Marine Litter Prevention

Reducing plastic waste leakage into waterways and oceans through circular economy and sustainable waste management

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Eschborn, June 2018

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Acronyms

AND	Agence nationale des déchets / Algerian National Agency for Waste Management
APEC	Asia-Pacific Economic Cooperation
ASEAN	Association of Southeast Asian Nations
BMZ	German Federal Ministry for Economic Cooperation and Development
CBD	Convention on Biological Diversity
CET	Centre d'enfouissment technique / Sanitary landfill in Algeria
DHW	Direction de l'Hydraulique de la Wilaya d'Annaba / Water Management Authority of the Annaba Province
DLHK	Dinas Lingkungan Hidup dan Kebersihan / Department of Environment and Cleansing in Sidoarjo
DPUPR	Department of Public Works and Spatial Planning in Sidoarjo
EPR	Extended Producer Responsibility
G7	Group of Seven
G20	Group of Twenty
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GPA	Global Programme of Action against Pollution from Land-Based Sources
ISWA	International Solid Waste Association
KfW	Kreditanstalt für Wiederaufbau / KfW Development Bank
LBS	Land-based sources
MAP	Mediterranean Action Plan
NGO	Non-governmental organisation
ONA	Office National de l'Assainissement / National Office in charge of sewage treatment in Annaba
PET	Polyethylene terephtalate
PROGDEM	Programme dédié à la gestion des déchets ménagers et assimilés / Algerian programme on waste management
RDF	Refuse-derived fuel
t	Metric tonne (1,000 kilogram)
TPS	Tempat Pembuangan Sementara / Temporary Disposal Sites in Sidoarjo
TPS-3R	Tempat Pengolahan Sampah Terpadu berbasis Reduce-Reuse-Recycle / 3Rs based Integrated Waste Treatment Plants in Sidoarjo
TPST	Tempat Pengolahan Sampah Terpadu / Integrated Waste Treatment Plants in Sidoarjo
UNCLOS	United Nations Convention on the Law of the Sea
UN	United Nations
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
UNGA	United Nations General Assembly
WEF	World Economic Forum
WTO	World Trade Organisation

EXECUTIVE SUMMARY

SIGNIFICANTLY REDUCING MARINE POLLUTION BY 2025, AS ENVISAGED BY THE UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS, REQUIRES CONCERTED INTERNATIONAL ACTION. Several international forums have adopted declarations and action plans to achieve this. A crucial challenge lies in translating global commitments into national, regional and local action. This study deals with the question of how decision-makers can improve their municipal solid waste management systems and move towards a circular economy in order to prevent plastic leakage into waterways and the ocean. It focuses on plastic waste from human settlements as a substantial share of marine litter consists of plastics stemming from land-based sources. In contrast to organic waste, which also enters waterways, plastics are durable and degrade only slowly into ever-smaller particles, which impact marine ecosystems.

THE STUDY OUTLINES POTENTIAL APPROACHES TO PREVENT MARINE PLASTIC LITTER AND ANALYSES THE SITUATION IN TWO LOCAL CONTEXTS IN SOUTHEAST ASIA AND NORTH AFRICA. It is based on an extensive literature review as well as field visits, observations and interviews in Sidoarjo Regency, Indonesia, and Annaba Province, Algeria. A methodological approach is elaborated to assess plastic waste leakage in qualitative and quantitative terms, enabling deeper understanding of these characteristically chaotic plastic waste flows. While the context of each case study is different, the analyses and recommendations will also be relevant for other municipalities and regions.

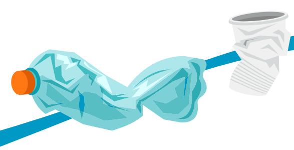
THE TWO CASE STUDIES UNDERLINE THE NEED FOR ACTION AT LOCAL AND REGIONAL LEVEL. They show that plastic waste enters into the riverine and marine environment through various pathways. Sidoarjo in Indonesia generated an estimated 7'616 t of marine plastic litter in 2017 or 3.17 kg per inhabitant. This is equivalent to one plastic bottle of 30g thrown into the ocean every 3 to 4 days by each of its inhabitants. It is estimated that the Algerian province of Annaba contributed 1'494 t of marine plastic litter in 2017 or 2.09 kg per capita – the same as throwing one plastic bottle into the ocean every 5 days. Whilst demonstrating the need to act, these two case studies also show that marine litter can be avoided if stakeholders take appropriate measures.

PROMOTING INTEGRATED SUSTAINABLE WASTE MANAGEMENT IS KEY TO PREVENTING MARINE LITTER. Waste collection coverage and efficiency need to drastically increase to reduce wild disposal and burning of plastic waste. Promoting separate collection and recycling of plastics is instrumental to enhance resource efficiency and reduce negative impacts of landfilling. Nevertheless, under certain conditions, energy recovery and landfilling can be viable options to keep plastics out of the environment. Sound governance, operator models and cost-recovery mechanisms are necessary to ensure organisational effectiveness and financial sustainability. Implementing extended producer responsibility mechanisms as well as deposit-refund systems can play an important role in this regard.

DECISION-MAKERS SHOULD PROMOTE A SHIFT TOWARDS CIRCULAR ECONOMY IN PACKAGING VALUE CHAINS. Single-use plastic packaging and items should be reduced and replaced by reusable alternatives. Policies should also take the impacts on other environmental objectives into account such as preventing food waste and mitigating climate change. Moving towards circular value chains requires product design that makes end-of-life recycling easier and uses recycled materials for new products. It requires political incentives and enhanced exchange amongst stakeholders along the packaging value chain. Plastic bag regulations can represent important, emblematic initiatives, even though they only concern one type of plastic waste.

MARINE LITTER PREVENTION ALSO REQUIRES COOPERATION ACROSS SECTORS AND BORDERS. Plastic flows in rivers can connect several regions and countries. Source-to-sea approaches can be helpful in dealing with fragmented governance systems along them. In all cases, various stakeholders from public authorities, the private sector, civil society and scientific institutions must be involved. Due consideration should be made to include biodiversity conservation, coastal management, water management, wastewater management and waste management. Global plastic value chains also require enhanced dialogue with consumer good companies active in various countries. ‘Glocal’ governance is necessary to enhance exchange of experiences between committed municipalities as well as to deepen international cooperation.

LOCAL AND REGIONAL DECISION-MAKERS CAN TAKE ON A MORE ACTIVE ROLE IN THE GLOBAL EFFORT TO PREVENT MARINE PLASTIC LITTER. The methodology used in this study presents a practical first step to overcome information barriers, an important pre-requisite for involving decision makers at local level. In quantifying how much plastic waste enters into water bodies instead of counting what can be found at beaches or in the sea, this approach complements other marine litter monitoring approaches. It is, however, based on a large number of assumptions that must be presented in a transparent way. In a next step, the methodology could be developed further into a practical tool and graphic visualisation of plastic waste flows, which could be used in different regions to support the dialogue in municipalities on marine litter prevention. Linking the methodology to cost-benefit analyses may also support decision-making about which measures and investments are suitable in a given context.



INTRODUCTION

Plastic waste leakage into rivers and the ocean is a global issue. Plastics and microplastics have become ubiquitous in landscapes as well as in marine and freshwater environments (UNEP 2016).[1] Their accumulation in the environment is growing rapidly due to a strong increase in plastic production and consumption, unsustainable waste management practices as well as the slow degradation of plastics into ever-smaller particles. However, there is also growing international mobilisation for reducing plastic leakage into waterways and the sea. For instance, the United Nations Agenda 2030 for Sustainable Development intends to "prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution" by 2025 (UNGA 2015).[2] In order to achieve this Sustainable Development Goal, concerted action at different levels and by various stakeholders will be required.

Plastics and microplastics threaten riverine and marine ecosystems. They spread throughout rivers and the ocean, sink to the river and sea floor and accumulate in sediments and biota. Their ingestion by animals and dispersion through the food chain constitute hazards in terms of digestion and toxicity. Plastic particles include different chemical substances and absorb pollutants from the environment. Sea animals get entangled in plastics as well as in abandoned, lost or otherwise discarded fishing gear. A recent publication by the Secretariat of the Convention on Biological Diversity (CBD 2016) estimates that marine litter affects 817 species – 453 species if 'ghost fishing' by lost fishing gear is not considered. Effects at population and ecosystem level still need to be better understood but could be significant (CBD 2016).[3]

Land-based plastic waste and marine litter
Marine litter can be defined as "any anthropogenic, manufactured, or processed solid material (regardless of size) discarded, disposed of, or abandoned in the marine environment, including all materials discarded into the sea, on the shore, or brought indirectly to the sea by rivers, sewage, stormwater, waves, or winds" (UNEP 2011).[4] About 60 to 90% of marine litter consists of plastics (UNEP-GRID 2016).[5] A rather small fraction of it stems from sea-based sources, e.g. waste that ships discard directly at sea. The vast majority of marine plastic litter comes from land-based sources, entering into the marine environment from human settlements along coastlines and river catchments.

Plastic pollution leads to negative socio-economic impacts. Marine litter can cause hazards for shipping by damaging propellers and other equipment of vessels. The fisheries industry incurs costs from removing waste by-catch and experiences reduced catches through 'ghost fishing' by lost fishing gear. The tourism sector encounters costs for cleaning beaches and other sites or loses revenues from deterred tourism related to unaesthetic plastic pollution (IEEP 2015).[6] Floating waste in rivers can impair hydropower stations and cause maintenance and clean-up costs. In urban canals, mismanaged waste can congest drainage systems, thereby increasing the risk of flooding and contribute to breeding grounds for mosquitos.

Growing consumption and mismanagement of plastics in human settlements are root causes. The global plastic production has been rapidly increasing. In 2016, it totalled around 335 million t compared to 230 million t in 2005 (PlasticsEurope 2018).[7] About 25-40% of plastics consumption currently serves for single-use packaging, which turns relatively quickly into waste (UNEP/GRID 2016; WEF 2016).[8] At the same time, around 2 billion people still lack access to regular waste collection and the waste of about 3 billion people does not reach environmentally sound treatment and disposal facilities (UNEP/ISWA 2015).[9] If municipal services cannot provide for regular waste collection, households often resort to open burning or wild disposal of waste. Open burning contributes to air pollution by toxic smoke, negatively affecting human health and the climate. Discharge of waste at wild dumpsites partly leads to leakage of plastics and other waste into canals and rivers. Collected waste can also contribute to riverine and marine plastic pollution through leakage from waste transport, treatment, storage and landfills. An often-cited research study by Jambeck et al. (2015) estimates that worldwide around 4.8 to 12.7 million tonnes of plastic waste entered in 2010 from land into the sea, generated by populations living within a distance of 50 km from the coast.[10]

Low- and middle-income countries play a significant role. According to estimates by Jambeck et al. (2015), a big share of global plastic leakage into the ocean stems from China and Southeast Asian countries such as Indonesia, the Philippines, Vietnam, Thailand and Malaysia. G20 countries such as South Africa, India, Turkey, Brazil and the United States play a significant role, too. Furthermore, the North African countries Egypt, Algeria and Morocco are also part of the Top 20 list suggested by Jambeck et al. (2015). The coastal countries of the European Union taken together would be number 18 on this list.[11] Another recent study by Lebreton et al. (2017) estimates that rivers contribute around 1.15-2.41 million tonnes of plastic waste per year to marine litter, based on global modelling of floating plastics at the surface of rivers within a certain size range.[12] The importance of big rivers as pathways for marine plastic pollution is also highlighted by analyses of Schmidt et al. (2017), referring to rivers such as the Chang Jiang (Yangtze River), Indus, Huang He (Yellow River), Hai He, Nile, Meghna/ Bramaputra/ Ganges, Zhujiang (Pearl River), Amur, Niger and Mekong.[13]

Microplastics in marine and freshwater environments

'Microplastics' are often defined as plastic particles smaller than 5 millimetres. Microplastics can emerge through degradation of macro-plastics into smaller particles. They can also enter into the environment from sources such as the abrasion of tyres, washing of synthetic textiles, plastic pellet spills, the abrasion from paints or releases from cosmetics and personal care products (UBA 2017).[14] Microplastics are found in all parts of the ocean and in various species (GESAMP 2017)[15], even in Arctic sea ice (AWI 2017).[16] They can leach toxic chemicals as well as absorb and concentrate pollutants from seawater (Worm et al. 2017).[17] Microplastics are also an emerging concern for freshwater environments and are found in remote areas such as Lake Khuvsgul in Mongolia (UNESCO 2018).[18] They are even reported in tap water, while potential health impacts remain uncertain (Orb Media 2017).[19]

International cooperation has started to intensify. Similar to the issue of climate change caused by disperse greenhouse gas emissions, local plastic leakages at many different places lead to an environmental issue at regional and global scale. The UN Environment Assembly (UNEA) and the Convention on Biological Diversity (CBD) have taken up the issue in the form of resolutions and decisions.[20] Outside of the UN system, the G7 and G20 have adopted action plans on marine litter and resource efficiency.[21] These various voluntary commitments complement legally binding international agreements such as the MARPOL Convention on the Pollution from Ships, the London Protocol and the UN Convention on the Law of the Sea (UNCLOS) as well as Regional Seas Conventions such as the Barcelona Convention for the Protection of the Mediterranean.[22]

The question arises how to translate international commitments into national and local action. How can decision-makers improve their municipal solid waste management systems and move towards a circular economy in order to prevent plastic leakage into waterways and the ocean? This study seeks to contribute to answering these questions, focusing on municipalities in low- and middle-income countries. Chapter 1 outlines potential approaches for marine and riverine litter prevention, linking different levels of intervention. It is based on a literature review. One challenge consists in adequately estimating plastic leakage in order to kick-start evidence-based dialogue at local and regional level. Chapter 2 therefore introduces a methodological approach to assess plastic leakage into the ocean by cities and regions. Chapters 3 and 4 present two case studies of different local contexts in South-East Asia (Sidoarjo Regency in Indonesia) and Northern Africa (Annaba in Algeria). They describe the respective entry pathways of plastics into waterways and the sea and provide specific recommendations. The results are discussed in a concluding chapter.

The study draws on insights from German development cooperation. The advisory project 'Concepts for sustainable waste management and circular economy' of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) conducted this study on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). It closely cooperated with the project 'Emission reduction in cities – solid waste management' of KfW Development Bank in Indonesia and the GIZ project 'Waste management and circular economy' in Algeria. Two consultants of the Resources and Waste Advisory Group (RWA) for Indonesia and a consultant in Algeria conducted the respective case studies and substantially contributed to the conceptual development.

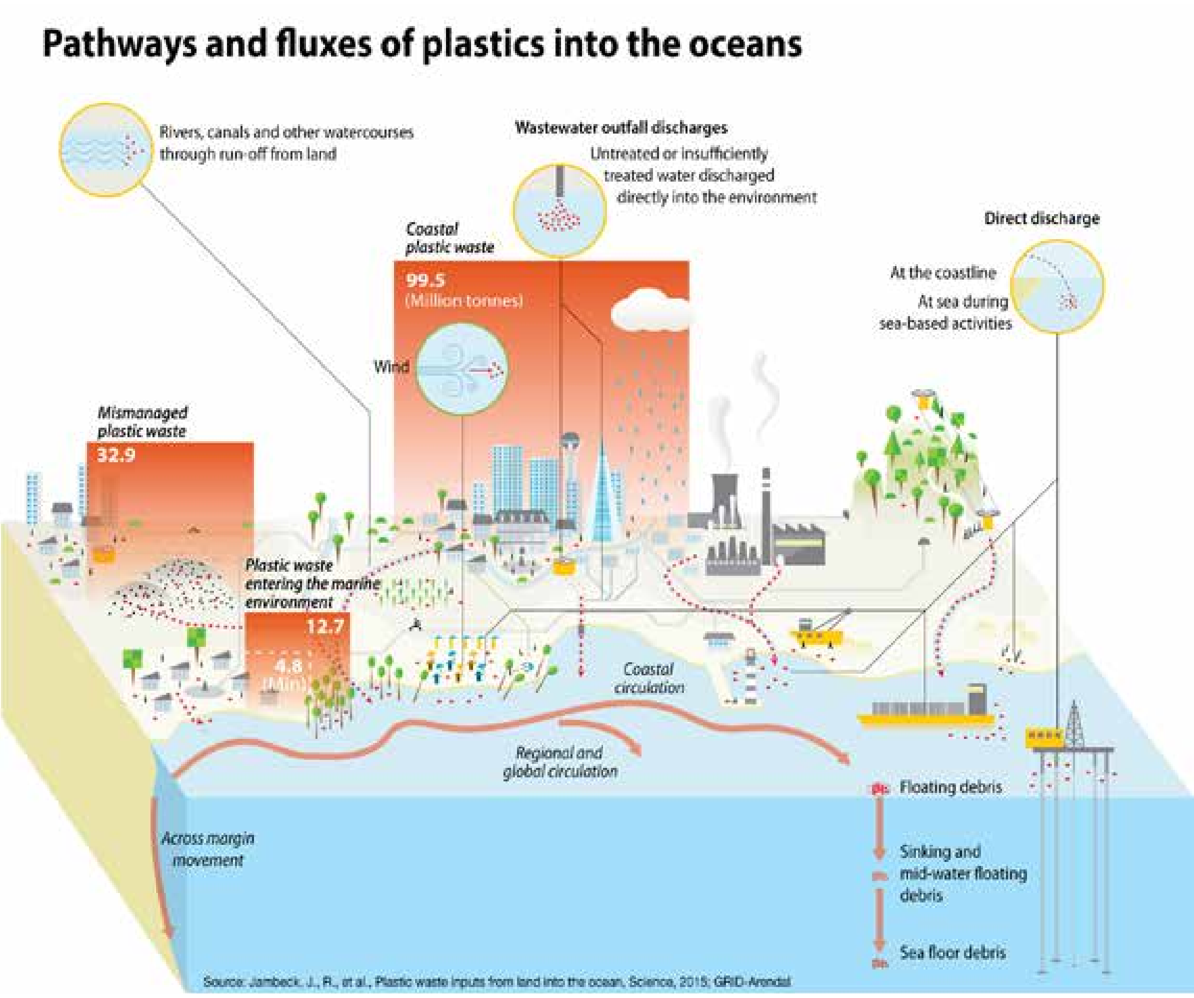


Fig. 1 Pathways of plastic litter into the ocean (GRID-Arendal 2016)[23]

APPROACHES FOR PREVENTING MARINE LITTER

Marine litter represents a growing global concern. Dealing with waste is usually not at the forefront of political agendas and the busy schedules of decision-makers. Yet, it is a field of environmental and urban governance where shortfalls are highly visible for local populations and have a direct impact on local as well as global ecosystems from polluted streets and rivers to effects on our oceans, climate and resource availability. The effective and efficient provision of municipal services, such as solid waste management, requires integrated governance approaches. They need to fit into the respective socio-economic context and take into account larger trends of urbanisation, economic development and political change.

