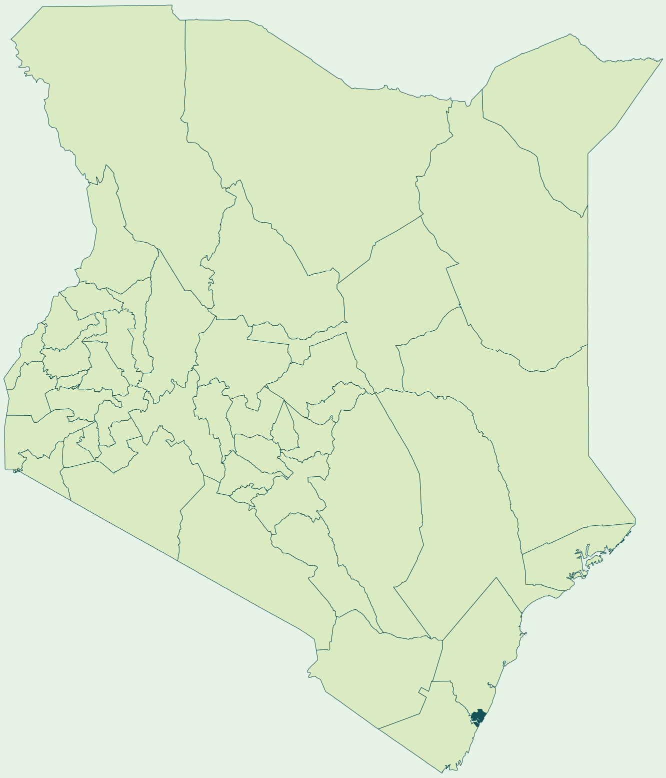
© Mateo Carcia Prieto, GIZ

Case study

Mombasa, Kenya
Africa

Mombasa

Kenya



Population
1,208,333

Size of the city
229.9 km^2
65 km^2 water mass

Settlement type
urban

Year of Survey
2021

Total MSW Generation
215.35 kg/cap/year

MSW Collected
56%

Plastic Waste Generation
16.06 kg/cap/year

Plastic to water systems
3 kg/cap/year

Context and description

Mombasa is the second largest city in Kenya and located on the shore of the Indian Ocean, a cosmopolitan city with an estimated resident population of 1.2 million persons, translating to a density of 4,097 persons per square Kilometre.

There are 6 sub-counties and 29 wards within Mombasa County with varying means of MSW collection within the wards. There are county collection trucks, mainly collecting from common collection points, private companies and registered individuals/groups using handcarts, collecting from households (HH) and premises.

Mombasa County generates approximately 708 t/day of MSW and out of this, 56% (396 t/day) is collected. Out of 396 t/day of waste collected in Mombasa, 5% (36 t/day) is managed in controlled facilities through processing for recovery. There are numerous companies dealing with recovery of various types of materials including paper & cardboard, plastic (HDPE, LDPE, PP and PET), metals and glass with paper & cardboard having the highest demand and biggest fraction recovered, up to 20t/day.

There is one main designated waste disposal site in Mombasa, Mwakirunge. It is located approximately 30 kilometres from the city centre and sits on 50 acres of land that is owned by the county government. The city also has 4 other 'recognised' disposal sites; 50% (355 t/day) of the MSW generated is managed through disposal sites. All the dumpsites in Mombasa have no environmental control.

This case study's data was collected by UN-Habitat Waste Wise Cities Campaign.

Survey Implementation Arrangement

City	Mombasa
Financed by	UN Habitat
Implemented by	International and National consultant

Overview data

Population	1,208,333 (2020)
Waste generation rate, including commercial and institutional waste	0.59 kg/cap/day (WaCT Survey)
Total MSW generation	708 tonnes/day (WaCT Survey)
Collection rate	56%
MSW sent to disposal	355 tonnes/day / 50% (WaCT Survey)
MSW sorted for recovery	40.5 tonnes/day / 6% (WaCT Survey)
MSW managed in controlled facilities	4% (WaCT Survey)
Plastic waste generation	19,401 tonnes/year
Unmanaged plastic	9,961 tonnes/year 51% of the entire plastic waste generation

MSW composition at point of generation

paper 7.74%

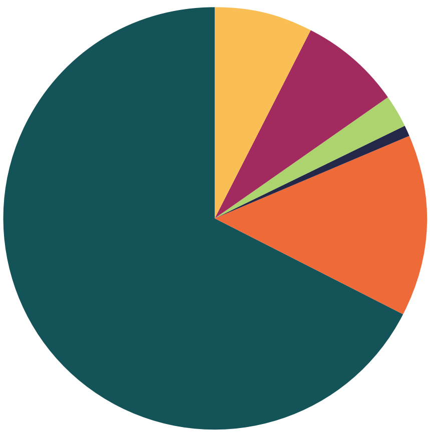
metals 0.89%

plastics 7.54%

other 14.06%

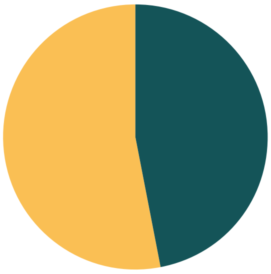
glass 2.51%

organic 67.25%



WFD results

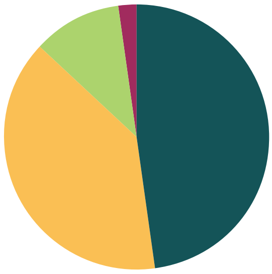
Plastic waste generation: 19,401 t/y



unmanaged 51%

managed 49%

Fate of unmanaged plastic waste



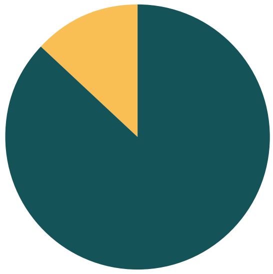
retained on land 48%

cleaned from drains 2%

ending up in water systems 39%

openly burnt 11%

Plastic to water systems

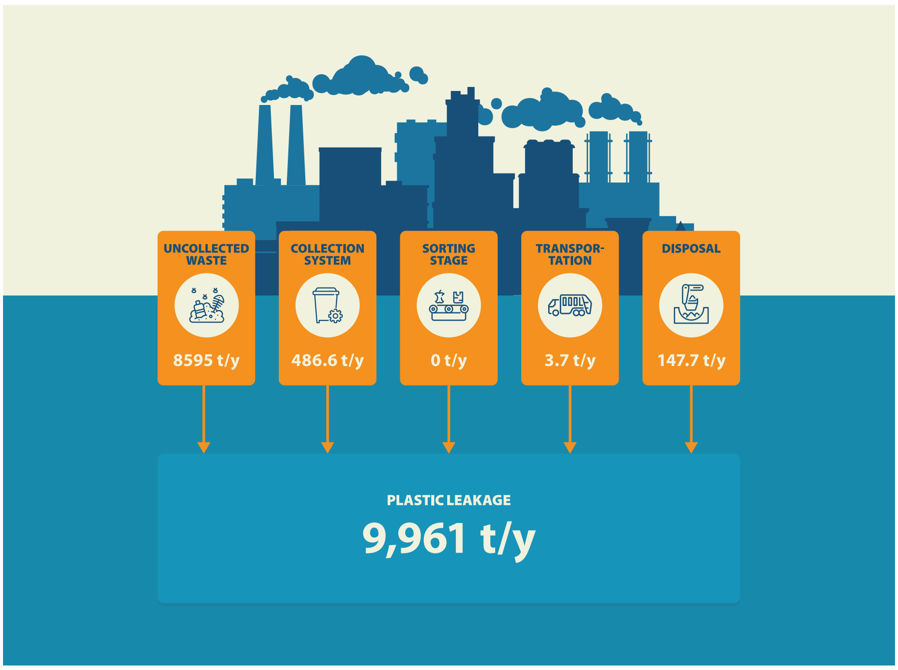


contribution directly entering water systems 87%

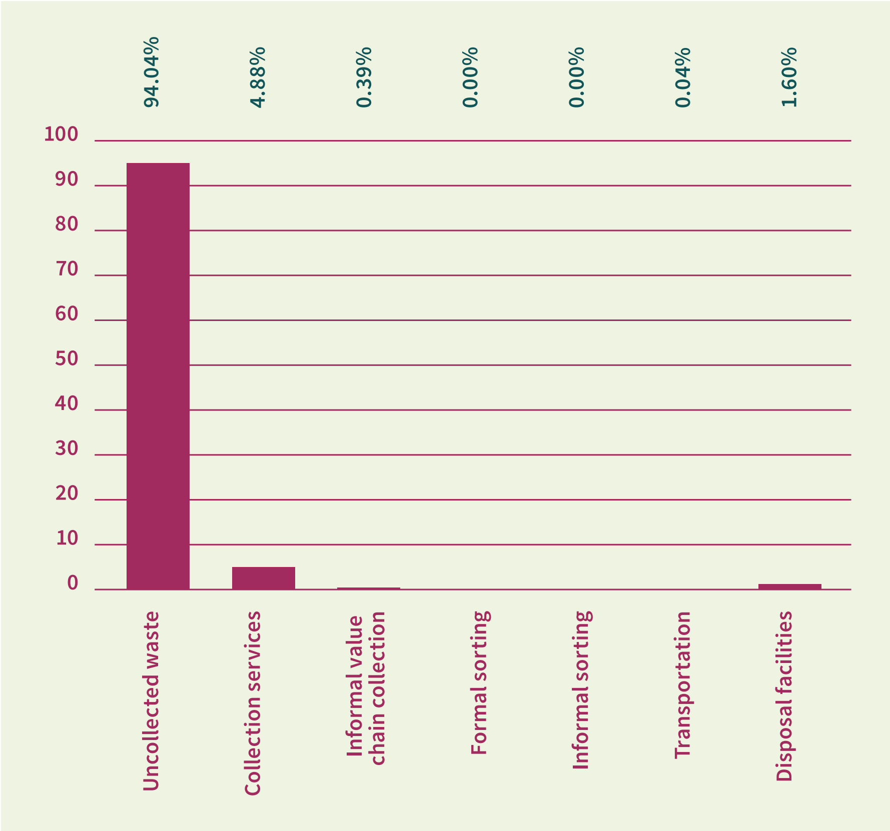
contribution entering via storm drains 13%

Plastic waste to the environment	9,961 tonnes/year	51% of the plastic waste generated
Plastic to water systems	3,885 tonnes/year	5,287 trucks
Plastic to water systems per person	3 kg/person/year	99 PET bottles per person

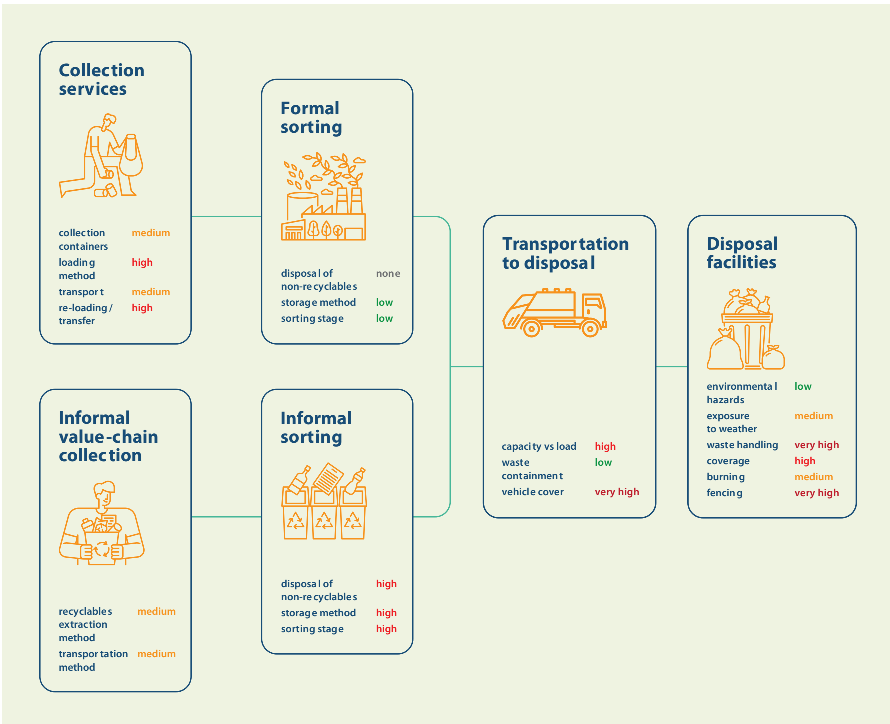
Contribution to unmanaged plastic by SWM stage



Contribution to unmanaged plastic by SWM stage



Plastic leakage potential levels per leakage influencers



Lessons Learned & Challenges

- Very small changes in the WFD baseline data entry interface results in significant differences in the results. For example, should there be a minor error in calculating composition analysis, even by 1%, the amount of plastic to water per person increases or decreases significantly;
- The tool requires skilled predictions when assigning formal and informal sorting for recovery. Therefore, this requires an expert to conduct this assessment, as training others with limited experience may not result in accurate outcomes.