A conceptual approach for reducing plastic waste leakage into waterways and the sea needs to consider different dimensions (Fig. 2). How to improve solid waste management in municipalities, e.g. how to better collect and treat waste including plastics, is at the core of the issue. The public sector is responsible for ensuring a functioning system in this regard. It directly relates to the question of how to catalyse the transformation towards a circular economy where plastic and packaging design reduce waste generation and where material value chains make plastic recycling and recovery easier. The private sector plays a particularly important role in this. Beyond these two aspects, there is a need to strengthen collaboration between a wide array of stakeholders from different sectors in a 'source-to-sea' continuum. Furthermore, effective action requires enhanced interweaving of local and global ('glocal') governance efforts.

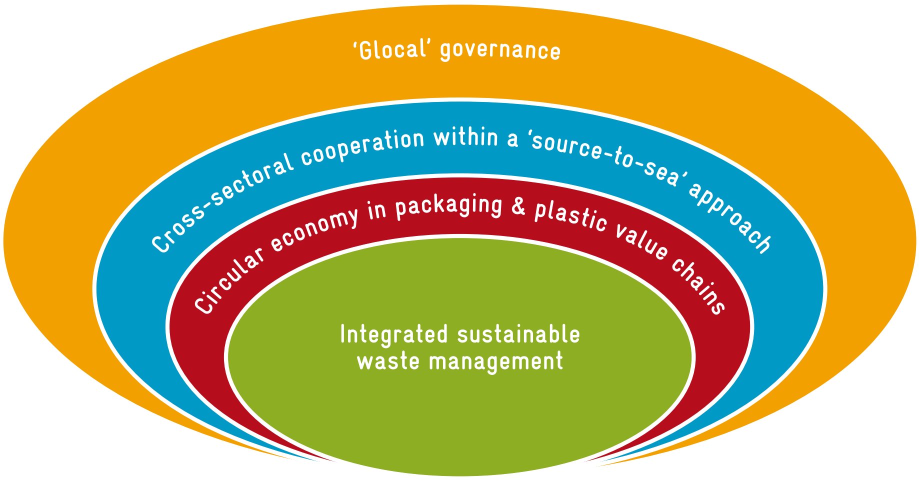


Fig. 2 Conceptual dimensions for preventing plastic leakage into waterways and the sea

1.1. Integrated sustainable waste management

Plastic represents one of several waste types. It usually accounts for around 7 to 12% of total municipal solid waste generation but can also be above or below this range.[24] In low- and middle-income countries, plastic waste is frequently mixed with organic waste, which makes up around 50 to 60% of total municipal waste. Waste separation at household level is often non-existent. Separate collection and recycling of individual plastic types only take place when they offer some market value and are in low- and middle-income countries often the domain of informal waste collectors and small businesses that sort, bale and resell it or work at different further stages of resource recovery.

Improving plastic waste management directly relates to strengthening overall municipal solid waste management systems. The concept of 'integrated sustainable waste management' provides an analytical framework that can be helpful for marine litter prevention (Fig. 3). It gathers the various aspects that decision-makers need to consider for enhancing the performance of their waste management systems. It serves as a framework from which to plunge into more details for individual aspects. Waste management personnel, equipment and infrastructure only work in an effective and efficient way if adequate organisational structures, financial flows, motivational incentives and leadership go hand in hand.

Physical components of waste management systems in cities include three aspects. They include (Wilson et al. 2013):[25] 1) *waste collection* to reduce public health hazards; 2) *waste treatment* and disposal to reduce environmental hazards; 3) *'reduce, reuse, recycle'* to achieve a resource efficient and circular economy. Experience shows that considering technological aspects alone is not sufficient to improve waste management systems.

The concept also considers three governance aspects. They are a kind of "software" for the waste management system and include (Wilson et al. 2013):[26] 1) *inclusivity* in terms of the involvement of all concerned stakeholders such as municipal authorities, users, providers and external agents; 2) *financial sustainability* concerning recovery of operating and investment costs; 3) *institutions and policies* capable of creating an enabling environment and implementing improved services. In order to enable cities to assess these different elements, Wilson et al. (2014) have also developed a comprehensive set of associated indicators for this concept. Amongst others, they include waste collection coverage, treatment and recycling rates as well as indicators for user and provider inclusivity, financial sustainability and local institutional coherence.[27]

Fig. 3 The 'Two triangles' integrated solid waste management representation.
Source: ©David Wilson, Costas Velis and Ljiljana Rodic. Concept adapted from: Scheinberg et al. (2010)[28]

1.1.1. INCREASING WASTE COLLECTION COVERAGE AND EFFICIENCY

The organised collection of municipal solid waste plays a crucial role. If households do not have access to proper waste collection, plastics end up in open burning or at wild dumpsites. Municipalities therefore need to determine where collection services are non-existent or insufficient. They should ensure sound primary collection services, ideally for all households. Service delivery should include regular pickup of waste from households as well as the provision of sufficient containers or bins at public places with regular emptying. If households need to bring their waste to fixed places within neighbourhoods or to vehicles when they pass by, they need to have sufficient awareness and obligations or incentives to do so.[29]

Municipalities or their operators need to procure and maintain adapted equipment for functioning municipal solid waste collection. While small streets in crowded areas demand flexible and sometimes manual vehicles for door-to-door collection, large streets invite the usage of large motorised vehicles, which can be more efficient. In both cases, waste collection is labour intensive. The personnel in charge needs to be sufficient in number as well as adequately qualified and incentivised to ensure proper collection services. They also need to care for regular maintenance to keep equipment functional. Health and safety precautionary measures for waste workers are also important to avoid accidents and infections.

Municipalities need to prevent waste leakage during collection and transport. Untidy collection and transfer points or uncovered vehicles contribute to potential plastic leakage into waterways and the ocean. The personnel in charge needs to be sufficiently trained and the equipment in an appropriate state to avoid such leakages. It involves the transport of waste from households to community containers as well as waste transfers from temporary storage sites to treatment facilities or landfills.

Waste collection services, Algeria

1.1.2. ENHANCING SEPARATE WASTE COLLECTION

Ideally, municipal solid waste separation already takes place at household level. It serves to segregate organic from non-organic waste as well as different non-organic waste fractions such as plastics, glass, metals, paper and cardboard. It makes recycling, composting and energy recovery easier and more cost-efficient. It is also a pre-requisite for high-quality outputs of recycling that ensure higher revenues. Hazardous waste like waste electrical and electronic equipment, batteries, paints, lubricants and pesticides should also be handled separately and carefully.

Successful waste separation requires extensive awareness raising amongst citizens. It also depends on functioning logistics of collection services and transport routes. In low- and middle-income countries, waste separation at household level is often still rudimentary. Introducing and implementing extended producer responsibility mechanisms would be an effective way to increase separate collection e.g. of packaging waste and thereby prevent marine litter generation. This is primarily a task for the national level but requires active participation by municipalities.

Separate waste collection can also pass through specific collection points. It can involve deposit-refund systems for beverage containers such as plastic bottles, aluminium cans and glass bottles. Citizens have to pay a deposit when they buy beverage containers in shops and receive the deposit back when they return the beverage containers to shops or other selected return points. Deposits have the advantage that they give a value to items after their use and a direct financial incentive to citizens to hand them back. Introducing such systems requires efforts in terms of creating the necessary organisational structures, financial flows and infrastructure (GIZ 2015c).[30] Alternative incentives without prior deposits to hand selected packaging waste back, e.g. to so-called ‘Waste Banks’, are also possible. It requires funding of these incentives. Alternatively, citizens can also be invited to bring recyclable packaging items to collection points without any financial incentives, which requires sufficient awareness raising.

To some extent, informal waste collectors take up the role of waste separators. They go from door-to-door and ask households for specific waste items such as plastic bottles or metal waste, sometimes even paying small amounts. Alternatively, they search for scrap materials in mixed garbage bins in streets or at dumpsites. They sell valuable waste items to middlemen who sort, clean, bale and sell them to domestic recyclers or export firms. However, informal waste workers have very low income and often work in extremely hazardous environments and unhealthy conditions. Furthermore, they only collect materials that have some market value, which is rarely the case for many types of single-use plastic packaging. Their sorting activities may also adversely affect waste collection systems by increasing littering around containers or cherry picking valuables from designated collection systems of recyclables.

Single-use packaging

Small single-use packaging such as 'sachets' represent a particular challenge in low- and middle-income countries. Cheap drinking water sachets are common and often the only affordable way to access safe drinking water for certain low-income population groups. They consist of plastic films that consumers generally throw away after emptying them on the go, polluting streets, landscapes and drainage systems. They are more affordable than water in plastic bottles but more difficult to handle from a waste management point of view.[31] The same holds true for other products packed in very small units, from shampoo to instant coffee.[32]

Such 'sachet marketing' intends to make products available to households that calculate on a day-to-day basis. They are a way for multinational consumer goods companies to tap into 'base of the pyramid' markets. Recycling of sachets is technologically possible.[33] It requires however their separate collection. Effective extended producer responsibility schemes, as well as adequate incentives for citizens to hand them back, are necessary. In order to replace sachets altogether, an alternative might be to change packaging systems from single-use to reusable and refillable containers for different portions.

Plastic sachets, Indonesia[34]

1.1.3. EXPANDING CLEANING ACTIVITIES

Regular street sweeping is important to prevent littered plastic waste from slipping into gullies and the drainage system. Once entered into drainage systems, plastic waste might continue into rivers and the ocean. Waste traps within canals can also play an important role, especially for hot-spot areas, albeit they represent an end-of-pipe approach and require careful evaluation. Cleaning up beaches and riverbanks can also significantly contribute to marine litter prevention, especially in terms of public awareness raising. The massive clean-up campaign at Versova beach in Mumbai, India, is a prominent example.[35] Even though street sweeping, waste traps and clean-ups do not replace collection, they need to be closely linked with each other. Retrieved solid waste requires transportation to transfer stations and to final treatment sites or landfills. Otherwise, it might end up in the environment again.

Street sweeping

1.1.4. PROMOTING PLASTIC RECYCLING

Collected plastic waste should be recycled. In order to increase plastics recycling, the private sector needs to set up sorting and treatment facilities. Businesses need to invest in infrastructure and the training of recycling professionals. High-technology solutions are necessary to achieve high-quality recyclates for usage as secondary raw materials in the production of plastic products. They need to separate different plastic polymers and colours, clean and shred plastics and transform them into standardised re-granulates, which can be a difficult task due to the high variety.[36] For instance, PET bottles can become PET bottles again through such processes. Secondary plastic materials can also serve for the production of garbage bags, pipes, construction materials, textiles, furniture, filling material for blankets and other products. It can involve labour intensive processes, providing job opportunities and assisting livelihoods of families.[37]

Successful recycling requires a business case. It relates to various factors such as costs for recyclables, treatment infrastructure and equipment, personnel, transport and energy use. Sufficient demand for recyclates, reflected in the level of market prices, represents a key factor for a good business case. Demand depends on external aspects such as fluctuating oil prices. Demand also depends on trust in the material properties of recyclates and their adherence to health standards. Furthermore, plastic recycling has become a global market and value chain. The biggest importing country of plastic waste, China, has however announced in July 2017 to the World Trade Organisation to ban plastic waste imports (WTO 2017).[38] Since January 2018, China implements the import ban.[39] This decision provides an additional incentive for countries to enhance domestic recycling capacities and value chains.

National governments and municipalities can support the development of recycling value chains. It involves appropriate framework conditions and incentives for the supply side and demand side of secondary materials as well as the promotion of adequate environmental and social standards. Public authorities can increase demand for secondary plastic materials by developing quality standards for recyclates, providing clear orientation to companies and consumers. Furthermore, they can increase recyclate demand through their public procurement policies. Concerning the supply side, increasing recycling requires the introduction and implementation of extended producer responsibility mechanisms to improve separate plastic waste collection. Furthermore, governments can support 'design for recycling' through multi-stakeholder processes, linking different actors of the value chain.

Waste management policies and planning need to consider the integration of informal sector workers. They need to secure their inclusion. Initiatives can consist of creating more stable organisational structures such as co-operatives, small enterprises or social businesses. They can also include designing adapted infrastructure, e.g. sorting platforms. Implementation experience for such approaches exists (GIZ 2011 and 2015d).[40]

The substitution of primary plastic production with secondary materials can contribute to marine litter prevention as well as to energy savings and climate change mitigation. Depending on local contexts, recycling of 1 tonne of plastics can save 0.4 tonne of CO_2equ (GIZ 2017a).[41] Yet, plastics recycling does not make plastics disappear. The recycling process as well as the transport and storage of recyclables can also represent sources of riverine and marine litter and therefore should adhere to certain environmental standards. Usually, recycling processes also generate residues, which require energy recovery or landfilling. Furthermore, plastic recycling into textiles, e.g. PET into fleece, can lead to microplastic fibres entering into water systems through the washing process.

Baled plastic bottles, Costa Rica

1.1.5. CONSIDERING ENERGY RECOVERY AND ENVIRONMENTALLY SOUND DISPOSAL

Energy recovery from non-recyclable plastic waste can contribute to preventing plastic leakage into the environment. A distinction is necessary between the use of plastic waste as alternative fuels in cement plants or other industries, so-called 'co-processing' or 'co-incineration', and the use of plastic waste in waste incineration plants. State-of-the-art co-processing has the advantage that cement plants already exist in low- and middle-income countries, that co-incineration of prepared plastic waste as alternative fuels takes place under very high temperatures and that residues are physically integrated into the final cement product instead of producing toxic ashes. However, co-processing needs to adhere to certain environmental, operational, health and safety standards (Geocycle/LafargeHolcim, GIZ, FHNW 2018).[42] Prior treatment of separated plastics is necessary, mostly cleaning and shredding. Incineration of waste should always enable the use of the produced energy, heat and steam to offset some of the operating costs of these facilities. (Co)-incineration usually takes place at lower temperatures than co-processing. Therefore, there is a risk of dioxins and other toxic emissions. Expensive systems for flue gas treatment, constant monitoring and emission control need to be mandatory.

Municipal decision-makers should carefully assess different aspects before applying Waste-to-Energy technologies. Such aspects include the general level of the waste management system, the composition of waste and its calorific value as well as the quantities of suitable waste. Decision-makers should consider the level of experience and efficiency of the operation of current waste facilities and take into account the distance and transport time to potential Waste-to-Energy plants. There need to be safe disposal possibilities for hazardous residues like toxic ashes and a legal framework for Waste-to-Energy options. Furthermore, the revenues of energy sales do generally not cover the costs for facilities. If municipalities already struggle with covering the costs of waste collection and disposal in their current systems, Waste-to-Energy facilities might be hardly affordable. Other aspects to consider include the access to energy users, the availability of spare parts or access to foreign currency to procure them as well as the existence of economic incentives for low-carbon heat and electricity. High environmental standards need to be fulfilled (GIZ 2017b).[43]

In terms of resource efficiency and the 'waste hierarchy', reducing, reusing and recycling are preferable to energy recovery as well as to landfilling. In many countries, landfilling of collected waste including plastics is however still the most common practice. If landfills are not managed in an environmentally sound manner and are located close to waterways or the sea, plastics can leak into the riverine and marine environment. Municipalities should therefore provide for sanitary landfills that comply with certain technical and environmental standards. The International Solid Waste Association (ISWA 2010) has published guidelines for landfilling.[44] Concerning plastic waste leakage, landfills should especially fulfil requirements such as daily covering of waste to avoid windblown litter, drainage systems for stormwater control and leachate collection systems.

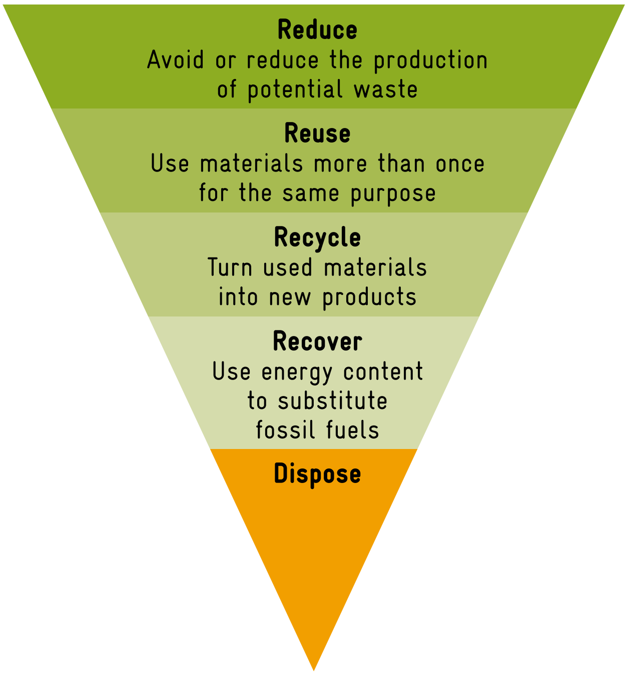


Fig. 4 Waste hierarchy

1.1.6. BUILDING INSTITUTIONS, POLICIES AND OPERATOR MODELS FOR WASTE MANAGEMENT

Functioning institutional mechanisms are prerequisites for environmentally sound waste management and marine litter prevention. National, regional and local decision-makers need to develop and adapt continuously the respective policy framework and decision-making processes. At national level, ministries with environmental protection in their mandate are usually responsible for standard-setting, monitoring and control as well as national policies, strategies and master plans for waste management. Ministries responsible for local administration often provide implementation guidance and financing to municipalities in charge of waste collection and disposal. Ministries of finance also play an important role in terms of taxation and budget allocation from the national treasury. Ministries of economy can become relevant when designing extended producer responsibility mechanisms or support instruments for recycling markets.

Environmental protection laws and specific waste management laws need to provide the general legislative framework concerning rights and obligations of different stakeholders. Decrees on individual waste fractions such as packaging and waste electrical and electronic equipment or treatment options such as co-processing and waste incineration are necessary to prescribe more in detail the intended functioning of waste management systems. Standards and implementation guidelines complete the national regulatory framework. The enforcement of this framework often lies with national environmental protection agencies under the supervision of the Ministry of Environment.

Municipalities are key players for waste management and marine litter prevention. They are generally in charge of implementing the above-mentioned regulatory framework and of providing the waste collection and transport services. Sometimes, they are also in charge of waste treatment. Local waste management authorities thus need to be sufficiently equipped with qualified staff, resources and capacity to organise and supervise service provision. They need to monitor waste related data in their municipality, ensure the application of environmental, health and safety standards, organise financial flows and conduct tendering processes for private service providers. Local waste management plans help to define objectives and actions for a given timeframe. Waste management authorities need to develop them in close cooperation with political decision-makers as well as stakeholders of civil society, science and the private sector. In some cases, inter-municipal cooperation can be useful to share treatment and disposal facilities.

Regional authorities also contribute to the governance of solid waste management systems. They can take over responsibilities in regional planning of such systems as well as in monitoring and supervising them. They also can provide advisory services to municipalities and legislative bodies. Furthermore, they can contribute to the development of recycling value chains as well as to regional waste treatment and disposal facilities.

The right choice of 'operator models' influences the effectiveness of waste management and marine litter prevention. Besides the already described policy, planning and regulation level, there are three different roles in the day-to-day operation of waste management systems (GIZ 2013). The *'client'* of waste management services is mostly the public administration of municipalities, who needs to ensure its provision at certain standards. *'Operators'* are in charge of the actual service delivery of waste collection, transport and treatment. They can consist of public companies, private companies, public-private joint ventures, NGOs, community-based organisations, micro-scale enterprises, the informal sector or also be an integral part of public administration units. Furthermore, *'revenue collectors'* for the service provision can be different stakeholders than the 'operators' and 'clients'. Arrangements between these different stakeholders need to be concluded for the different services such as primary and secondary collection, street sweeping, transport, recycling, composting, co-processing, incineration or landfilling.[45]

Awareness raising and behavioural change are key for reducing plastic litter alongside canals, beaches and coasts. Besides having access to proper waste collection and treatment, citizens need to know how to handle their waste. Regular information and interaction with citizens on separating, reducing, reusing, recycling and disposing of their waste are therefore crucial. Municipalities and public companies need to have public communication units for this purpose. Civil society organisations also play an important role in sensitising citizens for the need to keep cities and the environment clean. Clean-up campaigns can be instrumental in activating the sense of citizenship and complement regular waste collection. Campaign materials such as posters and handouts, media advertisement as well as staff and volunteers require however adequate funding. Governments and municipalities might consider such funding as investments in making the own city attractive to tourism and external investment.

1.1.7. FINANCING WASTE MANAGEMENT SERVICES FOR MARINE LITTER PREVENTION

Recovering the costs of municipal solid waste management services is a prerequisite for effective marine litter prevention. It often represents a challenge to finance the recurrent operational costs of staff and equipment as well as the investment for sanitary landfills, sorting and recycling stations or other treatment facilities. Many municipalities spend substantial parts of their budgets on waste management as they shy away from introducing or increasing adequate waste management fees from households, shops, restaurants, hotels, public institutions and other stakeholders. Decision-makers fear protest against such fees, including by those who can hardly afford any additional financial burden. In contrast to electricity or water bills, non-payment of waste fees or taxes is difficult to sanction, as stopping waste collection services would only result in uncollected waste on streets. Lack of funding hampers the employment of sufficient waste collection staff and equipment and stalls necessary infrastructure investments. Local decision-makers should thus find ways to set local service provision on financially sustainable fundaments.

Municipalities can follow several steps to improve cost-recovery of waste management services (GIZ 2015a). [46] A first step consists in identifying the real costs of the current system, calculating unit costs per tonne of waste and analysing future costs. As a second step, municipalities should determine a policy on the costs to recover and the funding sources to use. Possibilities are e.g. a share of property taxes, the sale of products from waste streams, tourist taxes, fees for disposal at landfills and user charges. Following the 'polluter pays principle', a third step should consist in designing user-charging regimes in terms of 'pay-as-you-throw' charges or flat-rate charges. It requires user databases, billing systems as well as differentiation between user groups such as households in high- and low-income areas of a city, commercial entities, institutions and industrial entities. In a fourth step, municipalities need to involve civil society in choosing the user-charging system and should conduct a broad public information campaign on its introduction to increase its acceptance. Fifth, legal modifications of local tax and fee regulations might be necessary, e.g. for earmarking the revenues of the user-charge for waste management services. Finally, the new system needs to be implemented and monitored. For the case of plastic bottles in the Caribbean island of Cozumel, Mexico, a study shows how waste management fees, recycling fees or tourist environmental fees could be used to incentivise separate collection (GIZ 2015b).[47]

On a national or regional level, 'Extended Producer Responsibility' is key to involve the packaging, plastics and retail industry in waste management and marine litter prevention. It means that those who produce and sell products, such as packaging, are also responsible for an appropriate collection and treatment at the products' end-of-life. While respective legal regulations exist in more and more countries, their implementation is often lacking effectiveness or needs to be further developed. Functioning systems typically include certain take-back obligations as well as advanced recycling contributions, which producers or importers have to pay into a public or private fund to co-finance collection and recycling activities (GIZ 2015a).[48] Associated costs are generally transferred from the producers to the consumers through slightly higher product prices, which is justified through the polluter-pays principle. It thus represents an additional financial source but also a mode of organisation.

Separate collection of packaging waste through EPR schemes in Switzerland (left) and Germany (right)

1.2. Circular economy in packaging value chains

A paradigm shift from a 'linear' to a 'circular economy' will be necessary. Current modes of production and consumption still predominantly follow a "take, make, dispose" logic (Ellen MacArthur Foundation 2017).[49] To prevent marine litter and to use available resources more effectively, a shift towards a circular economy is necessary. While solid waste management focuses on the collection and treatment of discarded materials, there is also a need to act further 'upstream' in the value chain of products. The objective consists in increasing resource efficiency and minimising waste in value chains. Ministries in charge of the environment, economy, industry, research and other areas can establish incentive mechanisms, programmes and regulations to facilitate circular economy solutions. Governments, companies, business associations and civil society should take initiatives to strengthen resource efficient consumption and production patterns. Such initiatives should include the design of products for reuse and recyclability as well as resource efficient production processes. They should also include business models that favour reuse, repairing and sharing as well as a respective consumption behaviour of citizens.

Products and materials should remain in a circular flow and the associated value within the economy instead of losing valuable resources and damaging ecosystems through linear waste disposal. Positive examples already exist in most societies. Where incomes are lower, the relative value of goods is higher and people therefore tend to be more creative in reusing and sharing them. Where incomes are higher, there are more resources available for investments into improved design and production processes. Still, there is a lot more to explore for moving towards circular economies. In light of global value chains and the need to close the loop at products' end of life, it is a common endeavour of international cooperation and 'glocal' governance. Innovative concepts exist but require application.

Single-use plastic packaging and items represent a critical concern in terms of circular economy and marine litter prevention. A considerable share of plastics entering rivers and the sea relate to single-use packaging and items such as bottles, bags, cups and cigarette filters. In their current form, they are not designed for reuse but for fulfilling their respective functions with minimised material, production and logistical costs. In the absence of effective policy instruments providing adequate economic incentives for reduction, reuse and recycling, the associated environmental costs are carried by the society as a whole and future generations. In the following, approaches how to promote reusable and recyclable packaging for waste minimisation and resource recovery will be illustrated.

1.2.1. PROMOTING REUSABLE PACKAGING AND ITEMS FOR WASTE MINIMISATION

A first objective should consist in avoiding single-use packaging and items and substitute them with reusable alternatives. At local level, promoting drinking from glasses and eating from washable plates with reusable cutlery is an example to avoid unnecessary waste, e.g. from take-away food consumption. Refillable bottles, cups and food boxes for transporting beverages and lunch are also examples. In tourist destinations, avoiding plastic straws or replacing them with reusable alternatives and preferring refillable shampoo dispensers should become standard.

Reusable packaging options require environmentally sound citizen behaviour as well as business and policy initiatives. Municipalities can promote reusable tableware through voluntary agreements with caterings, hotels, festivals, public events and other stakeholders. Positive reinforcement and 'nudging', e.g. through visible placing in shops or small discounts for choosing reusable cups, can also be helpful. Promoting buying fresh food at local markets instead of packaged food in supermarkets is also an option. Reusable food packaging requires however also high hygiene standards. A balance is necessary between avoiding food waste and reducing packaging waste as packaging serves to make food more durable and marketable. Innovative approaches would be necessary for small-scale, often informal, street vendors of freshly prepared beverages and snacks in low- and middle-income countries.

Plastic bag regulations are a highly visible example for promoting reusable packaging for waste minimisation. Several countries have introduced plastic bag regulations during the last couple of years. Rwanda, Kenya and Morocco are examples with visible impacts.[50] In the European Union, a specific directive stipulates to reduce the number of plastic bags consumed per person and per year to 90 by the end of 2019 and to 40 by the end of 2025.[51] It allows for equivalent objectives by weight and for exemptions of very light-weight plastic bags. Member states are relatively free in choosing their preferred policy instruments. However, they need to ensure that plastic carrier bags are no longer available free of charge at the point of sale by the end of 2018.[52]

Plastic bag regulations

Policies on plastic bags can refer to bans or voluntary agreements. In December 2015, Morocco has introduced a law that bans the production, import, export, sale and free distribution of plastic bags starting from July 2016. Plastic bags for usage in industry, agriculture, refrigeration and waste management are exempt. Violations of the law can be punished with fines for the production and sale of plastic bags.[53] The 'Zéro Mika' public awareness raising campaign has supported the implementation of the ban.[54]

France also introduced an interdiction of single-use plastic bags. Since July 2016, only reusable bags made of thick plastic or of other materials can be handed out at points of sale. Since January 2017, only compostable bags are allowed for products such as fruits, vegetables, fish and meat.[55] In Germany, the Ministry of Environment has concluded in 2016 a voluntary agreement with the German Retail Federation.[56] The private sector has voluntarily introduced an obligation for consumers to pay for plastic bags. Between 2015 and 2016, plastic bag consumption decreased from 68 to 45 bags per person and year (5.6 to 3.7 billion plastic bags in total per year).[57]

Regional cycles of reusable beverage bottles should replace single-use plastic bottles. Life-cycle assessments show that reusable bottles are better for the environment than disposable bottles (IFEU 2010).[58] An important factor consists however in the distance that bottles have to travel for refilling. Refilling cycles should be local or regional (e.g. around 100 km) to limit transport distance and associated emissions. Reusable beverage bottles can be made of glass or hard plastic PET. Their weight also influences the results of life-cycle assessments.

Returnable bottles and deposit-refund systems can contribute to marine litter prevention. By paying a deposit on each bottle, consumers have the direct monetary incentive to return bottles. Additionally, informal waste collectors have a higher reward if they bring littered bottles to take back centres. In many countries, deposit-refund systems for local beverages still exist or existed before single-use bottles swamped them out of the market. Deposit-refund systems can also be introduced through a combination of extended producer responsibility policies and cooperation with the private sector.

Shop without single-use packaging, Germany[59]

1.2.2. PROMOTING DESIGN FOR RECYCLING

Designing packaging should take into account their end-of-life recycling. It requires designers to reconsider aspects such as the material composition and the size of packaging. The combination of different types of polymers and additives makes recycling very difficult in terms of technology and cost-efficiency. Very small items such as sachets or wraps for sweets are hard to collect separately for recycling. Design for recycling is often not the upmost concern of designers who need to focus on optimising the products' protection and an attractive appearance for marketing purposes. Adequate incentives are necessary to include design for recycling in the decision matrix of packaging and product designers. It requires appropriate policies by private companies as well as guidelines or regulation by political decision-makers at national level. Simply requiring the private sector to make packaging thicker is not a solution as it goes hand in hand with higher resource consumption and does not automatically increase recycling rates. Product innovation is a dynamic process, which makes standardisation difficult. Certain standards are however already available.[60]

Design for recycling also requires the design of products containing recyclates. A considerable challenge for increased recycling consists in generating sufficient demand for recycled materials (Velis et al. 2017).[61] Such demand depends on prices as well as trust in the quality of recyclates. Public policies as well as value chain initiatives can contribute to increasing trust by product designers and thereby demand. Designers need to find out to what extent they can combine recycled and virgin raw materials in order to achieve the intended quality. Public policies can also prescribe minimum contents of recyclates for certain products.

Promoting design for recycling requires enhanced exchange along the value chain. Consumer goods and retail companies, waste managers and regulators need to come together with packaging designers to better understand their respective needs and challenges. For instance, the Ellen MacArthur Foundation and the World Economic Forum (WEF) conduct such a process at global level with their 'New Plastics Economy Initiative'.[62] The initiative estimates that worldwide material recycling of plastic packaging currently accounts for only 5%. It states that "about 95% of plastic packaging material value, or USD 80-120 billion annually, is lost to the economy after a short first-use cycle" (WEF 2016).[63] About 30% of plastic packaging by weight would require redesign and innovation, while further 20% could be reused and 50% be recycled (WEF 2017).[64] The initiative thus calls for developing a 'Global Plastics Protocol' to provide orientation for a more harmonised design of packaging for better recycling. At the World Economic Forum 2018, several multinational companies have committed to reuse, recycle or compost all their packaging waste by 2025.[65] The European Commission's *Strategy for Plastics in a Circular Economy*, released in January 2018, also pursues the idea of a new plastics economy and the objective that by 2030 all packaging is "either reusable or can be recycled in a cost-efficient manner"(EC 2018a).[66]

1.2.3. CAREFULLY ASSESSING 'BIODEGRADABLE' PACKAGING

Packaging that fulfils all criteria of stability for product storage and then dissolves after product use without creating any environmental hazards would be a convenient technological solution. Some well-known packaging, such as paper bags or some innovative biodegradable materials, might fulfil such conditions in the future. Yet, 'biodegradable' plastics can also be misleading and need careful assessment. They are usually designed for biological degradation within conditions of industrial composting. In rivers and the ocean, the environmental conditions are however less suitable for their complete degradation. It means that they continue to represent a threat to wildlife and ecosystems in the short and medium term (UNEP 2016).[67] Furthermore, 'biodegradable' bags can also disturb composting processes, e.g. by clogging machines. If they are mixed with other plastics in recycling plants, they can also disturb recycling processes and reduce the quality of recyclates.