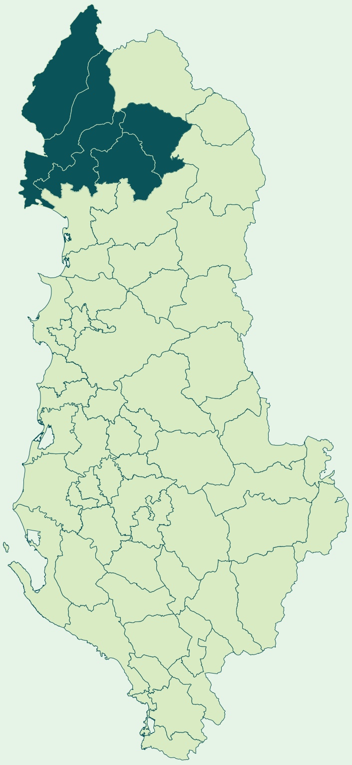
Use of WFD / Triggered Change

- The WFD results have been utilised at multiple international events to promote recognition of the importance of tacking plastic pollution emissions in coastal cities in low and middle income countries;
- The WFD outcomes informed the development of investment projects in partnership with international development organisations.

Case study

Shkodër, Albania
Europe

Shkodër
Albania



Population
202,254 (2020)

Size of the city
873 km square

Settlement type
Urban & rural

Year of Survey
2021

Total MSW Generation
162 kg/cap/year

MSW Collected
70-95%

Plastic Waste Generation
35 kg/cap/year

Plastic to water systems
1.6 kg/cap/year

Context and description

The municipality of Shkodër is composed of 11 administrative units, comprising 202,254 residents.

The municipality has a privileged proximity to water systems, as its main city (Shkodër) lies on the largest lake of the Balkans, which has the same name, and is also situated on the banks of the Buna, Drink and Kir rivers. The municipality spans from the Adriatic Sea to the foothills of the Albanian Alps.

The municipality of Shkodër offers diverse economic and societal realities, which are reflected in its SWM system. The entire municipality was studied by dividing it into 4 “clusters” to identify the upscaling potential of the WFD and capture the diversity of SWM operations. The clusters included (i) area receiving high collection coverage, (ii) area receiving low collection coverage, (iii) area with agricultural characteristic, and (iv) area with touristic activities.

This case study was done by GIZ project Marine Litter Prevention in the Western Balkans.

Survey Implementation Arrangement

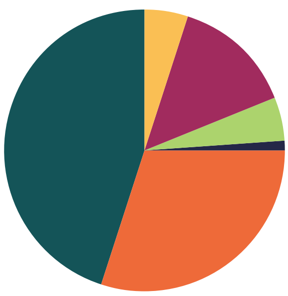
City	Shkodër
Financed by	GIZ
Implemented by	International and National consultant

Overview data

Population	202,254 (2020)
Waste generation rate, including commercial and institutional waste	0.9 kg/cap/day (high collection coverage) 0.3 kg/cap/day (agricultural)
Total MSW generation	113 tonnes/day (high collection coverage) 5.5 tonnes/day (agricultural)
Collection rate	94% (high collection coverage) 75% (agricultural)
MSW sent to disposal	106 tonnes/day / 94% (high collection coverage) 4 tonnes/day / 75% (agricultural)
MSW sorted for recovery	0.5 tonnes/day / <1% (high collection coverage) 0 tonnes/day / <1% (high collection coverage)
MSW managed in controlled facilities	0%
Plastic waste generation High collection coverage / Agricultural	5,772 tonnes/year 280 tonnes/year
Unmanaged plastic High collection coverage	394 tonnes/year 7% of the entire plastic waste generation
Unmanaged plastic waste Agricultural	76 tonnes/year 27% of the entire plastic waste generation

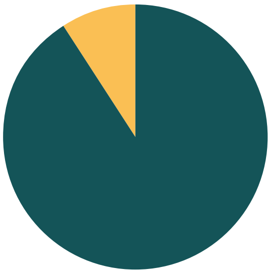
MSW composition at point of generation

paper 5%
metals 1%
plastics 14%
other 30%
glass 5%
organic 45%



WFD results Shkodra City

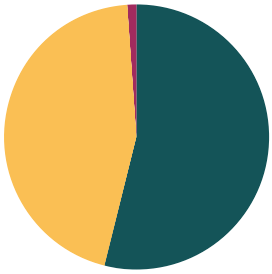
Plastic waste generation: 5,772 t/y



unmanaged 7%

managed 93%

Fate of unmanaged plastic waste



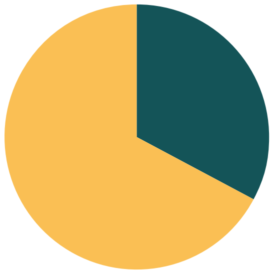
retained on land 54%

cleaned from drains 1%

ending up in water systems 45%

openly burnt 0%

Plastic to water systems



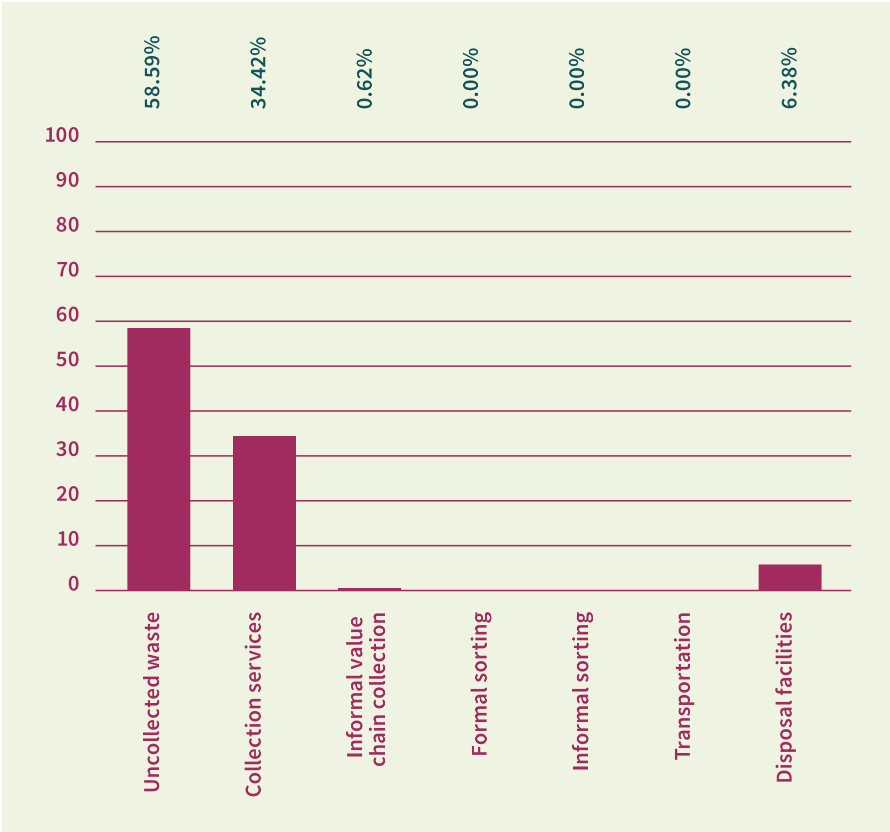
contribution directly entering water systems 67%

contribution entering via storm drains 33%

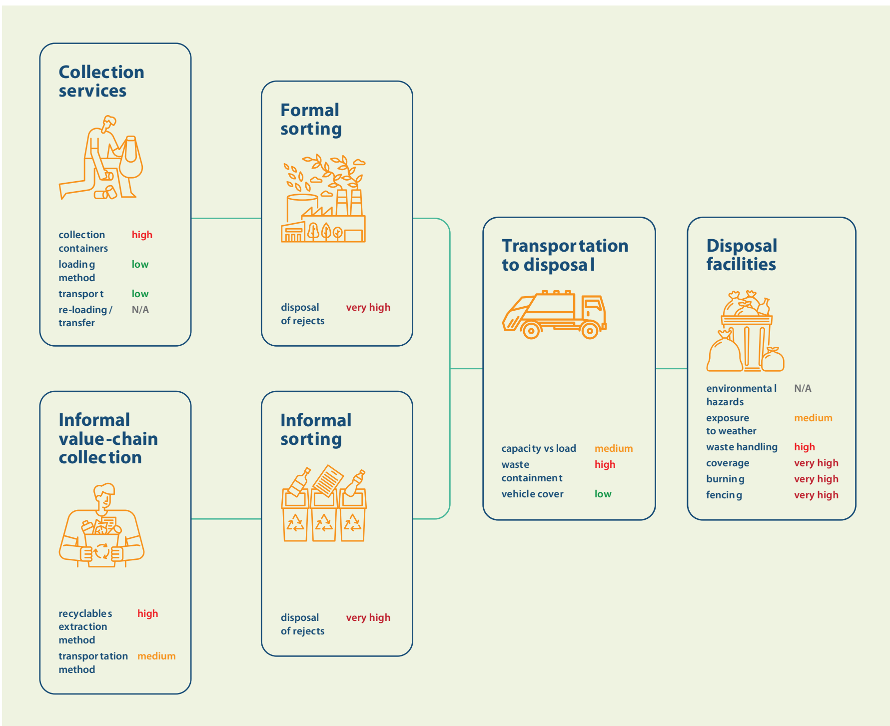
Plastic waste to the environment (High collection coverage / Agricultural)	394 tonnes/year	7% of the plastic waste generated
Plastic to water systems	175 tonnes/year	258 trucks
Plastic to water systems per person	1.4 kg/person/year	47 PET bottles per person