1.3. Cross-sectoral cooperation within a source-to-sea approach

Successful marine litter prevention relies on the interaction between a wide array of stakeholders. Waste management and circular economy approaches can contribute to effective marine litter reduction. The impetus to act often comes however from environmental associations, scientists, fishermen, diving clubs and others who work closely with riverine and marine ecosystems. They observe the actual dispersion of plastic litter and its impacts on wildlife and human activities. Those who have direct benefits from reduced littering, such as hotels, restaurants and other tourism stakeholders, can be important allies in implementing awareness raising campaigns for environmentally sound behaviour and for contributing to improved solid waste management and circular economy. In order to spur such interaction, public authorities should encourage the creation of roundtables and consultation processes at local or national level.[68]

Furthermore, marine litter is a topic at the intersection of waste, wastewater, water and sanitation management. The effective delivery of these different public services requires functioning governance mechanisms and development planning in urban, peri-urban and rural areas. As rivers and coasts connect different cities, they are also a regional topic, sometimes crossing national borders. Waste reception facilities in harbours connect local municipal service provision with international shipping, requiring adequate financial arrangements.

The 'source-to-sea' or 'ridge-to-reef' approach can provide a useful conceptual framework for tackling the marine litter challenge. It deals with the connection between land-based activities and sea-based impacts as well as the fragmented governance systems of water-related ecosystems from the source of a river to the open ocean and from the top of a mountain to the coast.[69] Granit et al. (2017) provide a useful conceptual approach for 'source-to-sea' management, which lacks however the inclusion of integrated sustainable waste management and circular economy approaches.[70] The international 'Action Platform for Source-to-Sea Management' gathers several organisations to promote this approach.[71]

Applying the conceptual framework to marine litter prevention requires considering waste management and circular economy alongside the mentioned management approaches of integrated water resources management and integrated coastal management. Plastics and microplastics represent a key "pollutant flow" next to flows of water, sediments, biota, materials and ecosystem services. Designing adequate interventions requires the identification of the right geographical scale, potential goals, the necessary stakeholders as well as the suitable institutional structures and coordination processes.[72]

Cross-border dialogue on marine litter prevention

Successful marine litter prevention requires organising multi-stakeholder dialogues and governance arrangements. In this sense, the Network of Associations of Local Authorities of South-Eastern Europe (NALAS) and the Regional Rural Development Standing Working Group (SWG) conducted a cross-border dialogue in 2015 to 2016 with support by GIZ.[73] It brought together 'impacting' and 'impacted' municipalities along the Adriatic coast, a neighbouring river basin and a mountainous area in Albania, Bosnia and Herzegovina, Kosovo, Macedonia, Montenegro and Serbia. City representatives and other stakeholders discussed at recurrent meetings the outcome of environmental and economic impact assessments of waste in waterways and the sea as well as potential solutions. They adopted joint policy recommendations for improved waste management, extended producer responsibility mechanisms, regionally coherent monitoring as well as an increased regional exchange of information.

Fig. 5 Regional map on waste management and marine litter challenges, South Eastern Europe[74]

1.4. 'Glocal' governance for marine litter prevention

Stepping up marine and riverine litter prevention requires interweaving of global and local governance. High-level commitments in international forums provide important impetus to put the issue of marine litter on the political agenda. They help to mobilise attention and resources of various stakeholders. Achieving actual marine litter reduction requires actions at the national and especially the local level where waste and plastic leakage into waterways and the ocean arise. Global governance initiatives thus need to expand in scope and depth as well as to integrate recommendations for national and local governance. They also need to consider transnational value chains of plastics and packaging. 'Glocal governance' is an interplay of a wide range of local and global actors who contribute to finding solutions to a global problem by implementing measures at local level.

1.4.1. ENHANCING GLOBAL GOVERNANCE ON MARINE LITTER

Global governance on marine litter has increased significantly over the last years, mainly based on voluntary commitments. Efforts in different realms of international relations have provided a set of principles, guidelines and commitments. They are a fragmented web of voluntary and legally binding norms, shared by multilateral organisations, governments as well as a growing number of business, civil society and scientific organisations. Further coordinated international action will be necessary to solve the global commons problem of marine litter.

One relevant forum for preventing marine litter and plastics pollution is the UN Environment Assembly (UNEA). It adopted resolutions on the issue in June 2014, May 2016 and December 2017.[75] Its most recent resolution on marine litter and microplastics emphasises the importance of preventive action for waste reduction and management. It calls upon member states to develop action plans for marine litter reduction and recommends source-to-sea approaches. It also seeks to involve the private sector and civil society, amongst others through extended producer responsibility and deposit-refund systems. Furthermore, the resolution calls for establishing an expert group for submitting a report on governance strategies and other response options for consideration by UNEA-4 in March 2019. In terms of coordination on marine litter reduction within the UN system, UN Environment plays a pivotal role. It hosts the *Global Partnership on Marine Litte*r, which is part of the *Global Programme of Action against pollution from land-based sources (GPA)*.[76] It also runs the global *Clean Seas* campaign on marine litter prevention, which reaches out to individuals, companies, NGOs and governments.[77]

An additional strong momentum has come from the UN Ocean Conference on achieving SDG 14. It took place in June 2017 at the UN headquarters in New York. Marine litter ranged among the major topics of the event, involving an official partnership dialogue and several side-events.[78] The conference's final declaration recommends voluntary measures on marine litter prevention. Several governments and other stakeholders have submitted voluntary commitments on the issue.[79] The next UN Ocean Conference will take place in 2020.[80] The annual 'Our Ocean Conferences', started in 2014 by the US Department of State and followed-up by other countries, have also highlighted the importance of marine litter prevention and gathered voluntary commitments.[81] Indonesia and Norway will host the next Our Ocean Conferences in 2018 and 2019 respectively.

The Group of Seven (G7) and the Group of Twenty (G20) Countries have become other relevant forums for global governance on marine litter and resource efficiency. In June 2017, the G7 adopted under German presidency the G7 Action Plan to Combat Marine Litter in the Annex to the Leaders' Declaration.[82] It includes priority actions for land- and sea-based sources of marine litter as well as on actions regarding removal, education, research and outreach. The subsequent G7 presidencies of Japan and Italy in 2016 and 2017 have followed-up the topic.[83] Marine pollution and plastics are also on the agenda of the Canadian G7 presidency in 2018.[84] In July 2017, the G20 adopted under German presidency a G20 Action Plan on Marine Litter as an Annex to the Leaders' Declaration.[85] The action plan is broader in scope. It includes an operational framework with specific measures on promoting the socio-economic benefits of marine litter prevention, waste prevention and resource efficiency, sustainable waste management, wastewater treatment, awareness raising, removal actions and stakeholder engagement. It also intends a 'Global Network of the Committed' for contributing to the action plan's implementation. In parallel to marine litter, the G7 and G20 have also kick-started resource efficiency dialogue processes, including plastics.[86]

Marine pollution has also found recognition in international forums on biodiversity and urban development. The 13th Conference of Parties of the Convention on Biological Diversity (CBD) adopted in December 2016 in Cancun a decision on marine litter. It calls upon member states to take appropriate action and includes a "voluntary practical guidance" in this regard.[87] The cross-sectoral nature of marine litter prevention is also reflected in the fact that the New Urban Agenda adopted at the Habitat III Conference in October 2016 in Quito includes a commitment on "reducing marine pollution through improved waste and wastewater management in coastal areas".[88]

Apart from these initiatives based on voluntary commitments, some international legally binding rules on marine pollution prevention exist. Concerning sea-based sources of marine litter, the MARPOL Convention on the pollution from ships sets out rules for waste handling by ships in its Annex V.[89] The discharge of plastics and several other waste types from ships outside and within special areas as well as from offshore platforms is explicitly prohibited. In order to facilitate the implementation of the MARPOL Convention, which lacks a strong enforcement mechanism, the establishment of functioning port reception facilities plays a crucial role.[90] Reducing marine pollution from dumping at sea is also the objective of the London Protocol, adopted in 1996 and entered into force in 2006.[91] For both agreements, the International Maritime Organisation (IMO) is the custodian agency. Furthermore, the UN Convention on the Law of the Sea (UNCLOS) stipulates in its part XII that states should take "(…) measures to prevent, reduce and control pollution of the marine environment from any source (…)".[92] It explicitly refers to sea- and land-based sources. In 2016, the UN Open-ended Informal Consultative Process on Oceans and the Law of the Sea dealt with the issue of marine litter.[93] The issue of plastics and microplastics in the ocean has also started to be considered in the framework of the Basel and Stockholm Conventions.[94]

Furthermore, Regional Seas Conventions play a significant role and can involve legally binding rules for their member states. The Barcelona Convention for the Protection of the Mediterranean is an example. It includes a Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities (LBS).[95] In 2013, the 18th Meeting of the Contracting Parties of the Barcelona Convention has adopted a 'Regional Plan for the Marine Litter Management in the Mediterranean' in the framework of the LBS Protocol. Concerning marine litter prevention, this plan calls amongst others for improved solid waste management, extended producer responsibility strategies, agreements with retailers, economic instruments for reducing plastic bag consumption and deposit-refund systems for beverage packaging. It also invites member states to update their national action plans under the LBS Protocol and to integrate marine litter prevention measures. A secretariat of UN Environment / Mediterranean Action Plan (MAP) coordinates this process and established a Regional Cooperation Platform on Marine Litter in the Mediterranean in 2016.[96]

The European Union also plays an important role in marine litter prevention. Since 2008, it disposes of a Marine Strategy Framework Directive, which addresses marine litter amongst other topics.[97] In January 2018, the European Commission has published a new "European Strategy for Plastics in a Circular Economy".[98] It envisages to move towards a "New Plastics Economy" and to render all plastic packaging reusable and recyclable by 2030. The strategy proposes several measures to increase plastics recycling through improved design, demand, separate collection and sorting. It also envisages reducing the amount of plastic waste as well as environmental pollution by plastics and microplastics, including marine litter. It seeks to spur investments and innovation within Europe. Furthermore, the strategy also includes measures for global action concerning transnational plastic value chains and partner countries.

Whether global governance should move towards more legally binding agreements or deepen voluntary commitments remains up for debate. Plastic and microplastic pollution represents a global risk (Kramm, Völker 2018).[99] Think tanks have suggested e.g. an 'International Plastics Convention' (Simon and Schulte 2017)[100] or a 'Global Plastics Protocol' (WEF 2017)[101]. On the one hand, lengthy negotiations should not divert attention from implementing existing commitments. On the other hand, negotiations for a visible international agreement might serve as a centre of rotation for international efforts. Similar to the Paris Agreement on climate change, 'nationally determined contributions' for reducing plastic leakage into the ocean combined with continuous efforts on harmonising approaches for accounting and on providing financial instruments might be a useful way forward
(Simon and Schulte 2017).

UN Ocean Conference at UN headquarters in New York (UN Photo by Kim Haughton)[102]

1.4.2. PROMOTING GLOBAL EXCHANGE BETWEEN INITIATIVES IN CITIES AND ALONG VALUE CHAINS

In the context of this global governance framework, local decision-makers need to take a stronger lead next to national representatives. As described in previous sections, improving waste collection and treatment is essentially a task of local governance in human settlements in cooperation with national policy frameworks and agencies. Physical and governance aspects of integrated sustainable waste management need to evolve hand in hand. It requires local decision-makers to develop visions of clean, plastic leakage free cities and to receive access to additional funds. They need to set targets and to dedicate adequate resources in order to drive effective implementation. They also need to mobilise various stakeholders from civil society, science and the private sector to increase awareness and joint action.

Global knowledge exchange between committed cities should therefore accompany such bottom-up efforts. Sharing lessons-learnt of municipalities can reinforce or inspire commitments by others. Such exchange can build upon experiences from examples in the field of climate change mitigation and other areas of sustainable development such as the C40 Cities Climate Leadership Group and ICLEI-Local Governments for Sustainability. Addressing plastic pollution requires the creation of adequate city networks, linked to existing efforts such as UN Environment's Global Partnership on Marine Litter and its Clean Seas campaign. Such exchange and networks can also take place at regional level across neighbouring countries.

'Glocal governance' can also help in involving the private sector. Several multinational companies of the consumer goods industry are active on many markets around the world. Initiating a transnational dialogue process between governments and the plastic, packaging, retail and consumer goods industry could support implementation within countries and cities for marine litter free value chains. Such dialogue could involve the elaboration of joint commitments, exchange of experiences and best practices as well as enhancing the joint knowledge base. It could build upon on-going initiatives such as the 'New Plastics Economy Initiative' of the Ellen MacArthur Foundation and the World Economic Forum, the 'Roadmap for Reducing Ocean Waste' of the World Business Council for Sustainable Development, the 'Trash Free Seas Alliance' of the NGO Ocean Conservancy and the 'Marine Litter Solutions' initiative of national plastic producer associations.[103]

Enhanced exchange can help in promoting extended producer responsibility schemes for plastic and packaging waste. Individual companies might be motivated to act and pledge targets for reducing, reusing and recycling. They face however high transaction costs in setting up functioning collection and recycling systems together with their competitors. Government action can help in this regard. National governments and Parliaments play a key role in developing legal frameworks for extended producer responsibility schemes. Promoting exchange of experiences between countries can help in this regard. Such exchange can involve public stakeholders as well as private sector stakeholders involved in setting-up and running extended producer responsibility schemes. High-level political support is crucial to make such approaches feasible.

10 KEY MESSAGES FOR PREVENTING MARINE LITTER

1. Promote integrated sustainable waste management
2. Respect the waste hierarchy: reduce, reuse, recycle as much as possible
3. Drastically expand waste collection coverage, efficiency and the separation of plastics
4. Enhance awareness raising and cleaning activities of streets, canals and beaches
5. Build sound institutions, policies, operator models and cost-recovery mechanisms
6. Implement extended producer responsibility schemes and deposit-refund systems
7. Promote reusable packaging and product design for recycling
8. Enable cooperation of stakeholders across sectors from source to sea
9. Facilitate the exchange of local decision-makers across borders
10. Strengthen dialogue along plastic and packaging value chains

2 METHODOLOGICAL APPROACH FOR ASSESSING PLASTIC LEAKAGE INTO THE OCEAN IN THE TWO CASE STUDIES

Cities and regional entities have a significant impact on marine litter generation. Yet, the discussion and programmes on marine litter prevention still need to reach municipal and regional decision-making. Enhancing the information base is an essential part of the puzzle. It can attract political attention and facilitate the mobilisation of relevant stakeholders and resources to take action.

The methodology used in this study seeks to complement existing approaches to assess marine litter. It focuses on assessing plastic waste leakage from human settlements into waterways and the ocean. Its central rational consists of describing plastic waste flows and estimating associated quantities in order to identify key intervention points. The focus on plastic flows is based on the assumption that about 60 to 90% of marine litter consists of plastics (UNEP-GRID 2016)[104] and that most of it comes from land-based sources. In the following, the assumptions, structure and needs for data gathering and estimating transmission factors as well as a brief comparison to other existing approaches will be outlined.

2.1. Assumptions and structure

This study intends to apply a methodological approach that facilitates assessing plastic waste leakage into waterways and the ocean in different contexts. The methodology therefore needs to enable a reasonably accurate assessment in any given solid waste management system at municipal or regional level. It should also allow for testing different improvement scenarios of solid waste management systems and their respective impact on marine litter prevention.

The chaotic nature in which plastic waste finds its way into waterways and the ocean render direct measurements virtually impossible. Several factors have a direct impact on the amount of plastics found in any given stretch of waterway. These factors include aspects such as the frequency or absence of waste management services, the level of awareness and behaviour patterns of citizens, local customs, seasonal changes in waste composition, rainfall and water flows and the direction of water flow including tidal influences. In addition, different types of plastic behave differently in water. Some sink to the ground while others rather float on the surface. Currents as well as tides influence the quantities of floating debris. In irrigation systems, water flows are not continuous but directed according to current water demand, transporting plastics in some cases far from their origin. Furthermore, strong floods might wash unmanaged plastics into the ocean in a single event.

Identifying an approach that allows a feasible and transparent approximation of the actual situation is required. The approach suggested in this study involves qualitative descriptions of key transmission pathways, i.e. the ways plastics travel from their users to the marine environment. Based on a harmonised logic of such transmission pathways, transparent estimations for the associated quantities of plastic waste at the different points of this complex system are developed.

The methodological approach rests upon four key assumptions:

» 1. Plastic waste that cannot be accounted for within the solid waste management system partly enters waterways and becomes marine litter.

» 2. Given the long lifetime of plastics, parts of the generated amount of plastic waste per year might also enter the marine environment during the following years.

» 3. As the actual quantities of riverine and marine plastic litter cannot be measured directly, the next best option consists in using structured assessments by solid waste management experts, guided by a unified approach and defined transmission factors.

» 4. The approach focuses on municipal solid waste sources of plastic waste. Other land-based sources such as industrial or agricultural waste require separate descriptions.

The methodological approach focuses on plastic waste. In general, the approach could consider different types of municipal solid waste flows, e.g. also the mostly dominating organic waste. In order to reduce complexity and due to the predominant role of plastics for marine litter pollution, the approach used in this study focuses however on plastic waste. It allows for taking into account the plastic content of hygienic waste such as diapers.

The approach displays plastic waste flows within the regular solid waste management chain in several steps:

- Plastic waste generation
- Reuse and recycling at source
- Formal and informal collection
- Formal and informal recycling / energy recovery and use as refuse-derived fuel (RDF)
- Transportation to landfill
- Landfilling

The methodological approach considers the following transmission pathways of plastic waste from human settlements into waterways and the ocean (Fig. 6):

- Uncollected plastic waste that is burned or disposed of in proximity to waterways, which leads to partial leakage of this plastic waste into waterways
- Uncollected plastic waste that is directly disposed of into waterways
- Uncollected plastic waste entering waterways through the drainage system, e.g. street litter entering gullies
- Plastic waste entering waterways through the wastewater system, e.g. microplastics from textiles or cosmetics, some hygienic products
- Leakage of plastic waste into waterways from formal and informal waste management activities during collection, recycling, energy use and RDF, transportation and landfilling
- Parts of the plastic waste in waterways are retained through natural and technical barriers, sedimentation and degradation before entering the ocean
- Additional littering of plastic waste on beaches and the coastline, especially from touristic and leisure activities, that directly enters the ocean

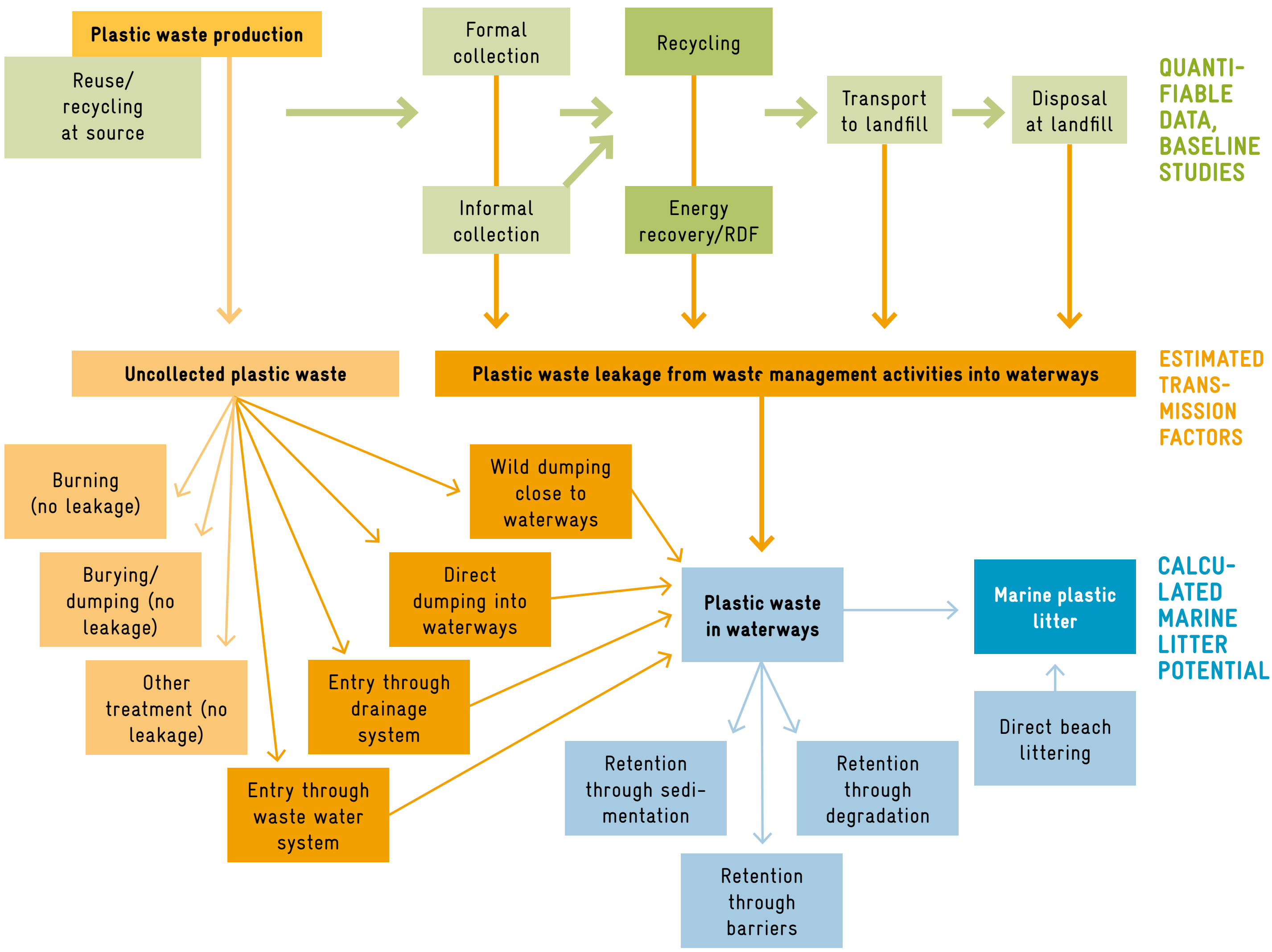


Fig. 6 Plastic waste flows

2.2. Data gathering and estimation of transmission factors

Applying the methodological approach involves assessing all of these pathways and estimating the corresponding transmission factors. In some cases, basic information about the regular solid waste management system is available or can be obtained through usual waste management planning exercises such as feasibility studies and master planning. For instance, this is the case for per capita waste generation, waste composition, waste collection coverage and collection efficiency, formal recycling and landfilling. Yet, information about unmanaged or informally managed waste is difficult to obtain and little is known about plastic quantities entering through wastewater or drainage systems. Fig. 7 provides an overview on regular solid waste management data more or less available. It also outlines specific data for marine litter generation that requires estimations.

Plastic waste Production	Plastic waste collection & treatment	Uncollected plastic waste	Plastic waste in waterways & ocean
Population	Reuse & recycling at source of plastic waste	Burning & dumping close to waterways	Leakage from wild dumpsites into waterways
Municipal solid waste generation per capita	**Solid waste collection coverage & efficiency**	Leakage into drainage system	Leakage from drainage system into waterways
Share of plastic waste in municipal solid waste	**Informal collection & recycling of plastic waste**	Direct disposal into waterways	
Share of hygienic waste in solid waste and plastic content in hygienic waste	**Formal recycling**	Burning, burying, dumping, other treatment without leakage into waterways	Leakage from waste collection, recycling, energy use & RDF, transportation, landfilling into waterways
	Energy recovery and RDF		
	Transportation between treatment and landfill		
	Landfilling		Leakage through wastewater system
			Retention in waterways through sedimentation, barriers, degradation
			Beach & coastal littering

Fig. 7: Data and transmission factors (bold: numbers refer to data that are sometimes available in municipalities or by international cooperation projects; not bold: numbers require estimates)

An Excel table computes the input data into plastic waste flows. It displays results in quantities expressed in tonnes per year and percentages. As in any model, the results cannot simply be considered as facts. The output is only as good as the input. The results rely on expert assessments of transmission factors. They serve as orienting figures to visualise the extent of the problem and to analyse intervention options and planned project outcomes.

Estimates of non-measurable transmission factors need to be sufficiently reliable. They need to deliver comparable results when used by different experts in a great variety of settings. In this study, 'transmission factors' are defined as numerical estimates, usually expressed as percentages of plastic waste flows, which distribute plastic waste quantities along different transmission pathways. Figure 8 provides an overview of the transmission factor categories. It also contains some leading questions for their assessment and potential data or information sources to sustain the assessment results.

Transmission factor categories	How to assess
Uncollected plastic waste burned, buried, dumped or treated otherwise (with or without leakage into waterways)	• Frequency of burning / dumping / burying waste and proximity to waterways • Survey of local disposal behaviour in unserved areas • Quantity and frequency of removal of wild dumpsites by local authorities • Prevalence of smoke from waste burning
Direct disposal of plastic waste into waterways / leakage through drainage system / leakage through wastewater system	• Characteristics of the drainage system (intake of street litter through lack of coverage, flow into canals and rivers or treatment of water, etc.) • Consumption of textiles and cosmetics with potential release of microplastics into wastewater system. Wastewater treatment characteristics.
Leakage from waste management system (formal / informal collection and recycling, energy recovery & RDF, transportation, landfilling)	• Site visits of recycling/ energy recovery facilities and landfills • Cleanliness of containers, collection points and transfer stations • Coverage of collection and transportation vehicles, transportation behaviour
Retention in waterways through barriers, sedimentation and degradation	• Very rough estimates for the behaviour of plastic waste in waterways. Further research needed.
Direct beach and coastal littering	• Estimations based on daily visits during season and consumption of plastics or beach clean-ups with surveys.

Fig. 8 Assessment of some transmission factors

The methodological approach used in this study requires solid waste management experts familiar with the waste management situation on the ground. Field visits of one to two weeks were conducted in the two locations in Indonesia and Algeria to obtain a good understanding of the transmission pathways. Basic waste management data was available through local authorities and the two development cooperation projects. Interviews were conducted with public officials, as well as other stakeholders, depending on the local context and availability. Visual observation and photographic documentation helped in getting a picture of the different plastic waste pathways from human settlements to waterways and the ocean.

2.3. Comparison to other marine litter assessment methodologies

The outlined methodology is different but complementary to approaches that measure waste or plastic concentrations found *within* freshwater and seawater or at beaches and coastlines. An example of this other approach consists in two comprehensive reports published in 2016 by the Technical Group on Marine Litter for the European Union's Marine Strategy Framework Directive. One report shares examples for assessing "where the litter recorded in a given area is coming from (…) and how it is getting into the marine environment and the site where it is recorded" (JRC 2016a).[105] Analysing litter items found in the marine and coastal environment in this way can provide a useful first idea on certain categories of land- and sea-based sources. Another report of the Technical Group on Marine Litter focuses on litter in rivers and on riverbanks that can become marine litter (JRC 2016b).[106] It presents a transport model with several monitoring options in the riverine environment. They include, for instance, visual observations as well as samples from booms and floats, riverbed nets and pumps for different plastic waste sizes.

There are further approaches focussing on the presence of waste in the marine and coastal environment instead of its input into waterways and the ocean. For instance, the 'Integrated Monitoring and Assessment Programme' for the Mediterranean includes three such indicators on marine litter for the period 2016-2021. They are namely: "trends in the amount of litter washed ashore and/or deposited on coastlines"; "trends in the amount of litter in the water column including microplastics and on the seafloor"; "trends in the amount of litter ingested by or entangling marine organisms focusing on selected mammals, marine birds, and marine turtles".[107] Following this approach, the study 'Marine Litter Assessment in the Adriatic & Ionian Seas' (Vlachogianni et al. 2017) reports numbers on beach litter, seafloor litter and plastics within selected fish species.[108] Furthermore, the 'Plastic Busters' project has reviewed potential 'bioindicators' for assessing the impact of marine litter on marine species in the Mediterranean.[109] Concerning beach litter, the NGO Ocean Conservancy uses a harmonised methodology and online application for its annual International Cleanup Day.[110] At Manila Bay in the Philippines, Greenpeace and the #breakfreefromplastics campaign tried to combine a beach clean-up with assigning collected plastic items to individual brands.[111]

The methodology used in this study builds upon existing attempts to estimate the amount of plastic leakage from land into the ocean. Such approaches identify population numbers and plastic waste production per capita within a given country or area. They match these numbers with an assessment of the efficiency of waste collection and treatment. Thereby, they calculate quantities of unmanaged plastic waste. By using additional transmission factors, they estimate how much of the mismanaged plastic waste eventually enters into the marine environment within a given period.

The vastly cited study by Jambeck et al. (2015) is the most prominent example, providing estimates for countries and the global level.[112] Using a comparable approach, the NGO Ocean Conservancy and the McKinsey Center for Business and Environment (2015) published in-depth assessments on plastic leakage into the ocean in China and the Philippines.[113] Both studies inspired our methodology. Furthermore, a study by Lebreton et al. (2017) developed a global model based on population density, mismanaged plastic waste, seasonal catchment runoffs, natural drainage patterns and artificial barriers to estimate the influx of plastics from worldwide 40'760 watersheds into the ocean.[114]

These approaches give an important idea about the scale of the problem. They serve as a basis for the much-needed political discussion. However, they rather apply a large-scale perspective for the global and national level. The methodological approach used in this study seeks to provide numbers at the level of municipalities and sub-national regional entities. It is used in the two following case studies in Sidoarjo Regency, Indonesia and in Annaba, Algeria.

CASE STUDY: SIDOARJO REGENCY, INDONESIA

Marine litter is a global issue caused by local plastic waste leakage into waterways and the ocean. Southeast Asia is considered a global hotspot for plastics entering the marine environment. Countries such as the Philippines, Vietnam, Malaysia, Thailand, Cambodia and Indonesia have been facing rapid economic growth, urbanisation and increasing waste amounts. Large percentages of the countries' populations live close to coasts and rivers. The following case study of Sidoarjo Regency in Indonesia serves to look deeper into the causes and potential solutions to marine plastic litter generation in a specific context. While each country, region and municipality is different, the case study can provide insights and give ideas that are also relevant for other areas in Southeast Asia.

3.1. Context of Indonesia and Sidoarjo

Indonesia counts amongst the world's most important generators of marine plastic litter. With more than 187 million people living within a 50 km radius of the sea, around 0.48 to 1.29 million tonnes of plastic per year end up in the ocean (Jambeck et al. 2015).[115] Insufficient waste management systems represent an essential driver in this regard. Indonesia is particularly sensitive to marine pollution. Large parts of the population depend on sea-based protein sources and the marine environment contains a high biodiversity. Amongst others, Indonesia is part of the 'Coral Triangle', which is considered a "global epicentre of marine life abundance and diversity".[116]

The Indonesian government has recently adopted a 'Plan of Action on Marine Plastic Debris 2017-2025`.[117] It intends to reduce marine plastic debris by 70% until 2025. The action plan's key principles include the prevention of marine litter at source as well as the "coordination between institutions responsible for waste management". It focuses on five pillars: 1) "improving behavioural change"; 2) "reducing land-based leakage", 3) "reducing sea-based leakage", 4) "reducing plastics production and use", and 5) "enhancing funding mechanisms, policy reform and law enforcement". It calls for actions at local, national and international level and addresses the plastics industry as well as academia and community-based organisations. In order to achieve the 70% reduction goal, Indonesia needs not only to improve the current situation but has also to cope with the expected increase in waste generation related to population and economic growth.

Internationally, Indonesia has started to play an active role in marine litter prevention. At the UN Ocean Conference in June 2017 in New York, Indonesia moderated together with Norway a partnership dialogue on marine litter. The Indonesian Coordinating Minister for Maritime Affairs also participated as a keynote speaker at the G20 Marine Litter Conference in Bremen in May 2017. In September 2017, Indonesia hosted an Asia Pacific Economic Cooperation (APEC) meeting as well as an East Asia Summit meeting on marine litter prevention.[118] In December 2017, a 'Regional Forum on Managing Marine Plastic Pollution – Policy Initiatives in ASEAN countries' took place in Jakarta.[119] In November 2017, an 'ASEAN Conference on Reducing Marine Debris in ASEAN Region' followed in Phuket, Thailand, organised by the Ministry of Natural Resources and Environment of Thailand and the ASEAN Secretariat, based in Jakarta.