WFD Results in Shkodër

Contribution to unmanaged plastic waste by SWM stage

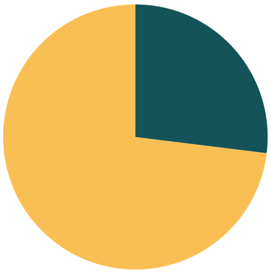


Plastic leakage potential levels per leakage influencers in Shkodër City



WFD Results Agricultural Area

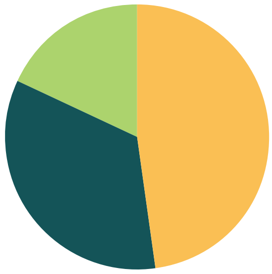
Plastic waste generation: 280 t/y



unmanaged 27%

managed 73%

Fate of unmanaged plastic waste



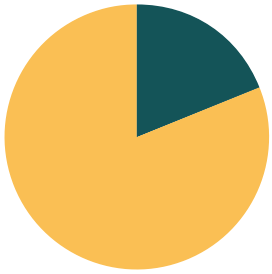
retained on land 34%

cleaned from drains 0%

ending up in water systems 48%

openly burnt 18%

Plastic to water systems



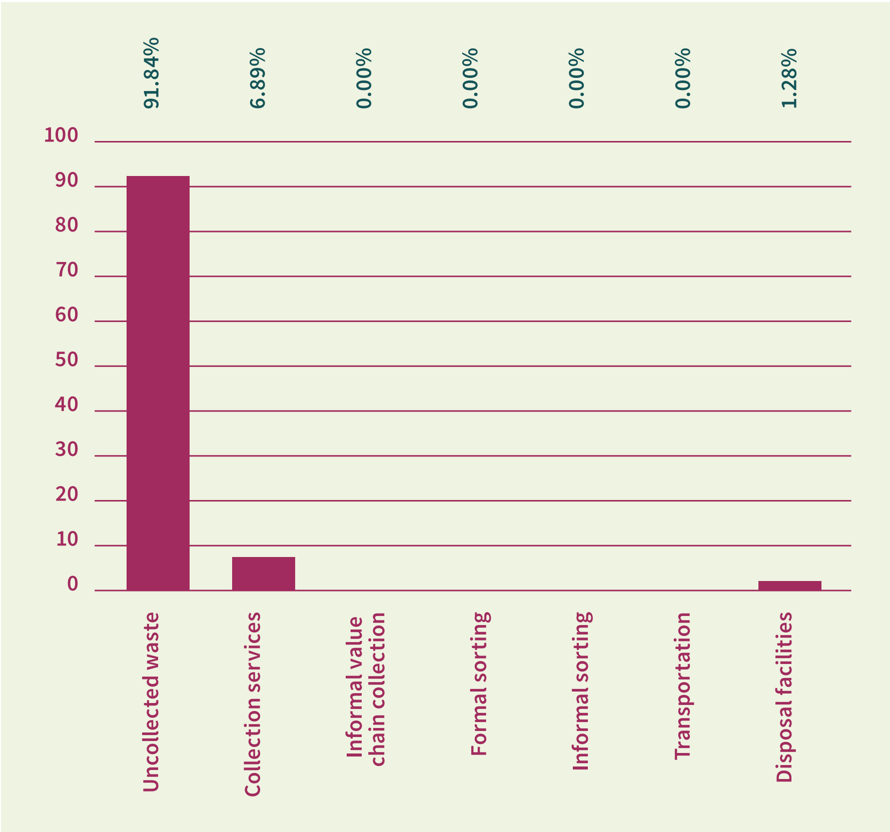
contribution directly entering water systems 81%

contribution entering via storm drains 19%

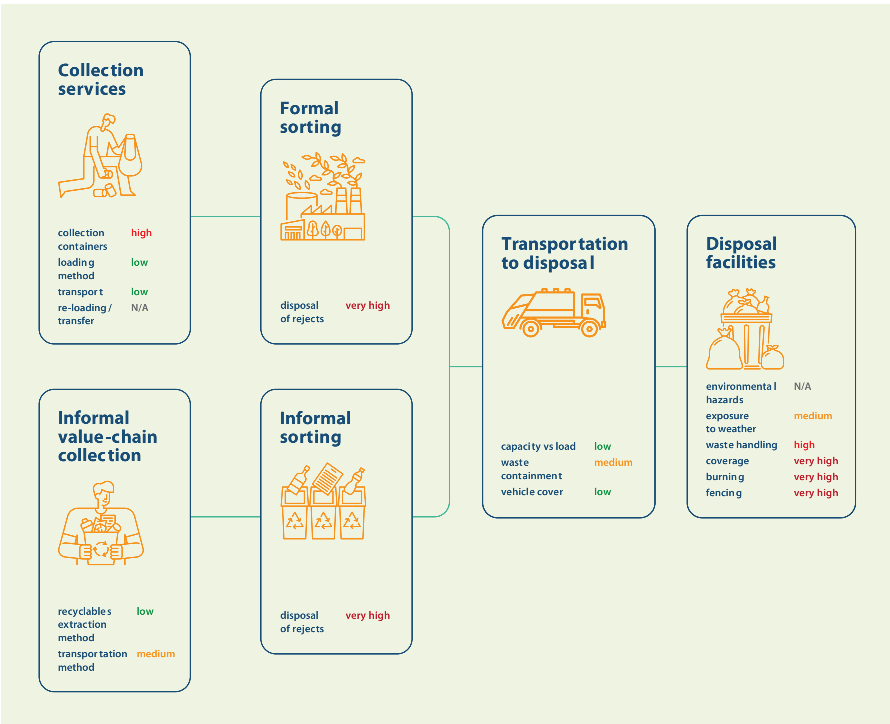
Plastic waste to the environment	76 tonnes/year	27% of the plastic waste generated
Plastic to water systems	36 tonnes/year	53 trucks
Plastic to water systems per person	2.0 kg/person/year	66 PET bottles per person

WFD Results in the Agricultural Area of Shkodër

Contribution to unmanaged Plastic waste by SWM Stage



Plastic leakage potential levels per leakage influencers in Shkodër Agricultural Area



Lessons Learned & Challenges

- The clustering approach is a useful when a city has diverse SWM realities. Although it duplicates the workload, it offers more precise information;
- Having a local guide saves a large amount of time and effort. Since contact with local stakeholders is more trusted, any plastic pollution hotspots are found more easily;
- Very little data is available for the role of the informal recovery sector and approaching this sector can be challenging, especially when they are in conflict with local authorities.

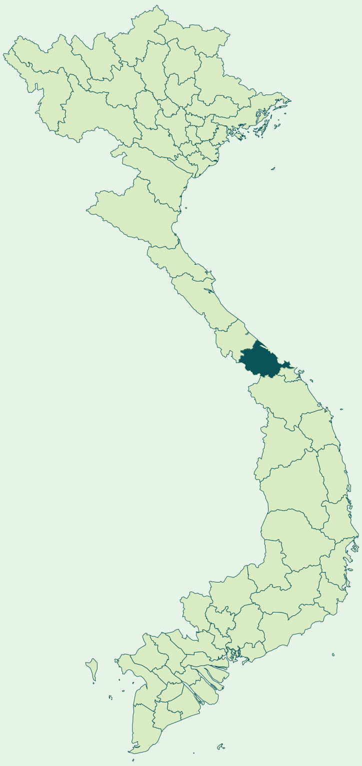
Use of WFD / Triggered Change

- The application of the Step 4 of the WaCT, “MSW received by recovery facilities”, provides reliable information on the quantity of recyclables recovered, especially when the informal sector dominates the recovery value chain;
- The use of the WFD allowed the municipality to understand the mechanisms that release plastics into the environment, and the need to expand collection services to rural areas and raise awareness;
- The WFD results have been used in national events as a basis for opening discussions on tackling plastic pollution emissions. The Shkoder case study pioneered an approach to Upscaling results into wider regional assessment.

Case study

Huế, Viet Nam
Asia

Huế
Vietnam



Population
488,157 (2020)

Size of the city
266 km square

Settlement type
urban

Year of Survey
2021

Total MSW Generation
303 kg/cap/year

MSW Collected
97%

Plastic Waste Generation
46.8 kg/cap/year

Plastic to water systems
1 kg/cap/year

Context and description

Huế city is located in central Viet Nam with the Perfume River running through it and leading to the East Sea.

The population was estimated to be 488,157 people in 2020, prior to the 2021 administrative boundary extension with the Extended city area now encompassing 266km^2. The WFD was carried out for both the Core and Extended areas which included collecting samples from 9 wards and communes including 6 in the Core area and 3 in the Extended area of the city.

The extension of the city resulted in an urgent need to assess its MSWM system and reduce plastic waste. This included undertaking the WFD in order to build a database and implement the project "Huế city – A Plastic Smart City in Central Viet Nam" which aims to improve their MSWM system.

This case study's data was collected by WWF

Survey Implementation Arrangement

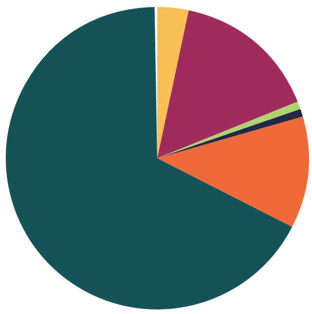
City	Huế
Financed by	WWF - TV Action-Plastic Smart Cities
Implemented by	National consultants with backstopping support from International consultants

Overview data

Population	488,157 (2020)
Waste generation rate, including commercial and institutional waste	0.83 kg/cap/day (WaCT Survey)
Total MSW generation	408 tonnes/day (WaCT Survey)
Collection rate	97% (WaCT Survey)
MSW sent to disposal	313 tonnes/day / 77% (WaCT Survey)
MSW sorted for recovery	83 tonnes/day / 8% (WaCT Survey)
MSW managed in controlled facilities	77% (WaCT Survey)
Plastic waste generation Core / Extended Area	19,337 tonnes/year 3,516 tonnes/year
Unmanaged plastic waste Core Area	349 tonnes/year 1.8% of the entire plastic waste generation
Unmanaged plastic waste Extended Area	366 tonnes/year 10.4% of the entire plastic waste generation

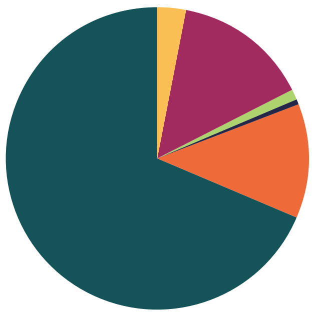
MSW composition at point of generation Core Area

paper 3.48%
metals 0.64%
plastics 15.58%
other 12%
glass 0.91%
organic 67.40%



MSW composition at point of generation Extended Area

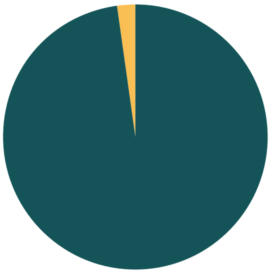
paper 3.19%
metals 0.67%
plastics 14.33%
other 12.15%
glass 1.20%
organic 68.45%