Sidoarjo Regency is officially home to 2.16 million people. It is located in Eastern Java, south of the second largest city in Indonesia, Surabaya. Sidoarjo Regency is characterised by residential areas serving as an extension to the ever-growing Surabaya metropolis. It also comprises semi-urbanised residential areas in the centre as well as rural residential areas to the west and south. To the east, extensive aquaculture in the coastal mangrove area roughly covers 29% of the total regency. Population growth ranges between 2.45% and 2.78% per year (EAWAG, 2015).[120] Main sources of income are agriculture, labour intensive industries and informal activities. Sidoarjo is also a regional centre for plastic recycling. The climate is tropical wet and dry savannah with a distinct rainy season from November to March. Located between three river systems, the whole regency is connected to extensive irrigation systems. Even in the city, waterways and irrigation channels can be found close to every house. The regency is one of the participating regencies in the "Emission Reduction in Cities – Solid Waste Management" project between Indonesia and KfW Development Bank.

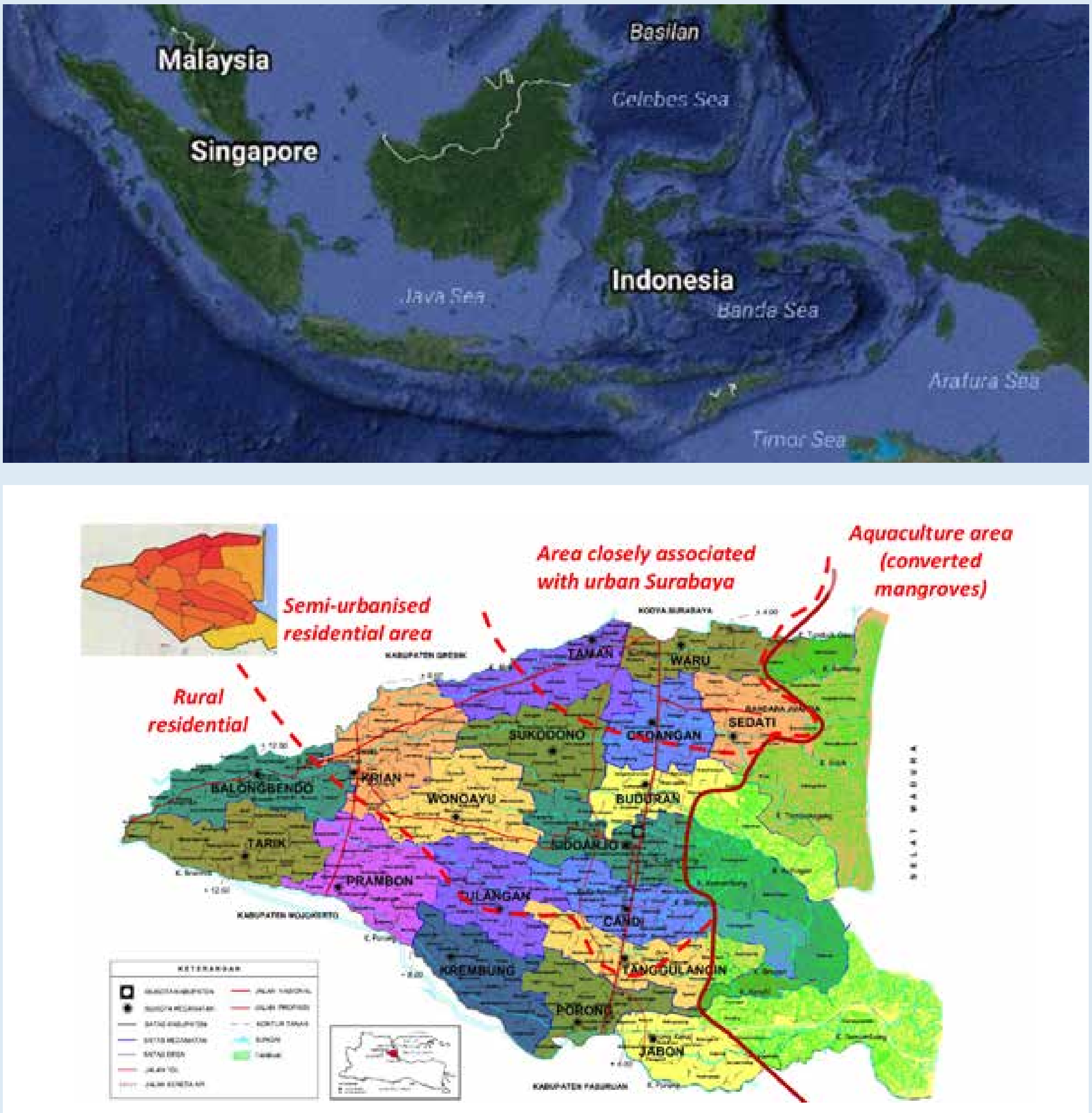


Fig. 9 Map of Sidoarjo Regency (EAWAG, 2015) and Indonesia[121]

3.2. Solid waste management situation in Sidoarjo

3.2.1. CURRENT SITUATION OF THE SOLID WASTE MANAGEMENT SYSTEM

Waste management in Indonesia is the responsibility of local governments, in this case the Sidoarjo Regency. The Department of Environment and Cleansing (DLHK, *Dinas Lingkungan Hidup dan Kebersihan*), formerly called Cleansing and Park Department (DKP), manages solid waste in Sidoarjo. The department is handling policy-making, planning, implementation and supervisory tasks. The Department of Public Works and Spatial Planning (DPUPR) manages the drainage and irrigation system and is therefore responsible for cleaning and removing waste that accumulates in waterways.

The Department of Environment and Cleansing is responsible for waste collection not at the household level but only from collection points. These collection points are called *Tempat Pembuangan Sementara* (Temporary Disposal Sites, TPS). Waste producers such as households have the responsibility to deliver their waste to these points. However, there is no legal leverage to enforce either that waste producers bring in their waste or that they contribute financially to the collection system. The formal solid waste management system in Sidoarjo therefore starts at dedicated collection points across the regency. It covers only an estimated 40% of the total service area and its actual collection efficiency ranges between 65% and 78%. Only 25% to 32% of all municipal solid waste actually enters the formal solid waste management system.[122]

Various approaches exist at community level to provide primary collection services. Waste is either collected from different types of waste containers in front of houses or from nearby collection points. Frequency and quality of service vary significantly. The service is either provided by workers from the community administration or by small private initiatives. The waste is then taken to the next collection point serviced by the Department of Environment and Cleansing.

Most of the citizens do not have any waste collection service provision at household level. They consequently refer to unmanaged forms of waste disposal. In the best case, they bring their waste to the next collection point. The most frequent ways of dealing with the uncollected waste are:

- Placing it alongside roads in front of houses and partially burning it
- Burying it in the backyard
- Disposing waste at informal waste accumulations
- Throwing it directly into waterways, sometimes close to homes, even in the city centre

Informal waste accumulation, Sidoarjo

Open dumping and burning, Sidoarjo

Temporary disposal site, Sidoarjo

Diaper in a waterway, Sidoarjo

Private initiatives play a certain role for waste collection. In very few areas, so-called 'waste banks' have been established by private initiatives at community level. These buy-back centres pay a small fee to citizens who bring their separated recyclables. In parts, they are also sorting waste or have managed to establish separate collection at source, usually a two or three fraction system. Informal waste pickers are active in all areas. They focus on the city centre and on selected valuable materials such as specific plastics and metals. Sidoarjo is a centre for plastic recycling and has a well-developed value chain for the materials that can be economically recycled.

There is a total of 75 reduce-reuse-recycle centres. These *Tempat Pengolahan Sampah Terpadu berbasis Reduce-Reuse-Recycle* (3Rs based Integrated Waste Treatment Plants, TPS-3R) receive waste either directly from the surrounding communities or from regular waste collection trucks. They are sorting stations, in charge of separating recyclables, organic waste and residues. These stations range from small-scale backyard manual sorting to mid- and large-scale facilities with motorised screens, conveyor belts and balers. Either the DLHK or private, licensed companies operate them. Of the 75 facilities, only 36 are active, seven are currently under development, the remaining 32 are not operating. TPS-3R manage an estimated 11% of all waste. Integrated sites, called Tempat Pengolahan Sampah Terpadu (Integrated Waste Treatment Plants, TPST) usually add some composting activities. Waste burning, in some places even with very low-tech incinerators, takes place as means to reduce waste quantities, specifically of paper and plastics not suitable for recycling.

Residues are then delivered to the final disposal site at Jabon. The site has little space left and is not in good operation. There are about 80 waste pickers on site. The KfW project "Emission Reduction in Cities – Solid Waste Management" supports Sidoarjo Regency to rehabilitate and upgrade this landfill and to extend its lifespan.

3.2.2. FUTURE DEVELOPMENTS OF THE SOLID WASTE MANAGEMENT SYSTEM

Indonesia addresses solid waste management systems with regulation and several strategic plans that are also relevant for Sidoarjo Regency. The legislative framework includes a national waste management law of 2008.[123] The 'Long-Term National Urban Development Plan 2015-2045' sets targets for urban service standards and municipal waste management. The 'National Medium-Term Development Plan (RPJMN)' includes an ambitious "100-0-100" target by 2019 for achieving 100% household access to water supply, zero slums and 100% household access to sanitation, including wastewater treatment and solid waste collection. As mentioned above, Indonesia has also committed, in its 'National Plan of Action on Marine Plastic Debris (2017- 2025)', to reduce marine plastic litter by 70% in 2025.

Sidoarjo had previously developed strategic plans for the improvement of solid waste management. Reported targets, such as an increase in collection rates to 85% coverage in 2018, are far from being achieved. According to the Head of DLHK, the Sidoarjo Regency focuses its efforts on improving services and separate collection at community level in order to avoid overburdening of the existing collection system. A Zero-Waste Academy was established in March 2017 to train "agents of change". These are individuals, mostly community representatives, charged with the tasks to report on waste problems (i.e. accumulations, infringements, etc.), develop concepts for solid waste management improvements, create awareness and change behaviour within the community. So far, 240 agents have already completed the training. At the same time, there are plans to install larger scale low-tech incinerators at five TPS-3R locations to deal with the residues after sorting.

The KfW project "Emission Reduction in Cities – Solid Waste Management" supports Sidoarjo Regency and its solid waste management system in two ways. Investments are prepared to rehabilitate, upgrade and expand the existing landfill site. Specialised consultants are working with DLHK on measures to improve service delivery and coverage. The first step in this process is the development of a current master plan for the regency. After assessing the situation in Sidoarjo, the consultants of KfW Development Bank have developed a 5-years development scenario with realistic parameters for future development.

3.3. Marine plastic litter generation in Sidoarjo

Sidoarjo Regency was chosen for this case study mainly due to its very exposed characteristics related to marine litter generation. Its location in an area completely structured by channels and rivers next to the ocean includes the whole population as potential contributors to the problem. The poor performance of the formal solid waste management system creates considerable amounts of unmanaged waste. A lack of awareness about marine litter aggravates the situation. Solid waste management in general is at a relatively low development stage and underfinanced, posing significant barriers to short- and medium-term reductions in plastic leakage into waterways and the sea. These aspects put Sidoarjo at the forefront of the discussions about combating marine litter. Much of the worldwide marine plastic pollution stems from settings similar to Sidoarjo.

3.3.1. LAND-BASED MARINE LITTER SOURCES AND PATHWAYS IN SIDOARJO

One key objective of the case study was to quantify the estimated amount of plastics entering the ocean from a specific region. The application of the methodological approach described in chapter 2 for Sidoarjo Regency bases upon extensive site visits, visual inspections, interviews and an indicative sampling of the composition of mixed waste found in drainage channels during a one-week field mission in July 2017 by a team of two solid waste management experts.

Plastic waste seems omnipresent in Sidoarjo Regency. The site visits and visual inspections indicate that very few areas in urban and rural environments show no traces of unmanaged waste being burned or dumped along the roads or in uncontrolled accumulations. Most waterways, from small drainage channels up to the three main rivers, show significant pollution with plastics and other waste. As the direction of water flow changes with the distribution of irrigation water and with incoming tides, plastics and other types of waste are widely distributed along the water system. While the visits happened during the dry season, heavy rains and partial flooding during the rainy season exacerbate the amount of waste transported into waterways. Rivers also carry plastics that found their way into the water further upstream. In general, openly spread waste is more common in urbanised areas and close to residential areas, but can also be found in rural settings.

The observed behaviour of people indicates that there is little awareness of the consequences of waste polluted waterways among the population. Only the department responsible for the maintenance of the irrigation channels is concerned about the increasing amount of waste. However, they are mainly worried about potential blockages of the water distribution, causing flooding or water shortages. Their plans include straightening the walls of the channels and removing obstacles so that waste does not get stuck but is washed directly into the rivers and the sea.

Plastic residues from informal recycling activities contribute to marine litter generation. There were frequent indications of informal recycling activities, such as storage next to houses in residential areas or substantial accumulations of plastics not suitable for recycling. Sidoarjo hosts a large recycling industry that receives sorted plastics from all over East Java. On the positive side, local markets provide a good value chain for plastic recycling. On the downside, the recycling business brings in large amounts of plastics, which are not all suited for recycling. Furthermore, dynamic markets for recycled plastics and shifting quality requirements produce additional residues from the recycling process itself. Given the poor state of the solid waste management services, they represent an additional threat to the marine environment.

Informal recycling, Sidoarjo

Accumulation in irrigation canal, Sidoarjo

Waste accumulation in water, Sidoarjo

Clean neighbourhood, Sidoarjo

3.3.2. OBSERVATION OF PLASTIC POLLUTION IN WATERWAYS AND THE MARINE ENVIRONMENT

An inspection of the river mouth of the main river in Sidoarjo Regency allowed making several observations. They need however to be dealt with carefully as it was not possible to cover larger areas and to validate them systematically. On the river and in the tidal zone, only larger pieces of plastics are easily spottable. They include, for instance, plastic bottles, shoes and bags. On closer inspection, a significant amount of plastic consists of very small pieces, which are visually hard to recognise. All inspected areas show traces of plastic pollution, only varying in quantities and visibility. The distribution of plastics changes with the tides and depends significantly on the currents creating patches of accumulated plastics. River systems accumulate plastics in areas with low current or along existing barriers. There is no information available on sedimentation rates for different types of plastic and other materials.

In the mangrove areas, plastics are easily visible in some places. On closer inspection, smaller pieces are found everywhere. Floating vegetation is particularly prone to large amounts of smaller plastic pieces. Overall, plastic has become an integral part of the ecosystem. It is virtually everywhere and poses a significant risk to ecosystems. Due to its disperse distribution and ongoing fragmentation, it would require an enormous effort to remove it from the environment. The presence of plastic pollution in Sidoarjo's coastal environment is both easily observable and in its dimension intimidating.

Waste in mangroves, Sidoarjo

Waste trap in a canal, Sidoarjo

Floating barrier, Sidoarjo

Waste composition analysis, Sidoarjo

A sampling and sorting exercise served to get an idea of the main components of debris accumulating in the many drainage and irrigation channels in Sidoarjo. Initially, the plan consisted in cleaning a stretch of a channel, then blocking the channel and letting waste accumulate over a few days, while trying to block waste from other channels. This proved to be impossible as the direction of flow within the irrigation system was not controllable and changed frequently. In close coordination with the DPUPR and their logistical support, it was possible to get a sample of about 3 m^3 of waste that had accumulated at one particular barrier over 48 hours. Of this sample, about 1 m^3 of waste was separated for the sorting process. Sorting was done manually with support of DPUPR workers into a total of 51 singular fractions. For evaluation purposes, these were combined into six main fractions. Only the plastics fraction is presented in more detail.

Fig. 10 shows the composition of the waste sample. It is already corrected for dry weight for hygienic products. However, the sampling is not statistically reliable, nor can the data be used or transferred to other applications. It provides only an indication of the waste composition in this particular setting.

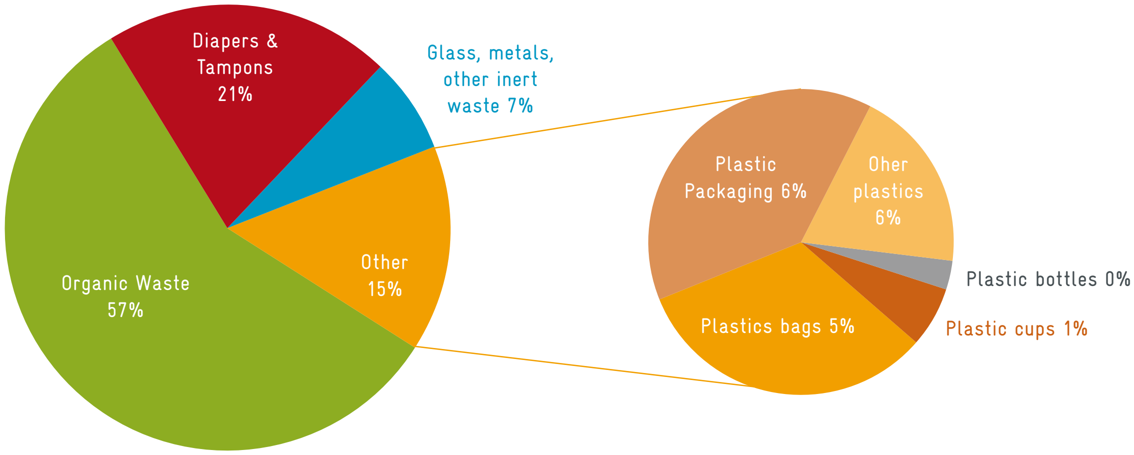


Fig. 10 Waste sample composition, estimated weight-%, Sidoarjo, 2017

Plastics are very visible when inspecting the sample, but due to their light weight they compose only 15% of the total sample weight. Main components are various types of packaging and bags. Plastic bottles are hardly found in this sample. The largest fraction with over 50% consists of organic waste. It is mainly composed of floating vegetation such as water lilies, branches and leaves as well as household organic waste. The second largest fraction are hygienic products, mainly diapers, but also tampons and other products. As these are products designed to absorb large amounts of liquids, their weight has been corrected to their expected, used dry weight. The huge quantities of diapers seemed very uncommon. On further investigation, the team discovered that large parts of the population throw most of the diapers into the water due to a local belief that to burn diapers would harm children. This belief and behaviour are very specific to some parts of Indonesia and would need to be addressed specifically.