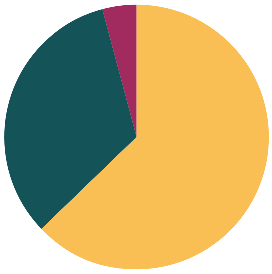
WFD results

Core Area

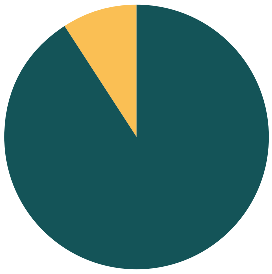
Plastic waste generation: 19,337 t/y



Fate of unmanaged plastic waste



Plastic to water systems

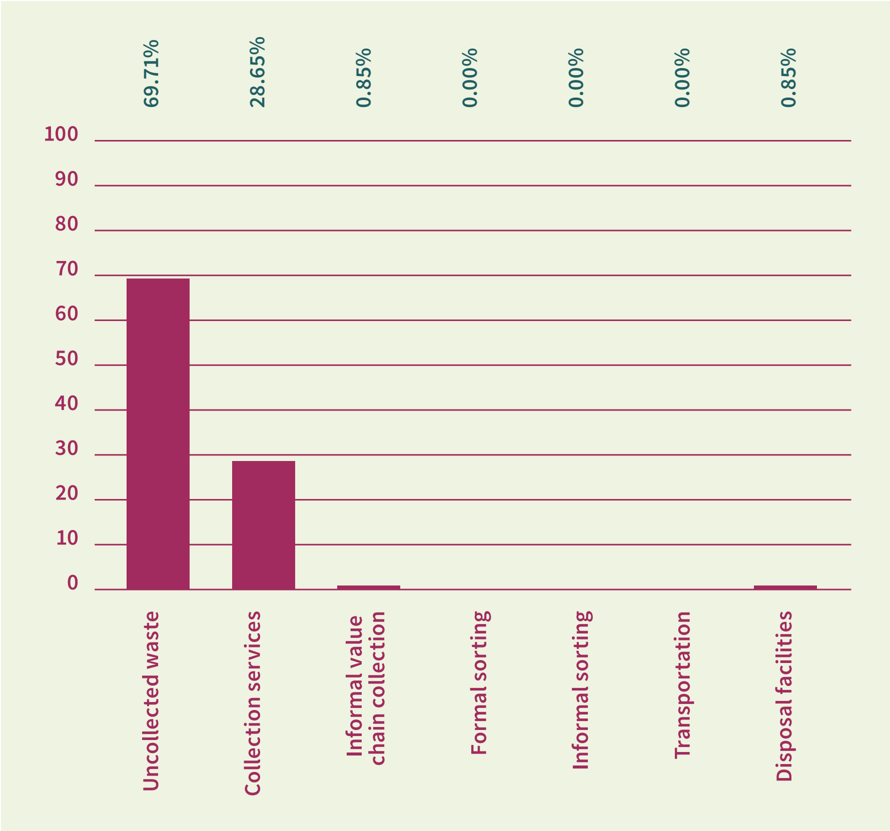


WFD Results Core Area

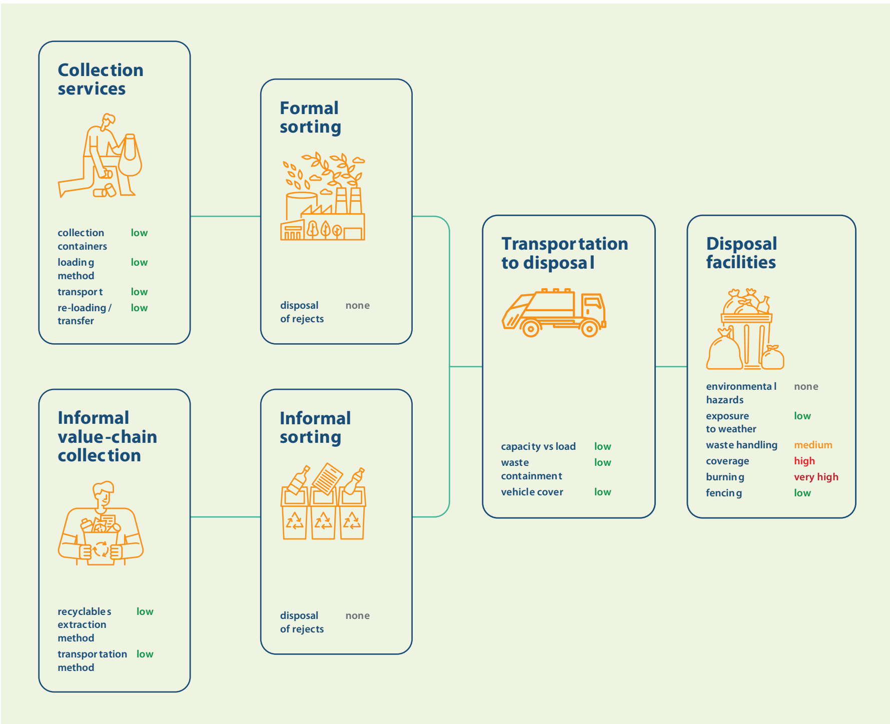
Plastic waste to the environment	350 tonnes/year	2% of the plastic waste generated
Plastic to water systems	219 tonnes/year	322 trucks
Plastic to water systems per person	0.6 kg/person/year	21 PET bottles per person

Contribution to Unmanaged Plastic Waste by SWM Stage Core Area

Contribution to Unmanaged Plastic Waste by SWM Stage Core Area

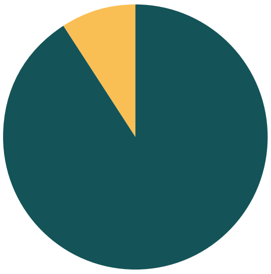


Plastic Leakage Potential Levels per Leakage Influencers in the Core Area

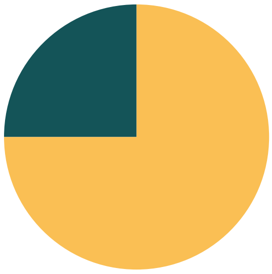


WFD results Extended Area

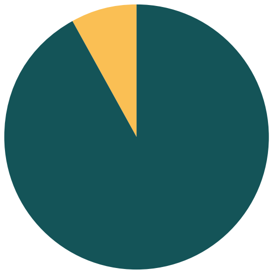
Plastic waste generation: 3,516 t/y



Fate of unmanaged plastic waste



Plastic to water systems

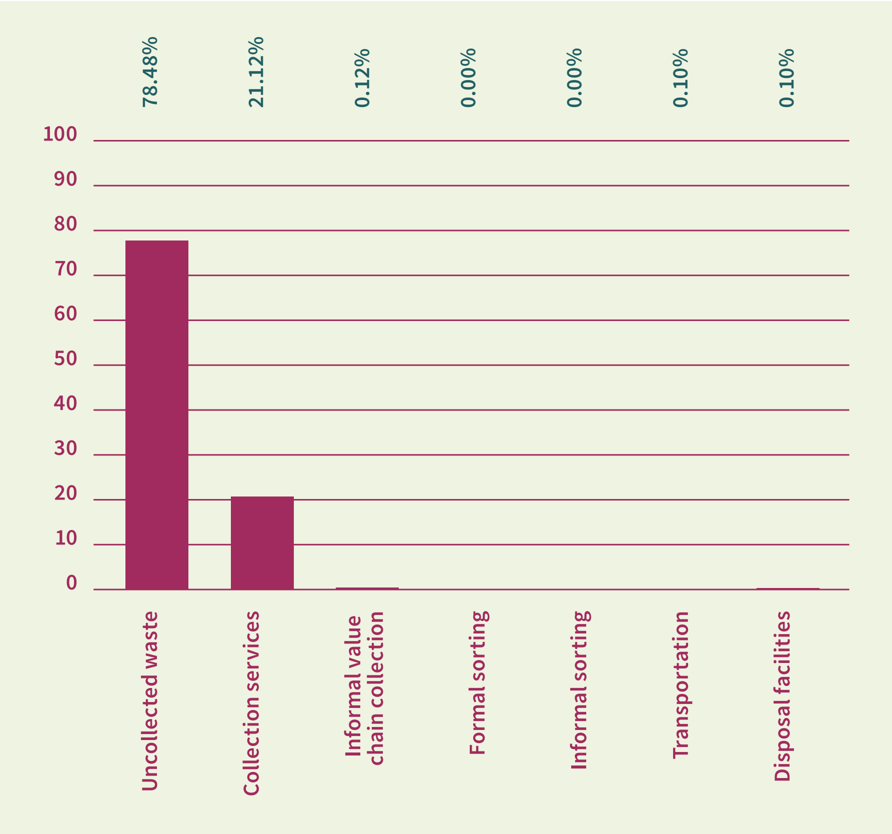


WFD Results Extended Area

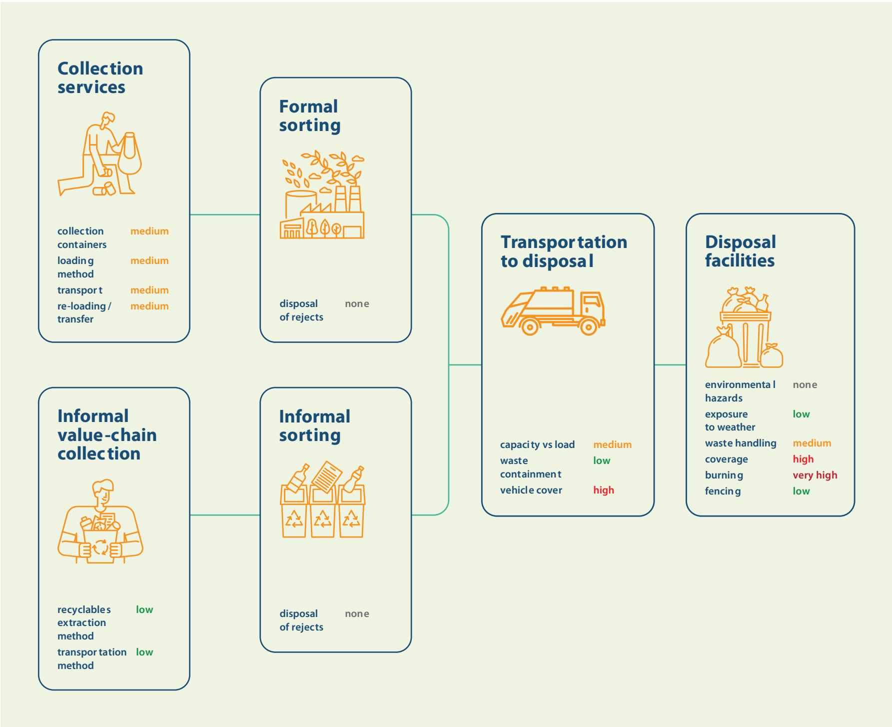
Plastic waste to the environment	366 tonnes/year	10% of the plastic waste generated
Plastic to water systems	273 tonnes/year	402 trucks
Plastic to water systems per person	2.0 kg/person/year	68 PET bottles per person

Contribution to Unmanaged Plastic Waste by SWM Stage Extended Area

Contribution to Unmanaged Plastic Waste by SWM Stage Extended Area



Plastic Leakage Potential Levels per Leakage Influencers in the Extended Area



Lessons Learned & Challenges

- Initially, the timescale of the assessment was longer than estimated, which was mainly due to COVID and a lack of data. Therefore, the assessment was performed by taking into consideration two approaches: Huế City Core Area and Huế City Extended Areas. Additionally, SWM data for the extended area was not always readily available;
- It was difficult to arrange interviews with and survey informal recovery facilities and waste pickers. This was due to the complicated trading relationship between recovery facilities;
- There was some concern that the WFD might structurally overestimate leakages to water, this was when compared to a plastic waste hotspots study;
- The WFD differentiates between informal service chain, informal value chain, formal sorting, informal sorting, collection rate, collection service coverage rate etc. All of these categories require careful attention when inputting data.

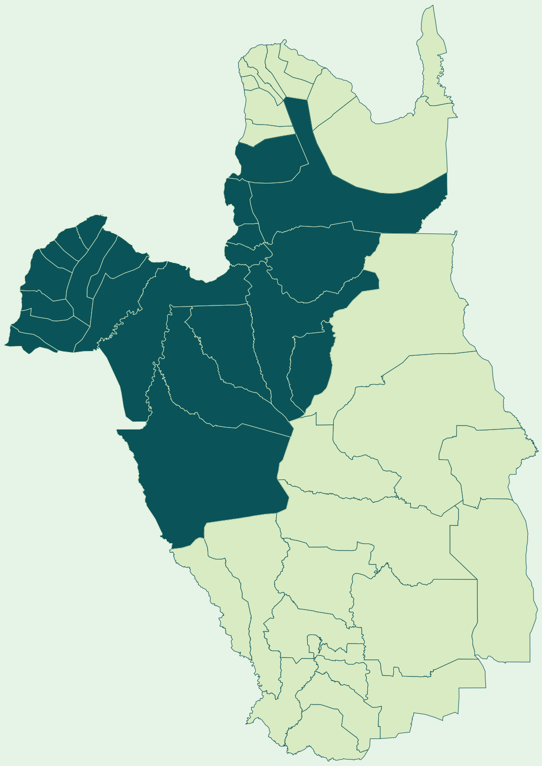
Use of WFD / Triggered Change

- Informal collection and recovery are currently not considered under collection efficiency, resulting in some complications when showing and highlighting materials extracted from landfill, whilst not losing these from collected waste;
- The Sankey diagram does not allow for differentiation between materials recovered from landfill either by waste pickers or formal recovery systems. Instead, it was redesigned to show diversion from landfill by informal recovery.

Case study

Cagayan de Oro, Philippines Asia

Cagayan de Oro
Philippines



Population
778,642 (2021 est.)

Size of the city
570 km square

Settlement type
urban, coastal

Year of Survey
2021

Total MSW Generation
138.7 kg/cap/year

MSW Collected
92%

Plastic Waste Generation
19.5 kg/cap/year

Plastic to water systems
0.3 kg/cap/year

Context and description

Cagayan de Oro is a highly urbanised city in the region of Northern Mindanao and the 10^{th} most populous city in the Philippines. It is the capital of the province of Misamis Oriental where it is geographically located.

According to the 2015 census, the population of Metro Cagayan de Oro is estimated to be 1.37 million. Located along the north central coast of Mindanao island facing Macajalar Bay, the city is covering an area of 413 km^2 and has a tropical monsoon climate, with a wet and dry season. The survey was conducted during the dry season.

The motivation for undertaking the WFD was to understand and visualise the plastic leakage at different MSWM stages, in order to come up with solutions to further improve the performance of the MSWM system. This case study was implemented under leadership of the UN Habitat HOCCI programme.

This case study's data was collected by UN Habitat

Survey Implementation Arrangement

City	Cagayan de Oro
Financed by	UN Habitat - Healthy Oceans and Clean Cities Initiative (HOCCI)
Implemented by	Cagayan de Oro municipality with backstopping support from International consultants

Overview data

Population	778,642 (2021 est.)
Waste generation rate, including commercial and institutional waste	0.38 kg/cap/day (WaCT Survey)
Total MSW generation	297 tonnes/day (WaCT Survey)
Collection rate	92% (WaCT Survey)
MSW sent to disposal	260 tonnes/day / 87% (WaCT Survey)
MSW sorted for recovery	16 tonnes/day / 5% (WaCT Survey)
MSW managed in controlled facilities	91% (WaCT Survey)
Plastic waste generation	15,203 tonnes/year
Unmanaged plastic	1,426 tonnes/year 9% of the entire plastic waste generation

MSW composition at point of generation

paper 9.00%

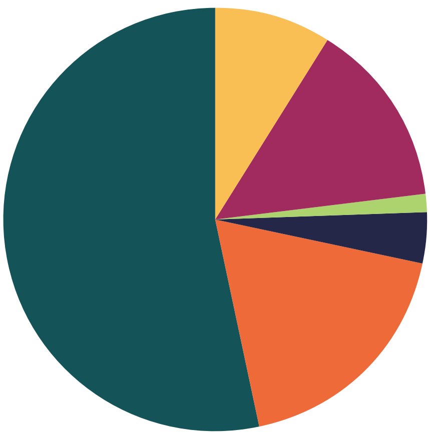
plastics 14.00%

glass 2.00%

metals 4.00%

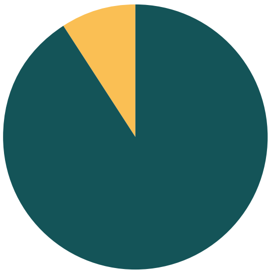
other 18.00%

organic 53.00%



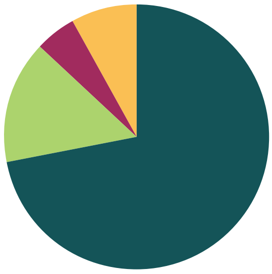
WFD results

Plastic waste generation: 15,203 t/y



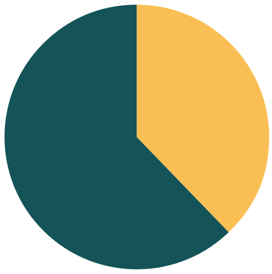
- unmanaged 9%
- managed 91%

Unmanaged plastic



- in water systems 15%
- cleaned from drains 5%
- openly burnt 8%
- retained on land 72%

Plastic to water systems



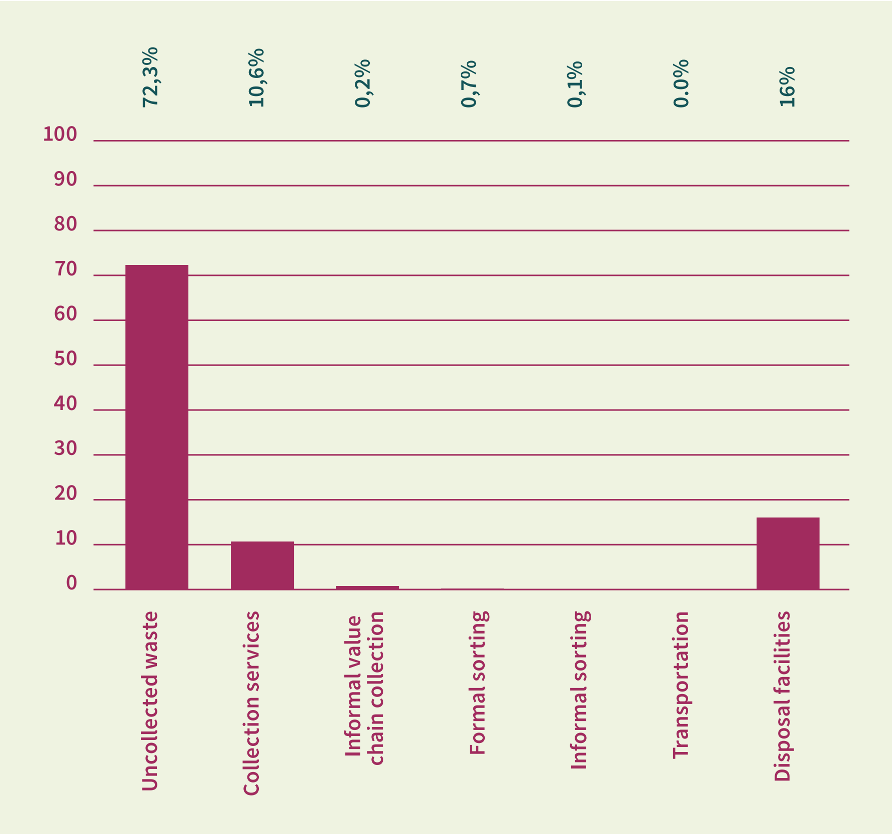
- entering via storm drains 38%
- directly entering water systems 62%

WFD Results in Cagayan de Oro

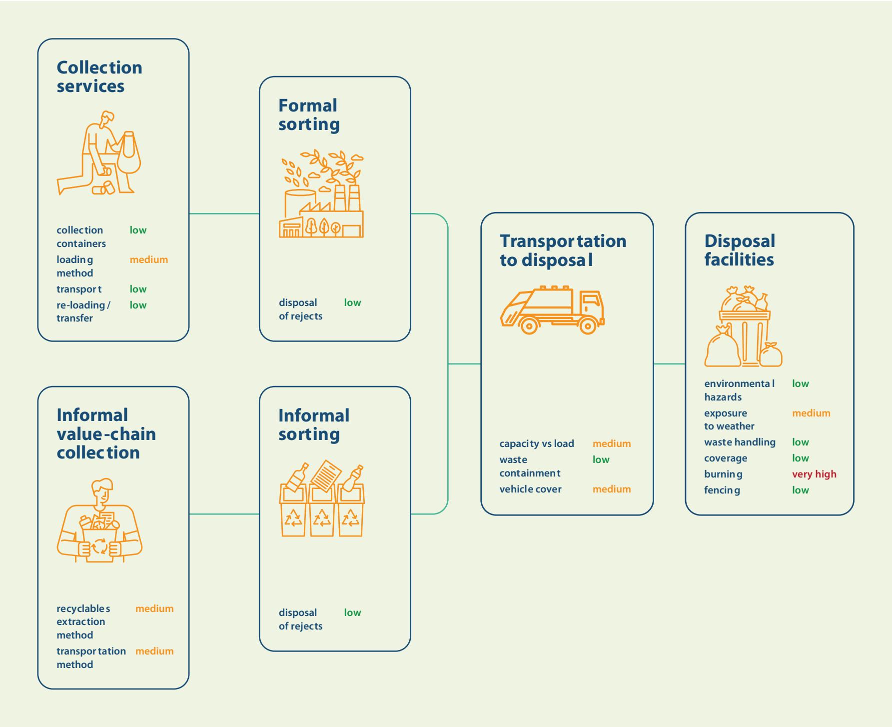
Plastic waste to the environment	1,426 tonnes/year	9% of the plastic waste generated
Plastic to water systems	214 tonnes/year	315 trucks
Plastic to water systems per person	0.3 kg/person/year	9 PET bottles per person

Contribution to unmanaged plastic by SWM stage

Contribution to unmanaged plastic by SWM stage



Plastic leakage potential levels per leakage influencers



Lessons Learned & Challenges

- The data published is collected in line with the WaCT concepts and definitions, which might not be aligned by similar concepts and requirements by laws and regulations in the Philippines when related to SWM;
- The WFD assessment was carried out during the Covid-19 pandemic, in tandem with a WaCT assessment. Therefore, it was not possible for a consulting team to visit the city due to travel and cross-infection restrictions, however, the city committed to undertaking the full assignment on their own with remote guidance and backstopping support;
- The city team was fantastic in their ability to mobilise the survey teams for the assessment and conducted a very thorough assessment;
- The main lesson learnt was that a city/municipal team can do a WFD assessment, so long as they have backstopping support for understanding the methodology, approach and toolkit, and quality assuring the final output.

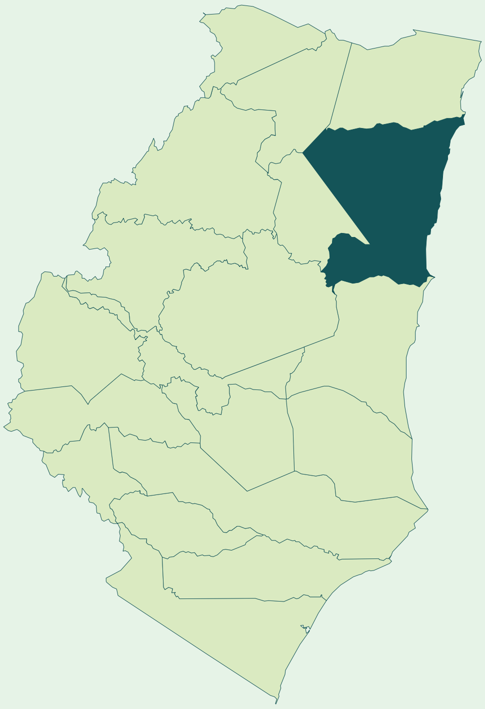
Use of WFD / Triggered Change

- The WFD (and WaCT) assessment fed into a wider project managed by UN-Habitat, 'Health Oceans and Clean Cities Initiative', the focus of which was on reducing marine plastic pollution;
- The WFD assessment provided an authoritative baseline upon which to design follow-up 'Action Planning' initiatives, with the City decision makers taking a lead role in formulating and adopting pollution prevention measures.

Case study

Porto Seguro, Brazil
Latin America

Porto Seguro
Brazil



Population
257,204 (2021)

Size of the city
2,285,734 km²

Settlement type
Urban

Year of Survey
2021-2022

Total MSW Generation
383.25 kg/cap/year

MSW Collected
98-100%

Plastic Waste Generation
53.65 kg/cap/year

Plastic to water systems
1 kg/cap/year

Context and description

The municipality Porto Seguro consists of six districts: Porto Seguro (headquarters), Arraial D'Ajuda, Caraíva, Trancoso, Vale Verde and Vera Cruz.

Porto Seguro is located in the extreme south of Bahia. This is a region extremely rich in biodiversity, with a high concentration of endemic species. Porto Seguro presents an enormous wealth of water resources, since the municipality is comprised of small valleys with many springs and water courses and around 22 micro watersheds in the territory. It also stands out for its social and economic importance and has relevant influence on other municipalities in the region, with an area of over 2,400 km² and 85 km of coastline. The beaches and coastal environments attract almost a million tourists each year, with marine resources that are the means of subsistence for hundreds of families of traditional coastal populations, while having several conservation units in its territory.

The main urban and tourist areas of the municipality were studied: headquarters, Arraial D'Ajuda, Trancoso and Caraíva. Visits were made to different neighborhoods of these locations.