The composition indicates that there will be no easy treatment options for waste in waterways. The high water content makes any energetic use inefficient. Mechanical separation seems very unlikely. Composting is not possible due to the mix of materials. The low amount of usable recyclables would not justify specific sorting. In the end, the only practical destination would be landfilling, adding significantly more waste to the scarce resource of landfill space. Most of the organic fractions consist of plants and leaves that should not go to landfilling at all but should be recovered. This shows that from a waste management point of view, the contamination of waterways with municipal waste is not only dangerous for the marine environment. It is also a significant and unnecessary burden for the solid waste management system.

3.3.3. APPLYING THE METHODOLOGICAL APPROACH TO ASSESS PLASTIC LEAKAGE IN SIDOARJO

The team applied the methodological approach described in chapter 2 to the case of Sidoarjo. Since Sidoarjo Regency has been part of solid waste management related development projects at least since 2012, baseline data was readily available to describe the general state of the waste management system. However, data quality was comparatively low as there is no regular recording of all relevant data. Given the specific setting for the primary collection, information about the current collection coverage and collection service efficiency is not readily available. The team therefore referred to reasonable estimates based on the number of equipment and mass flows at the landfill site.

To assess the situation in Sidoarjo, waste streams from households, commercial activities and street littering were analysed. The team focussed on the plastics fraction in solid waste and the plastic content of hygienic products in solid waste due to their relevance for riverine and marine litter. Around 2.4 million inhabitants produce about 0.65 kg of waste per capita and per day. Of this waste, about 9% consists of plastics. In addition, around 13% of the total waste consists of hygienic products that have an average plastic content of 6%. Only 40% of the population has access to regular waste collection. Amongst these 40% households, about 78% of the generated waste is effectively collected. Informal sector systems collect an additional 5% of the total waste amounts.

Several reduction and recycling activities take place. Plastics and other materials are commonly reused or separated at source for recycling purposes. It reduces the amount of plastic waste by 15%. Hygienic products have no secondary use and are therefore not separated at source. Formal recycling takes place at different stages along the waste chain, but most prominently at the TPST and TPS-3R. About 75% of formally and informally collected waste enter waste treatment instead of direct disposal at landfills. Sources estimate the current level of formal recycling to be 30% of the collected waste. Other formal uses such as the production of refuse-derived fuel (RDF) do not take place in Sidoarjo Regency. From informal collection, an estimated 20% of the collected materials are recycled. An estimated 50% of informally collected plastic waste ends up in the environment as it is not recovered nor reinserted into formal collection points.

Analysis of the solid waste management (SWM) system in Sidoarjo Regency			
General parameters	**Unit**	**Value**	**Comment**
Total population in area	Inhabitants	2'400'000	KfW feasibility study
Per capita waste generation	Kg/day	0.65	KfW feasibility study
Plastic fraction	Weight-%	9%	KfW feasibility study
Hygienic products fraction	Weight-%	13%	KfW feasibility study
Average plastic content of hygienic products	Weight-%	6%	Own calculations
SWM system parameters			
Collection coverage (population with access to service)	% of population	40%	KfW feasibility study
Collection efficiency (quantity collected vs generated)	% of plastic waste of covered population	78%	KfW feasibility study
Additional collection by informal systems	% of total plastic waste	5%	KfW feasibility study
Waste treatment parameters			
At source recycling and reuse	% of total plastic waste	15%	0% for hygienic products
Collected waste entering treatment	% of formally and informally collected plastic waste	75%	Own estimation
Formal recycling	% of collected plastic waste entering treatment	30%	KfW feasibility study
Formal RDF/ energy use	% of collected plastic waste entering treatment	0%	No RDF activities
Informal recycling	% of informally collected plastic waste	20%	Interviews with recyclers
Unmanaged waste in the informal sector	% of informally collected plastic waste	50%	Own estimation

Fig. 11 Solid waste management parameters with focus on plastic waste, Sidoarjo, 2017

The model uses several transmission factors for each waste stream (Fig. 12), which represent estimations based on site visits and expert interviews. Three transmission factors [14-16, see Annex 2] estimate how much of the uncollected plastic waste is disposed of in a way that leakage into waterways is very unlikely. Approximately 45% of the total unmanaged waste is openly burned and another 20% of plastic waste is either buried or openly dumped without any possibility to enter into waterways or the sea. Other potential treatment without leakage into waterways has not been identified in Sidoarjo.

Parts of the uncollected waste enter waterways and represent potential marine litter [17-19, 21-22]. About 20% of unmanaged plastic waste is dumped close to water systems, which makes leakage into water likely. Out of this 20%, an estimated 60% finds its way into waterways. It is washed away by rains and floods or eventually dumped when cleaning the roads and riverbanks. Around 5% of the uncollected plastic waste enters the drainage system. An estimated 90% of plastic waste in the drainage system enters into waterways. Approximately 10% of unmanaged plastic waste is directly dumped into waterways. This estimation relies on a calculation after assessing all other factors related to unmanaged waste.

There are only few regulated wastewater treatment systems in Sidoarjo. Yet, it is very difficult to assess how much plastic is flushed down the toilet or how much microplastic is washed out of textiles and cosmetics. A conservative value of 0.01% of total plastic waste generation was therefore used [20].

Furthermore, collected waste can also enter waterways [23-26]. It depends on the cleanliness of operations and the site management of waste facilities. Given the state of operations in Sidoarjo, the team applied transmission factors of 2.5% leakage during collection, 1.5% during treatment, 0.5% during transport from treatment to landfilling and 1.0% during landfilling.

Once waste has entered waterways, three retention factors determine the amount of plastic waste not reaching the marine environment [27-29]. In Sidoarjo, the team estimated that about 1% of plastics are removed by cleaning activities or through the few waste traps installed. Additional 15% of plastics are assumed to have a higher density relative to water and would therefore sink to the ground and remain in the river systems through sedimentation. As plastics do not decompose, the corresponding factor for degradation is set to 0%.

Beaches in Sidoarjo, either along the rivers or at the estuary, are not used for recreational purposes. Therefore, the amount of directly generated marine litter through beach littering is assumed negligible [30].

Transmission factor	Unit	Value	Comments on assessment
Uncollected plastic waste burned (no leakage)	% of uncollected plastic waste	45%	Site visits, expert interviews, existing assessments
Uncollected plastic waste buried or openly dumped (no leakage)	% of uncollected plastic waste	20%	Site visits, expert interviews, existing assessments
Uncollected plastic waste – other treatment (no leakage)	% of uncollected plastic waste	0%	Site visits, expert interviews, existing assessments
Uncollected plastic disposed of close to waterways	% of uncollected plastic waste	20%	Site visits, expert interviews, existing assessments
Percentage of potential leakage of uncollected plastic waste close to waterways	% of uncollected plastic waste close to waterways [17]	60%	Estimate of how much unaccounted uncollected waste will eventually enter waterways
Uncollected plastic waste directly entering waterways	% of uncollected plastic waste	10%	Calculation as difference of sum of all other unmanaged waste streams to total unmanaged waste
Leakage of plastic waste into waterways through the waste-water system	% of total plastic waste (additional)	0.01%	Based on site visits and composition analysis, further research needed
Uncollected plastic waste entering drainage system	% of uncollected plastic waste	5%	KfW feasibility study
Plastic waste in drainage system entering waterways	% of plastic waste entering the drainage system	90%	Site visits, expert interviews, existing assessments
Plastic waste leakage into waterways during collection	% of collected plastic waste	2.5%	Site visits, expert interviews, existing assessments
Plastic waste leakage into waterways during recycling, energy recovery and RDF	% of collected plastic waste entering treatment	1.5%	Site visits, expert interviews, existing assessments
Plastic waste leakage into waterways during transport	% of plastic waste transported from treatment to landfill	0.5%	Site visits, expert interviews, existing assessments
Plastic waste leakage into waterways during landfilling	% of landfilled plastic waste	1.0%	Site visits, expert interviews, existing assessments
Retention factor: technical and natural barriers in waterways	% of plastic waste in waterways	1%	Estimation
Retention factor: sedimentation of plastic waste in waterways	% of plastic waste in waterways	15%	Estimation
Retention factor: degradation of plastic waste in waterways	% of plastic waste in waterways	0%	Estimation
Direct beach& coastal littering	kg/day	0	Beaches in Sidoarjo are not used for recreational activities, insignificant littering

Fig. 12 Transmission factors for plastic waste, Sidoarjo, 2017

Based on these assumptions, an estimated 7'616 t of plastic waste potentially enter the marine environment per year in Sidoarjo Regency. Fig. 13 displays the estimated quantities for each pathway. In total, around 56'073 t of plastic waste, including plastic content of hygienic waste, are produced. About 11'798 t per year reach the formal final disposal site. An additional 8'411 t per year are reused or recycled at source. About 3'570 t of plastic waste are recycled after mixed waste collection. The estimated numbers show that the inefficient collection system is the key element to reduce marine litter pollution in Sidoarjo. Around 31'390 t of plastic waste remains uncollected. Based on the described model, around 9'066 t of plastics are leaked into waterways per year. After taking into account the retention factors in waterways, an estimated 7'616 t of plastic waste in waterways enters the ocean and becomes marine litter.

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in tonne/year

Total plastic waste production	56'073	Formal collection of plastic waste	14'871	Recycling of plastic waste	3'570	Transportation of plastic between treatment and landfill	7'871		
Reuse and recycling at source	8'411	Informal collection of plastic waste	1'402	Energy recovery & RDF of plastic waste	-	Landfilling of plastic waste	11'798		
Total uncollected plastic waste			**31'390**	**Total plastic waste entering waterways**			**9'066**	**Total marine plastic litter**	**7'616**
Uncollected plastic waste burned (no leakage into waterways)	14'125	Uncollected plastic waste burned or dumped close to waterways	6'278	Uncollected plastic waste entering waterways from wild dumpsites	3'767	Plastic waste leakage into waterways during waste collection	407	Direct beach and coastal littering (through tourism, leisure) entering into the ocean	-
Uncollected plastic waste buried or dumped (no leakage into waterways)	6'278	Uncollected plastic waste entering the drainage system	1'569	Uncollected plastic waste entering waterways through drainage system	1'413	Plastic waste leakage into waterways during recycling and energy recovery & RDF	178	Retention of plastic waste in waterways through technical and natural barriers (no leakage into the ocean)	91
Uncollected plastic waste with other treatment (no leakage into waterways)	-	Uncollected plastic waste directly dumped into waterways	3'139	Additional entry of plastic waste into waterways through wastewater system	6	Plastic waste leakage into waterways during transportation	39	Retention of plastic waste in waterways through sedimentation (no leakage into the ocean)	1'360
						Plastic waste leakage into waterways during landfilling	118	Retention of plastic waste in waterways through degradation (no leakage into the ocean)	-

Fig. 13 Results for estimated marine plastic litter generation, Sidoarjo, 2017

3.4. Potential impact of existing development scenarios in Sidoarjo

Several waste management development scenarios exist for Sidoarjo Regency. They have been prepared independently from this study in the framework of the ongoing cooperation between Sidoarjo Regency and KfW Development Bank. The parameters of these scenarios can be used to estimate the potential reduction of marine litter generation. The current situation can be compared with a conservative and a best-case development scenario for the next 5 years. Another option would be to compare with a business-as-usual development scenario for the future, what has not been done in this study. A further option would also be to compare with a more long-term scenario, which might allow increasing the collection coverage more significantly than within 5 years.

The parameters of the development scenarios relate to population growth and expected improvements in the solid waste management system (Fig. 14). In the coming 5 years, the population of Sidoarjo is expected to grow on average 1.66% per year, increasing the number of inhabitants from 2'400'000 to 2'605'925 in 2022. The conservative scenario shows an increase in collection coverage from 40% to 50%, while collection efficiency would improve only marginally from 78% to 81%. However, ongoing improvements of TPS-3R and TPST would cause recycling rates to rise from currently 30% to 55% of formally collected waste. In the 5 years best-case scenario, collection coverage will rise from 40% to 60% of the total population. Collection efficiency will increase even further to very high 93% and an impressive 80% of collected waste will be recycled, composted or otherwise treated.

For assessing potential marine plastic litter reduction for the two scenarios, only these four parameters were adapted. The assessment and joint planning for Sidoarjo is still in its early stages. Therefore, no further assumptions were made, even if the methodological approach would allow modifying all solid waste management parameters and transmission factors for each scenario individually.

	Baseline (2017)	Conservative scenario (2022)	Best-case scenario (2022)
Population	2'400'000	2'605'925	2'605'925
Collection coverage	40%	50%	60%
Collection efficiency	78%	81%	93%
Recycling of collected waste	30%	55%	80%

Fig. 14 Comparison of parameters of development scenarios, Sidoarjo

Fig. 15 displays the results for each scenario. It summarises the most important information to facilitate data comparison. The results show that the *conservative scenario* would reduce potential marine litter only by a slight margin from currently 7'616 t/year to 7'342 t/year. The increase in population and therefore the proportionally growing waste quantities would negatively compensate for the improvements in service delivery and recycling of the conservative scenario. The *best-case scenario* shows that significant improvements in collection service coverage and collection efficiency will reduce the potential for marine litter more drastically. In the best-case scenario, marine litter could decrease by about 20%, from 7'616 t/year to 5'816 t/year, over 5 years of project implementation, despite the increase in waste quantities of a growing population.

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in tonne/year

	Baseline 2017	Conservative Scenario (2022)	Best-Case Scenario (2022)
Total plastic waste production	**56'073**	**60'884**	**60'884**
Reuse and recycling at source	8'411	9'133	9'133
Recycling, energy recovery & RDF	3'570	9'645	21'340
Landfilling of plastic waste	11'798	11'671	7'571
Total uncollected plastic waste	**31'390**	**29'270**	**21'352**
Total plastic waste entering waterways	**9'066**	**8'741**	**6'923**
Retention in waterways	1'451	1'399	1'108
Direct beach and coastal littering	–	–	–
Total marine plastic litter	**7'616**	**7'342**	5'816

Fig. 15 Comparison of scenarios 2017–2022, Sidoarjo

Sidoarjo's estimated 7'616 t of marine plastic litter generation in 2017 is the same as if each of the city's 2.4 million inhabitants would have thrown every 3-4 days one plastic bottle directly into the ocean (106 PET bottles of 30g per bottle per person or year; 3.17 kg of marine plastic waste per inhabitant and year). Through the two 5 year scenarios, this amount would drop to 102 and 81 PET bottles per person and year respectively (2.82 kg and 2.23 kg of marine plastic waste per inhabitant and year). These numbers show that extensive efforts are required to achieve Indonesia's marine litter reduction objective and the respective Sustainable Development Goal at global level.

3.5. Conclusions and recommendations based on the case study of Sidoarjo

The case study shows that plastics have become omnipresent in the riverine and marine environment of Sidoarjo Regency. Mismanaged municipal solid waste is the single most important contributor to it. The efforts to remove it would be enormous given its widespread distribution and medium to very small particle size. Efforts should therefore focus on preventing plastic waste leakage into waterways and the ocean, especially through improved collection. The case study shows that the commitment of the Indonesian government still needs to reach the regional and local level. There is a significant lack of awareness about the issue of marine litter. Regional administrations, municipalities and communities usually focus on maintaining overall cleanliness and combating emergencies. Given the current lack of resources and institutional capacities, local administrations are far from alleviating the marine litter problem.

The following recommendations were developed based on the context of the case study in Sidoarjo Regency. However, they have been formulated in a more generic manner as they can also be relevant for other areas in Indonesia and potentially in Southeast Asia. They can serve as input for public policy and multi-stakeholder dialogues at the local and regional level. To design specific measures, more detailed preparation is required in close consultation between relevant stakeholders.