This case study was implemented under leadership of GIZ project, "Protecting Brazil's marine and coastal biodiversity (TerraMar)", and supported environmental planning for Brazilian coastal and marine zones. It focused on two coastal regions: Costa dos Corais (Coral coast) and Abrolhos, due to their unique ecosystems and their significance for costal and marine biodiversity.

This case study's data was collected by GIZ

Survey Implementation Arrangement

City	Porto Seguro
Financed by	GIZ
Implemented by	International consultant together with City SWM Managers

Overview data

Population	257,204 (2021)
Waste generation rate, including commercial and institutional waste	1.5 kg/cap/day
Total MSW generation	270 tonnes/day
Collection rate	98% formal collection 2% informal collection
MSW sent to disposal	264.6 t/day (98% formal collection) 5.4 t/day (2% informal collection)
MSW sorted for recovery	0.8 t/day / <1%
MSW managed in controlled facilities	0%
Plastic waste generation	13,800 tonnes/year
Unmanaged plastic	1,529 t/year 11% of the entire plastic waste generation

MSW composition at point of generation

paper 7%

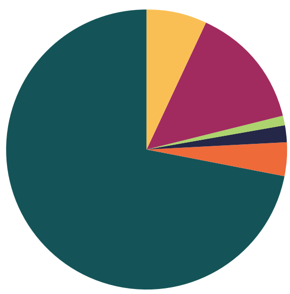
plastics 14%

glass 1%

metals 2%

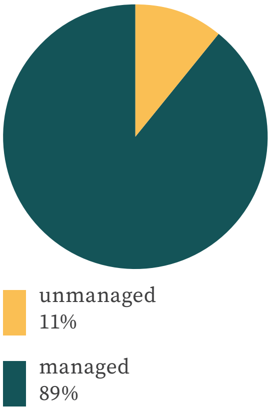
other 4%

organic 71%

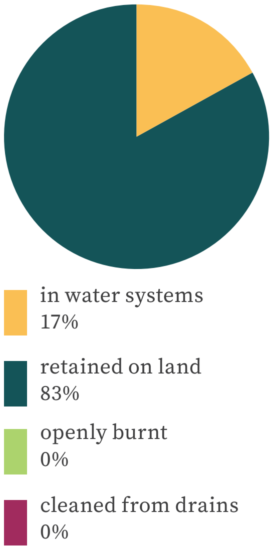


WFD results Porto Seguro

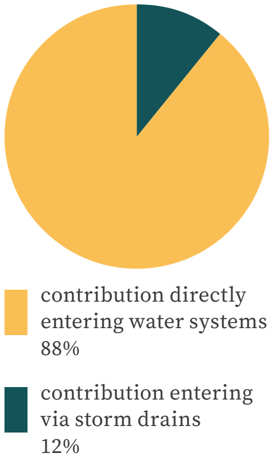
Plastic waste generation: 19,377 t/y



Fate of unmanaged plastic waste

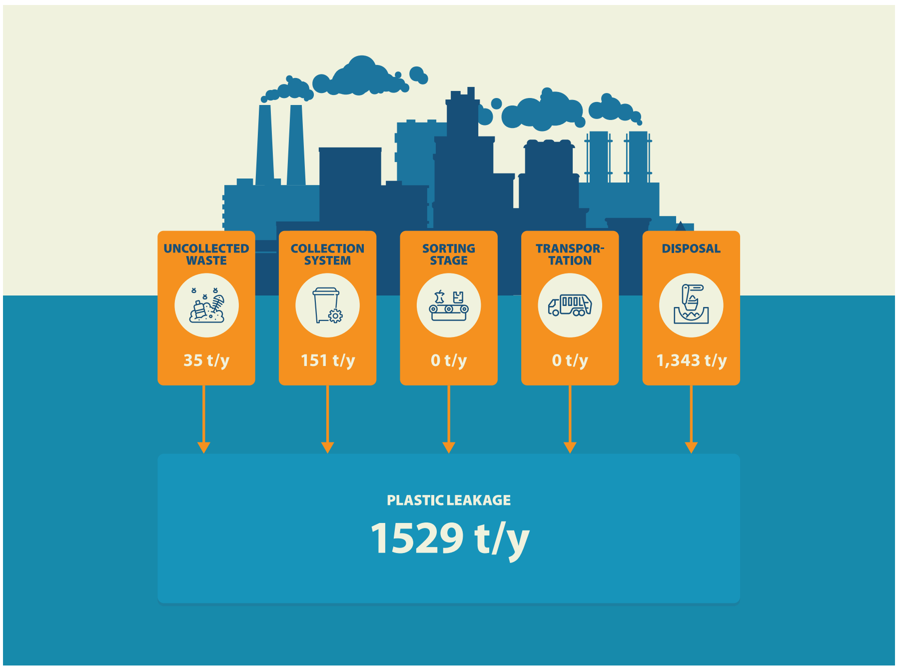


Plastic to water systems

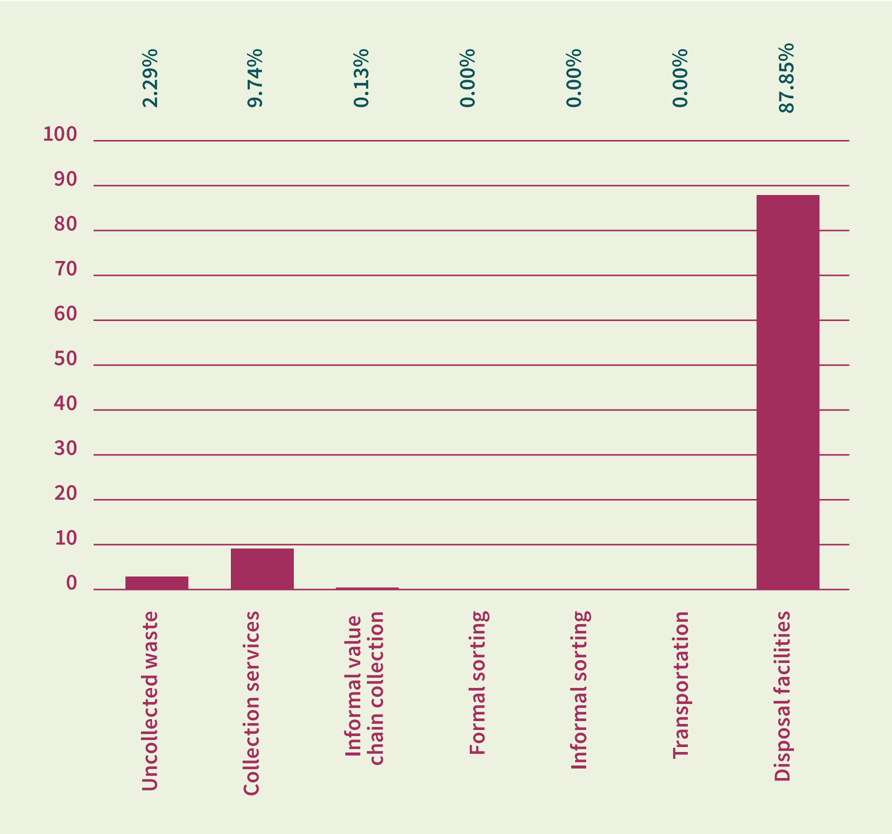


Plastic waste to the environment (High collection coverage / Agricultural)	1,529 tonnes/year	11% of the plastic waste generated
Plastic to water systems	255 tonnes/year	374 trucks
Plastic to water systems per person	1 kg/person/year	33 PET bottles per person

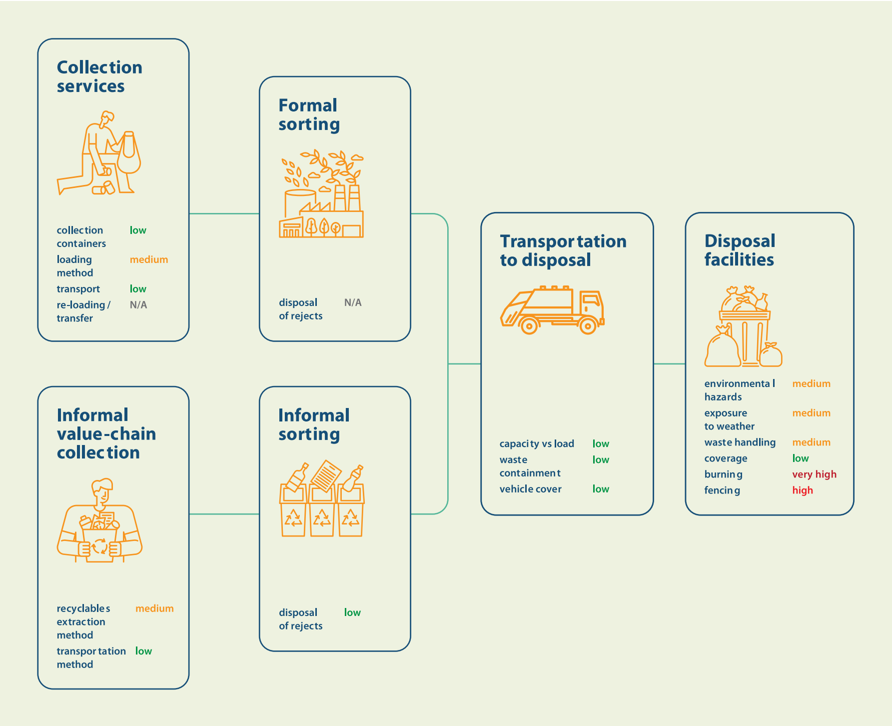
WFD Results in Porto Seguro



Contribution to unmanaged plastic waste by SWM stage



Plastic leakage potential levels per leakage influencers in Purto Seguro



Lessons Learned & Challenges

- Transparency and the support of local managers are essential for the field visits to reflect the reality in the municipality. It was very important to have the support and accompaniment of a local guide (manager) to indicate the hotspots of plastic leakage;
- Obtaining data from the municipality is a challenging task, especially in regard to the quantity and composition of waste collected by the informal chain. Obtaining data from waste pickers is delicate and it is necessary to establish a prior relationship of trust to obtain more reliable data;
- The WFD does not directly consider the top of the MSWM hierarchy (non-generation, reduction, and reuse). Therefore, measures that target these dimensions, such as regulations aimed at prohibiting or reducing plastic consumption are needed, as they are not considered in the methodology. Brazilian experience shows that the possibilities of introducing regulatory instruments with this scope at the municipal level are quite limited;
- In a few cases in Brazil, the collection of recyclables by informal recyclable collectors is often supported by the municipality by providing facilities for sorting contracted and appropriately paid separate waste collection. Thus, the transition between informally and formally provided services is fluid and both services overlap.

Use of WFD / Triggered Change

- The WFD was applied in seven coastal municipalities in Brazil to support them in developing plans to reduce marine litter. Scenarios were simulated with measures ranging from the implementation of selective collection, environmental education actions, improvements in the urban cleaning infrastructure, improvements in landfills, and increased recycling rates. The scenarios informed and helped municipalities in developing solutions to reduce marine litter and adjust strategic waste management planning;
- The conducted assessments considered the average waste generation in the observed time period, without considering eventual fluctuations throughout the year. Thus, they do not directly reflect the variations on waste generation and waste leakage by influx of visitors during the touristic high season months. To try to incorporate tourism data, the annual

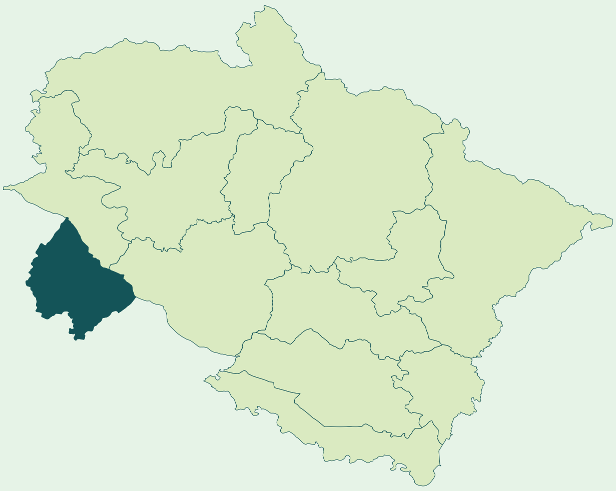
population was calculated considering resident population + the average number of tourists per month. A seasonal assessment may be implemented to understand tourism impacts, while the hotel industry requested to reduce and substitute their plastic consumption.

Case study

Haridwar, India

Asia

Haridwar
India



Population
251,197

Size of the city
12.3 km^2

Settlement type
Urban

Year of Survey
2020-2021

Total MSW Generation
335.1 kg/cap/year

MSW Collected
99%

Plastic Waste Generation
26.2 kg/cap/year

Plastic to water systems
328 kg/cap/year

Context and description

Haridwar is a city and municipal corporation in the Haridwar district of Uttarakhand. The city, which is situated on the western bank of the river Ganges, has a significant national cultural importance and serves as a gateway to several places of worship.

One of the most significant events is the Kumbh Mela, during which millions of pilgrims, devotees, and tourists congregate in Haridwar to perform ritualistic bathing on the banks of the river Ganges.

Haridwar Municipal Corporation, Haridwar Nagar Nigam (HNN), consists of 60 wards with a total population of 251,197 in 2018, which makes Haridwar the second largest city in the state of Uttarakhand and the largest in the district.

The assessment of Haridwar was conducted from November to December 2020 during the ongoing COVID-19 pandemic in India. In order to prevent infection risks for the personnel of this assessment and due to existing restrictions, this study had to be conducted with certain limitations and adjustments of the methodology. Due to the COVID-19 pandemic, deviations from the previous disposal behaviour were observed, with a tendency to an increased share of sanitisation and hygiene products, packaging waste as well as delivery and to-go food and beverage containers.

This case study's data was collected by GIZ

Survey Implementation Arrangement

City	Haridwar
Financed by	GIZ
Implemented by	GIZ

Overview data

Population	251,197
Waste generation rate, including commercial and institutional waste	0.91 kg/cap/day
Total MSW generation	228.6 tonnes/day
Collection rate	99%
MSW sent to disposal	216.11 t/day
MSW sorted for recovery	9.6 t/day
MSW managed in controlled facilities	0%
Plastic waste generation (high collection coverage)	5,099 t/year
Unmanaged plastic (high collection coverage)	1,069 t/year

MSW composition at point of generation

paper 5%

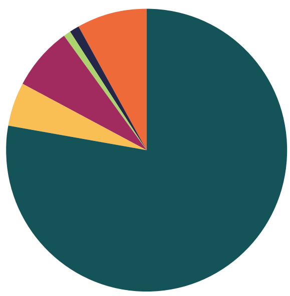
metals 1%

plastics 7%

other 8%

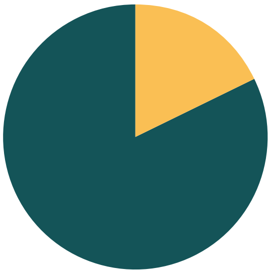
glass 1%

organic 78%



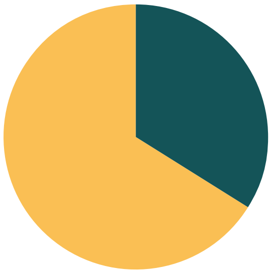
WFD results Haridwar

Plastic waste generation: 5,840 t/y



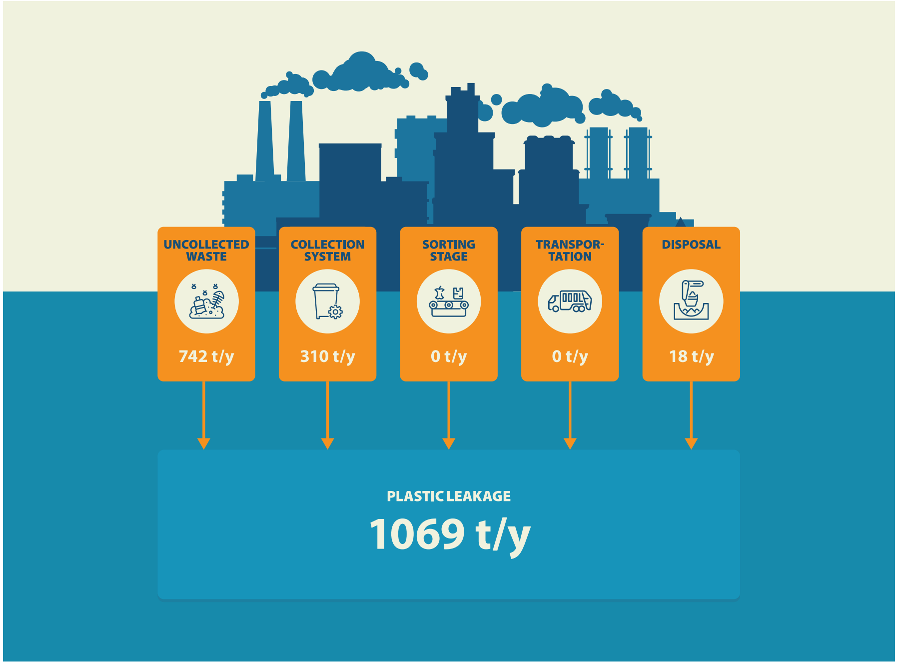
Fate of unmanaged plastic waste

Plastic to water systems

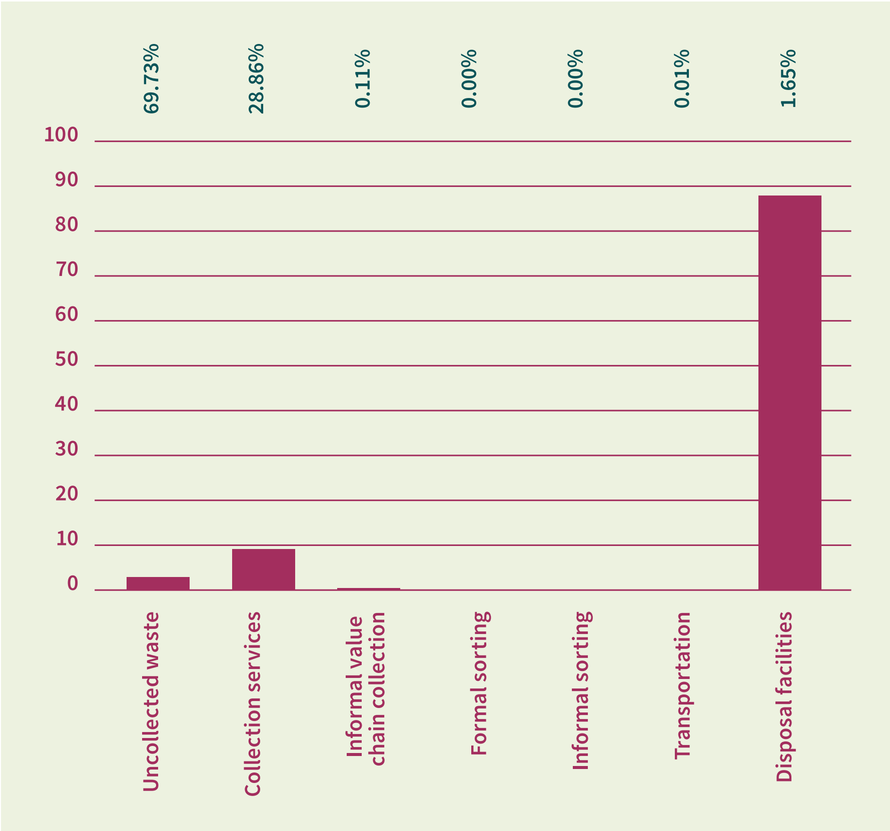


Plastic waste to the environment	1,069 tonnes/year	18% of the plastic waste generated
Plastic to water systems	328 tonnes/year	482 trucks
Plastic to water systems per person	1.31 kg/person/year	44 PET bottles per person

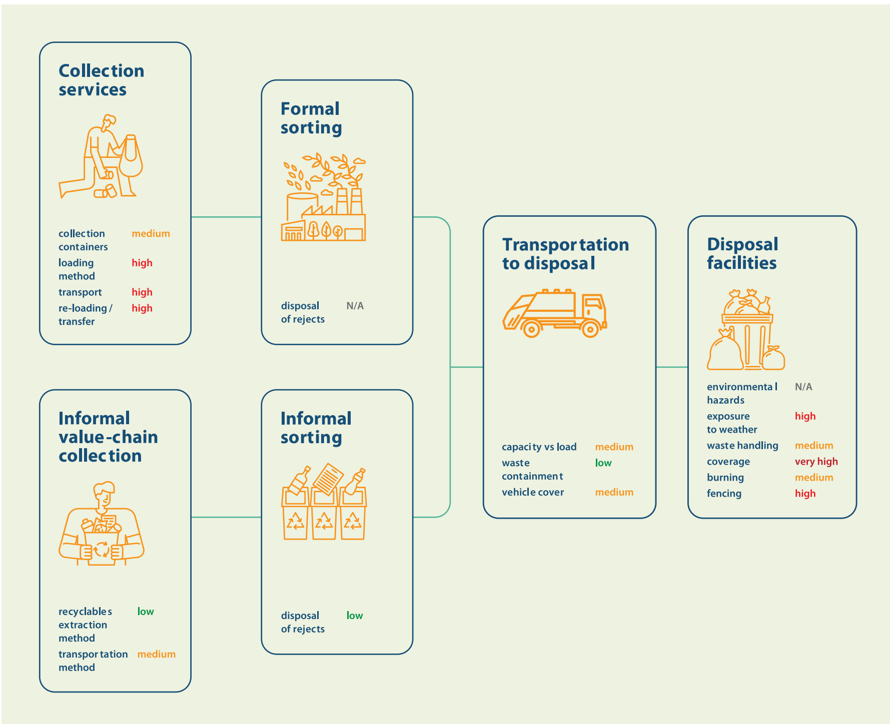
WFD Results in Haridwar



Contribution to unmanaged plastic waste by SWM stage



Plastic leakage potential levels per leakage influencers in Haridwar



Lessons Learned & Challenges	• Overall, volumes and capacities of primary waste collection vehicles and bins were found to be generally sufficient for the city's requirements. However, waste leakage at community bin locations, at transfer points between primary and secondary collection, as well as open littering are major challenges within the MSWM system; • In order to increase waste recovery, waste segregation, separate collection and transportation streams need to be introduced.
Use of WFD / Triggered Change	• Ground quantification of waste leakage in Haridwar requires significant resources and financial efforts, the application of the WFD provides an easy and low-cost way to estimate waste leakage and track progress of infrastructure interventions.

Annex B - Training Programme

Teaser video about the WFD and training course. (1 min)

Do you want to know how to measure plastic pollution in one step by identifying ways on how to reduce this pollution? This comprehensive training video (40 min) guides you through all the steps of applying a WFD:

- Introduction to the plastic challenge (start at 1:00)
- Motivation to use WFD as an assessment tool (start at 3:45)
- How the tool works (start at 5:20)
- Preparing for an WFD assessment (start at 7:30)
- Data requirements for a WFD (start at 14:15)
- Quantifying plastic leakages (start at 20:10)
- Function of the scenario feature (start at 29:20)
- Visualising results (start at 31:57)
- Introduction of the online portal (start at 36:32)

An additional case study video introduces a real- life case study in "Megalopolis" and the application of a WFD (7min)

The Train the Trainer Course is designed to support a WFD trainer deliver the course over a full day (8 hours). It is composed of 14 sessions.

All materials have been designed to support the trainer in delivering a smooth course, covering all the aspects of the WFD with confidence. The training material was developed based on two years of field experience by a team of experts, and provides a complete overview of the WFD tool, with a mix of theory and practical experience. The course is suitable for participants with all levels of knowledge of the WFD.

Annex C - Quality Assurance Matrix

The reliability of a WFD assessment still largely depends on a variety of factors. A quality assessment framework is shown in Figure 10. The framework developed builds upon the work of Laner et al. (2016) who outlined five indicators for assessing uncertainty in MFA input data:

1. The reliability of data sources, methods, and documentation used;
2. The completeness of the data;
3. The temporal correlation of data sources used (how close the data year is to the target year);
4. The geographical correlation (how close the spatial scale of the data matches the target area);
5. The correlation of other relevant factors (e.g. data is for the correct process / technology under investigation).

The quality assessment framework developed for the WFD incorporates these indicators but also further expands them into sub-indicators to reflect the specifics of the WFD and to allow for easier and more repeatable scoring. Each sub-indicator is scored from between 1 (most reliable) to 4 (least reliable) according to the explanations provided (see Figure 10). The average score is then taken to indicate the overall reliability of the assessment.

		Score			
Main indicator	**Sub-indicator**	**1 (most reliable)**	**2**	**3**	**4 (least reliable)**
Reliability of data collection and implementation	SWM data collection	SWM data was collected using the WACT methodology	Majority of SWM data was collected using primary sampling but not via WACT methodology. Details of the methodology used are provided.	Majority of SWM data was collected from secondary sources but the underlying methodology used is known.	Methodology of data collection is not known or assumptions / expert opinion is used.
	Provision of training	Full training of WFD provided by qualified assessors	Partial training of WFD provided by qualified assessors.	Training provided by unqualified assessors.	No training provided.
	Provision of backstopping	Significant backstopping provided on data collection and implementation of WFD	Significant backstopping provided on implementation of WFD only.	Limited backstopping provided on implementation of WFD only.	No backstopping provided.
	Stakeholder validation	WFD results validated through engagement of key stakeholders	Stakeholders engaged in validation but not on primary WFD results	Limited or superficial engagement of stakeholders in validation.	No stakeholder engagement for validation of results.

Completeness of data collection	Representativeness of SWM data collection	Primary sampling conducted across all key elements of SWM system. Substantial resources allocated to achieve high representativeness (e.g. WACT applied in full, sampling conducted at multiple facilities and waste generation sources)	Primary sampling conducted across most key elements of SWM system but with some omissions, (e.g. some facility types excluded, WACT applied partially etc.). Moderate resources allocated to achieve representativeness of data collected.	Primary sampling conducted only at disposal site with other SWM system components (recovery, waste generation at source etc.) not sampled. Low resources allocated to achieve representativeness of data collected.	Representativeness of SWM data poor or unclear (e.g. methodology of data collection not known or expert opinion used).
	Representativeness of observational assessments	Significant resources invested in observational assessments or high confidence observations are representative (e.g. Diffuse leakage and fate assessments sampled at several locations across the city)	Moderate resources invested in observational assessments or moderate confidence observations are representative (e.g. Diffuse leakage and fate assessments sampled at a small number of locations across the city)	Low resources invested in observational assessments or low confidence observations are representative (e.g. Diffuse leakage and fate assessments sampled at only a single location in the city)	Observational based assessments not based on fieldwork.
	Documentation of observational assessments	Full documentation of observational assessments including photos and justifications.	Partial documentation of observational assessments with justifications but no photos.	Limited documentation of observational assessments with some photos.	No documentation of observational assessments.
	Difficulties encountered in data collection	No difficulties encountered during data collection	Minor difficulties encountered during data collection but believed to have only negligible influence on results.	Moderate difficulties encountered during data collection with potentially important influence on results.	Major difficulties encountered during data collection with significant influence on results.
Temporal and geographical correlation	Data year	SWM data collected or relevant to target year	SWM data year deviates between 1 – 5 years from target year	SWM data year deviates between 5 – 10 years from target year	Data years not provided or over 10 years from target year
	Geographical correlation of SWM data	All data collection correlates with the study area.	Majority of SWM correlates with the study area, including all key data points.	Majority of key SWM points correlate with study area but all others originate from outside.	All SWM data originates from outside the study area.
	Level of adaption of WFD	WFD applied at city / municipal scale with clear defined boundaries. WFD implementation method not adapted.	WFD applied at adapted scale (e.g. regional, sub-municipal) or city / municipal boundaries are vague. WFD implementation method not adapted.	WFD applied at city / municipal scale but WFD implementation method significantly adapted.	WFD adapted significantly both in terms of geographical area and implementation method.

Table 2

Quality Assurance Framework used to
Assess the Reliability of WFD Applications

Annex D – Fieldwork Mobilisation Checklist

Preparation of a case study may take between1 to 2 months. Therefore, user preparation is essential in allowing the process to be more efficient, increasing the overall success of the mission. The following steps should be followed to successfully complete the assessment.

Preparation: 1 Month Prior to Fieldwork

☐ Set boundaries of study areas

☐ Liaise with local team

☐ Get familiar with existing data & previous studies, understand data gaps

☐ List all recovery and disposal facilities

☐ Draft a list of key stakeholders

☐ Draft a daily field plan

☐ Start liaising with key stakeholders, specifically the municipality

☐ Plan for translation/interpretation, if needed

☐ Logistics (accommodation, international and local transportation, etc.)

Field Assessment: Up to 7 Days

☐ Finalise the daily plan with the local team

☐ Organise a meeting with the Municipality

☐ Visit the disposal and recovery facilities

☐ Interview the disposal and recovery facilities' managers

☐ Visit and interview the informal service chain actors

☐ Track visits and your observations with an app (such as Runkeeper)

☐ Take pictures and videos

Key Data for the Waste Flow Diagram

The WFD relies on a set of key data points – combined with field observations – to compute the total plastic leakage from a solid waste management (SWM) system. This checklist presents the key SWM data points the WFD needs to quantify plastic leakages and explains how surveyors can find this data.

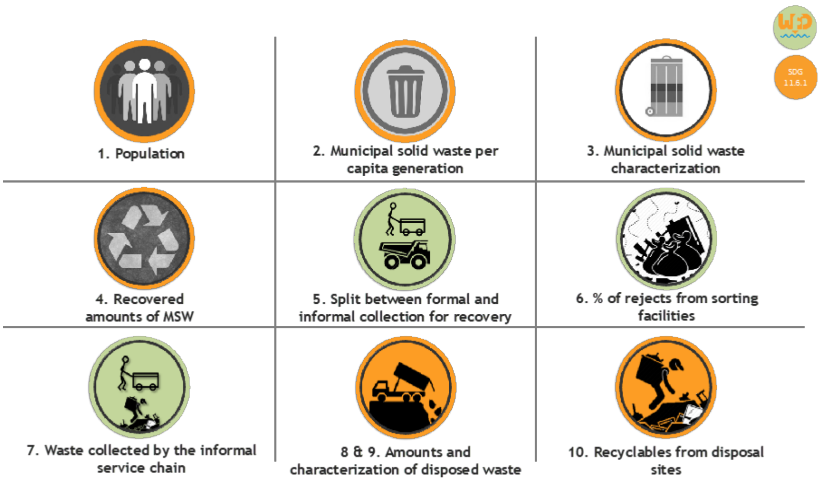


Figure 42
SWM data points needed by the WFD

The figure above shows the 10 key data points that are inputs in the WFD baseline assessment. All data points (except for 5, 6 and 7) can be obtained through the application of the WaCT baseline assessment methodology, which was developed in parallel to the WFD. If the WaCT (or any other baseline assessment) was not carried out recently, some of these data points may require the surveyors to perform a literature review and/or interviews with relevant stakeholders. The quality of the WFD results is highly dependent on the quality of the input (collected) data; therefore, the data collection exercise requires thorough research and investigation to maximise the reliability of the final results.

The table below summarises the data collection process for each of the data points.

Input data	Observation
MSW generation information	
Population	Where to find it/key stakeholders: National Statistic Authority (Population Census), Municipality (e.g. Urban planning unit).
MSW generation rate	Where to find it/key stakeholders: Municipality (SWM unit), past SWM surveys. How to find/use it: Adaptation of data from studies and available generation for different areas of the city might be needed (weighting according to population distribution). In case no survey was implemented in the municipality, surveys in other locations with similar context in the country can also be used.
MSW characterisation	Where to find it: Municipality (SWM unit), past SWM surveys. How to find/use it: Adaptation of available characterisation data for different areas of the city (low, middle and high-income) if possible. The WFD considers the following characterisation: Paper, Plastics, Glass, Metal, Organic, and Other. In case no survey was implemented in the municipality, surveys in other location with similar context in the country can also be used.
Collection, recovery and disposal of MSW	
Recovered amounts of MSW	Where to find it: Recovery site managers, apex traders, informal waste collectors, end-of-chain recyclers, municipality (SWM unit). Previous studies on the waste recovery sector, if available. How to find/use it: Prior to starting the field assessment, the surveyors need to identify key actors of the formal sector for recovery (separation, washing, processing, recycling, composting, etc.); these should be registered with the Municipality. Information on amounts of materials recovered by these actors should be found through interviews. If there is a strong informal sector, the main apex traders/end of chain recyclers can provide an insight on waste flows in the informal recovery sector.
Split between formal and informal collection for recovery	Where to find it: Recovery site managers, apex traders, informal waste collectors, end-of-chain recyclers, municipality (SWM unit). How to find/use it: If quantities of the amount of recovered MSW have been found, the split between formal and informal services will be easier to find. Information on the informal recycling sector can also be deduced by estimating the numbers of waste collectors in the city, at the disposal site, and in the rest of the city, along with the methods of separation and collection of recyclables.
% of rejects from sorting facilities	Where to find it: Recovery site managers, apex traders, informal waste collectors, end-of-chain recyclers. How to find/use it: This corresponds to the amount of materials that is not processed by the facilities (as they may not be MSW, are hazardous, or are not targeted by the facility), out of the total input.
Waste collected by the informal service chain	Where to find it: Municipality (SWM unit), residents, informal waste collectors, apex traders, end-of-chain recyclers, past SWM surveys. How to find/use it: If studies are not available on this subject matter, interviews with residents or other relevant stakeholders should be conducted.

Amounts of disposed waste	Where to find it: Disposal site manager, Municipality (SWM unit), Waste collection companies, past SWM surveys. How to find/use it: If the disposal site has a weighbridge, records of waste received at the facility should be available. If a weighbridge is not available, official registers of number of loads and types of trucks (including information on capacity - volume in cubic meter) can be used as a base for estimating quantities in tons. In case no register is available, the number of trucks coming into the site should be counted for a minimum 5-7 days period. The maximum capacity (volume in cubic meter) and load (the degree to which the load reaches the capacity, in %) should be noted. The full methodology for calculating the amount of disposed waste based on vehicle counting is available in Step 6 of the WaCT Methodology.
Characterization of disposed waste	Where to find it: Disposal site manager, studies How to find/use it: Adaptation of available characterization data for different areas of the city (low, middle and high-income if possible). The WFD considers the following characterisation: Paper, Plastics, Glass, Metal, Organic, and Other.
Other useful information	
Information on drainage systems and cleaning activities	Where to find it: Municipality (SWM unit, Unit in charge of drainage maintenance, etc.) How to find it/use it: This includes information on the drainage system in place (maps, etc.), and frequency/organisation/coverage of cleaning activities in the city (street sweeping, drainage clean-up).

Table 3

WFD Data Collection Process

During field work, it is important to:

1. Finalise the daily plan with the local team;
2. Visit the municipality;
3. Visit the recovery and disposal facilities and interview the managers;
4. Meet and observe the informal service chain;
5. Take pictures of all observation for further analysis and reporting;
6. Track visits and observations with an app and geotag them.

Online training content for the above WFD steps can be found here.

Annex E – References

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Find Wasteaware Benchmark Indicators (WABI) portal, including latest updated version of the WABIs at https://rwm.global/ (click on WABI icon).

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