» **Recommendation 1: Integrate riverine and marine litter prevention as an objective into efforts to improve solid waste management systems**
Currently, there is little linkage between waste management at municipal level and the problem of marine litter, despite the fact that unmanaged municipal waste is one of the key sources of marine plastic pollution. Marine litter is not yet on the agenda of decision-makers in urban areas such as Sidoarjo Regency, although they have a key role to play for achieving the Indonesian marine litter reduction goal of 70% by 2025.

» **Recommendation 2: Enhance collection services, including waste segregation at source, through support for the necessary institutional and legal framework**
The major challenge for waste management in contexts such as Sidoarjo consists in the low coverage of collection services. Support is required in order to create the necessary framework for a large-scale extension of primary waste collection services, including the introduction of waste segregation at source. One key pre-requisite is to establish a mutual or formal obligation for citizens to participate in improved collection services. As communities (smallest administrative entities of a municipality) are responsible for primary waste collection, they require support for the organisation and the identification of adequate operator models for service delivery. Aspects, such as sustained financing and service arrangements, have to be addressed at regency level.

» **Recommendation 3: Promote institutional and individual capacity development**
Strengthening the institutional capacities of local authorities charged with solid waste management is one important step for improving waste collection services. On a decision-making level, local authorities should become able to integrate marine litter into strategic planning processes. Exchange of experiences between different regencies and municipalities as well as the preparation of guidelines can help in this regard. At the level of individual professionals, expertise about waste management and planning processes can be enhanced. The local communities and small-scale operators could benefit from dedicated training and other capacity development measures.

» **Recommendation 4: Raise awareness at the political level and among citizens**
Marine litter is currently hardly recognised as a relevant problem by decision-makers and among citizens. Disposing of waste in an unmanaged way is a commonly accepted daily practise. Public health and ecosystems would benefit from changing behaviour. Increasing access to environmentally sound waste collection and treatment needs to go hand in hand with public information and awareness raising. In light of the big gap in terms of waste collection coverage and efficiency, active citizen engagement for environmentally sound waste disposal at collection points or the use of waste banks would also contribute to preventing marine litter.

» **Recommendation 5: Improve service quality and frequency**
Advisory services should stress the importance of improving collection services and provide options for enhancing operations and future investments to achieve such goals. They should consider an efficient use of available equipment. Furthermore, they should integrate capacity development of local waste collectors that could be tasked to enhance waste collection at community level in combination with regular monitoring and reporting assignments. The role and participation of the private sector in the waste collection process would need to be clarified.

» **Recommendation 6: Establish sustainable financing mechanisms for waste collection**
One of the key obstacles for extending the waste management services are the current lack of funds for necessary investments and sustained operations. Waste management plans can demonstrate alternative scenarios for financial requirements depending on the service levels to be achieved. Such plans would also provide adequate measures to realise the required revenues or subsidies in order to achieve financial sustainability. There is, however, a complex balance between the improvement of services, the required financing and the actual capacity of the population to sustain such a system. In addition, rapid extensions need public and political support, both not easily acquired. The development of systems, which promote decentralised, community-based collection systems, is one possible approach. Additional funding for operational costs might come from the introduction and implementation of Extended Producer Responsibility mechanisms for packaging waste. Such mechanisms would require action at national level and a close dialogue with the private sector, including the consumer goods industry, the plastics industry and retailers.

» **Recommendation 7: Install waste traps or other means of removing plastics in strategic locations**
Even if it is generally preferable to avoid plastics from entering the water system, the removal of floating debris through waste traps can prove feasible as a short-term measure and immediate alleviation of the massive pollution in waterways. The application is however limited to specific locations within the drainage and waterway system and cannot be the only solution to the marine litter problem. Waste traps have also a shredding effect on hard and soft plastics, further accelerating the fragmentation of plastics. However, suited locations can also serve to establish a monitoring system and to enhance knowledge about the local transmission factors of plastic leakage.

» **Recommendation 8: Regularly assess plastic waste leakage into waterways and the ocean and monitor marine litter**
Several monitoring approaches can be applied to get a picture on the extent and sources of plastic pollution as well as its impacts on the marine environment. It requires cooperation between different public stakeholders, scientific institutions, civil society and the private sector. Applying the approach to estimate plastic leakage used in this study is also an option. It can help to demonstrate the dimension of the problem, identify key sources of marine pollution and show the effect of various planned or implemented measures.

CASE STUDY: ANNABA PROVINCE, ALGERIA

Besides Southeast Asia, the Mediterranean Sea is another hotspot for marine pollution. It is a relatively closed basin with high population densities along its coasts. While monitoring of marine litter and its impacts is still limited, research has identified marine litter as a growing issue with effects on various species of fish, cetaceans, reptiles and invertebrates. About 85% of floating marine litter and 45 to 95% of marine litter at the sea surface consists of plastics (UNEP-MAP 2015).[124] Waste generation has significantly increased in Northern African countries such as e.g. Egypt, Morocco and Algeria while waste collection and environmentally sound treatment still requires improvement. The following case study of the coastal area Annaba in Algeria seeks to shed some light on plastic leakage sources and mitigation measures, which are also relevant for other contexts in Algeria and Northern Africa.

4.1. Context of Algeria and Annaba

Algeria counts worldwide amongst the top 20 countries for marine plastic litter generation. In 2010, an estimated 80’000 to 210’000 t of plastic waste leaked from Algerian coastal areas into the Mediterranean Sea (Jambeck et al. 2015).[125] In terms of surface, Algeria is the biggest country in Africa. Due to its geographical and socio-economic conditions, a significant share of the total population of around 41.2 million inhabitants (2017) lives in coastal areas.[126] The 14 coastal Provinces (‘Wilayas’) counted about 13.4 million inhabitants in 2008, which has grown to about 17 million inhabitants in 2017.[127] During the last decades, coastal areas in Algeria have experienced rapid urbanisation combined with strong pressures on the management of natural resources and the delivery of public services.

During the UN Ocean Conference in June 2017, Algeria has submitted several voluntary commitments related to marine litter prevention. Besides awareness raising activities in schools and through beach clean-ups, it announced to update its ‘National Action Plan for the Reduction of Land-based Marine Pollution’ by 2018.[128] Algeria is a Contracting Party of the Barcelona Convention for the Protection of the Mediterranean and its LBS Protocol. Updating its national action plan would contribute to the ‘Regional Plan for the Marine Litter Management in the Mediterranean’, adopted in 2013 in the framework of the Barcelona Convention. Algeria’s action plan on marine pollution of 2005 dealt with potential measures on wastewater treatment, municipal solid waste management, the management of industrial and hazardous waste as well as with institutional and regulatory actions.[129]

Since the early 2000s, Algeria has taken several steps for more sustainable waste management. In 2001, the ‘Law 01-19 on the management, control and elimination of waste’ was adopted. In 2002, the Algerian government created the National Agency for Waste Management (*Agence nationale des déchets, AND*) and launched a specific programme on waste management (*Programme dédié à la gestion des déchets ménagers et assimilés, PROGDEM*) under the responsibility of the Algerian Ministry of Environment.[130] Through PROGDEM, the service delivery of municipal waste management has improved and several wild dumpsites have been replaced by sanitary landfills. Further improvements in terms of waste collection and treatment are however necessary. While, for instance, a legal framework for a management system for packaging waste exists, the so-called “Eco-Jem” system is not yet functional. In 2012, Algeria has also adopted a ‘National Strategy for Integrated Management of Coastal Zones 2015-2030’, which contains several measures on preventing pollution and improving solid waste management in coastal areas.[131]

Annaba Province is located in the Eastern part of Algeria directly at the coast. It comprises 12 communes of which five communes border the sea. The coastline of about 109 km contains beaches as well as mountainous cliffs. One of Algeria’s most important rivers, the river Seybouse, crosses the province and spreads into the sea south of Annaba City. Based on a census of 2008 and an assumed population growth of about 1.8% per year, the province’s population in 2017 counted about 715’654 inhabitants.[132] The two biggest communes Annaba City and El-Bouni account for about half of the province’s population. Tourism during summer holidays, with about 3 million frequentations, plays an important role for Annaba’s economy.[133] Annaba City also hosts a commercial harbour and a fishing port, metal and agrochemical industries and a university. Since 2014, the Algerian-German cooperation supports activities on sustainable waste management and biodiversity conservation in Annaba Province through the projects “Waste management and circular economy” as well as “Environmental and biodiversity governance”, implemented by GIZ.

Fig. 16 Map of the Annaba Province, Algeria[134]

4.2. Solid waste management in Annaba and marine litter prevention activities

4.2.1. CURRENT SITUATION OF THE SOLID WASTE MANAGEMENT SYSTEM

Waste collection in the Annaba Province is either covered by municipal services of individual communes or through delegation to a recently created public company. In 2016, Annaba Province founded the public company 'Annaba Propre' (an *Etablissement Public à Caractère Industriel et Commercial, EPIC*). It has taken over waste collection and transport to the landfill at Berka Zarga for certain communes. At first, this public company only operated in Annaba City. In the meanwhile, it also expanded its services to El-Bouni, the second largest commune of the province. The other communes still depend on municipal services. Primary waste collection takes place from door to door and through voluntary waste disposal into containers of different sizes between 240 to 1'100 litres in the streets. There are also some sites for bulk collection. In general, collection takes place once a day. Often, citizens do not follow this procedure and put waste at other places where it accumulates and creates wild dumpsites.

Waste collection has improved over the last years, notably through the creation of the public company *'Annaba Propre'*. Collection coverage in Annaba City and El-Bouni, the two largest communes of the province, has reached most households. With support by GIZ, the collection and transport system has been reorganised and modernised in order to optimise the use of material means, to achieve redundancy of collection and to enhance service quality. The public company made more containers available and introduced a geo-localisation system to monitor waste transport vehicles.

Waste treatment has also improved considerably. The former waste disposal site at Berka Zerga was closed in 2012. Close to this former site, a new landfill was created, which had been planned in the framework of PROGDEM. Since 2013, it has received the waste of the four biggest communes of the province, about 80% of the province's waste. The remaining waste goes to five controlled dumpsites. A second public company *'CET Annaba'*, which exists since 2013, manages the landfill at Berka Zarga as well as the 5 controlled dumpsites. It also has taken over waste collection in some areas, e.g. in the area El Kalitoussa, and provides collection containers at the fishing port as well as along some beaches and coastlines. There is some extent of competition between the two public companies Annaba Propre and CET Annaba.

There are no official numbers for total collection coverage available. Based on observations and interviews during field visits for this study, waste collection coverage amounts to about 90% of households in the province. Furthermore, this study uses the estimate that the population produces on average about 0.9 kg of municipal solid waste per inhabitant and day. It is a conservative estimate as waste production in urban settings in Algeria is normally higher and as a study for GIZ had estimated 1.3 kg per inhabitant and day for Annaba City.[135] Based on a population of 715'654 inhabitants and a waste generation rate of 0.9 kg/inhabitant/day, the total waste production in Annaba Province was 235'092 t in 2017. Numbers provided by the public company CET Annaba indicate that the landfill and dumpsites received 198'842 t of municipal solid waste. The share of waste generation that has been collected and disposed of at controlled dumpsites and the landfill was therefore 84%. Citizens who are not covered by collection services use other forms of waste disposal, leading to wild dumpsites and burning of waste.

Separate waste collection does not take place in Annaba Province. It is still in an experimental phase in Algeria. While some other provinces have waste separation stations, there is none in Annaba. To some extent, separation takes place at the landfill and controlled dumpsites as well as through informal waste picking in the streets, e.g. of cardboard or PET bottles. There is no facility for composting organic waste.

Plastic separation for recycling mainly takes place at the landfill. The public company CET Annaba has signed agreements with micro-companies. Their teams of informal waste pickers get access to the landfill to separate plastic waste. For each tonne of separated plastic waste, the entrepreneurs pay a certain amount. The CET Annaba keeps the books about these amounts. According to statistics of CET Annaba, about 1'125 t of plastic waste were separated in the first 6 months of 2017. It is an approach to integrate the informal sector into plastic waste separation and to formalise it. The entrepreneurs (middlemen) can then legally sell sorted plastic waste to recycling companies. They usually compress, bale and transport it to other provinces, e.g. Batna, Constantine and Sétif, where recycling companies are active. Recyclers produce there e.g. plastic granules for usage in furniture and blankets. There is a demand for certain plastic types, e.g. PET and PE-HD. Informal plastic waste collection in the streets is less lucrative due to high transport costs. During the summer holiday season, the CET Annaba had also installed some specific containers for separate collection of PET bottles at some beaches, which they sold to the entrepreneurs.

4.2.2. ACTIVITIES BY CIVIL SOCIETY CONTRIBUTING TO MARINE LITTER PREVENTION

Several awareness raising activities on waste and marine litter have taken place in Annaba Province. The province's Environment Centre (*'Maison de l'environnement'*) plays an important role. In 2017, it has conducted the project "Eco-Gardes" at the beach Djenen El Bey in the commune of Seraidi, located in a forested natural area. Eight students were temporarily employed during the holiday season to talk with beach visitors about proper waste handling and to contribute to regular beach clean-ups. The Environment Centre also cooperates with the public companies Annaba Propre and CET Annaba on awareness raising campaigns on waste management in other areas. It has established a network with local NGOs and conducts trainings for young people and children. In 2017, it also co-organised beach clean-ups in the framework of the international 'Clean Seas' campaign of UN Environment as well as in the context of the Algerian annual campaign 'Garbage collectors for the sea' (*'Eboueurs de la mer'*). GIZ has supported the Environment Centre in some of their activities.

Another active stakeholder is the diving club 'Hippone Sub'. Founded in 2002, it has evolved into an environmental NGO.[136] In 2008-2009, the NGO conducted an ocean clean-up with financial support of the European Union. Through diving activities, they collected about 23 t of waste from the seafloor at the coastline of Annaba City, with a plastic content of approximately 70 to 80%. According to interviews with NGO representatives, the cleaned areas have become invaded by waste again. Club members regularly collect waste around their facilities and at the beach where they are practicing their sport. Furthermore, the NGO 'Green Bike' has also been conducting beach clean-up activities in Annaba. It became famous in Annaba for cleaning beaches every day during Ramadan in 2016.

The University Badji Mokhtar of Annaba hosts a specialised department for maritime science. It conducts several studies on different topics related to marine biodiversity and cooperates amongst others with 'Hippone Sub'. Marine plastic litter has not yet been a focus topic of a study thesis so far.

Beach clean-up campaign, Annaba
(Source: Maison de l'Environnement Annaba)

Diving cleanup, Annaba
(Source: Hippone Sub, film extract)

4.3. Sources and pathways of marine plastic litter generation in Annaba

Despite improvements during the last years, plastic waste is omnipresent in Annaba Province. It spreads around housings, in canals and rivers, along the coast, on beaches and on the seafloor. In the following, a qualitative description of plastic waste entry pathways into waterways and the Mediterranean Sea will be presented, based on observations and expert interviews conducted in September and October 2017 in Annaba Province.

4.3.1. PLASTIC WASTE ON WILD DUMPSITES

Remaining gaps in waste collection and lacking environmentally sound behaviour of citizens lead to waste accumulations on small and big wild dumpsites. The most striking example is a wild dumpsite close to the urban district Sidi Salem, which is separated from the beach only by a street. Waste is openly dumped and partly burned. It is very likely that remaining plastic waste is transported over time by wind and by rain into the Mediterranean Sea. This dumpsite is not covered by the province's two public companies in charge of waste management. The urban district of Sidi Salem is a socio-economic hotspot of the province, confronting different types of hardship and social problems, which also influence waste management. The communal authorities have installed some collection containers along the coastal road, which are however not always used as, besides other reasons, there is a lack of calculating the necessary container capacity. Containers are also sometimes overturned and cows are eating parts of the organic and plastic waste on the ground.

Wild dumpsite next to the sea at Sidi Salem

Wild dumpsite next to the sea at Sidi Salem

Waste accumulation at roadside, Annaba

Unmanaged waste at coastal roadside, Annaba

Wild dumpsites and untidy collection points are also frequent in other districts of the province. In some cases, e.g. for big buildings, the number of collection points with waste containers is still insufficient. Furthermore, containers are sometimes overturned or degraded, leading to waste spreading around them. When waste collection points are not regularly cleaned, they attract further open waste disposal.

4.3.2. PLASTIC WASTE IN THE RIVER, DRAINAGE AND WASTEWATER SYSTEM

One of Algeria's most important rivers, the river Seybouse, crosses Annaba Province and flows into the Mediterranean Sea south of Annaba City (Fig. 17). The river is about 225 km long and emanates from semi-arid high plateaus in the south-eastern part of Algeria. Several smaller tributary rivers flow into the river Seybouse, amongst them canals from lake Fetzara in Annaba Province. A systemic assessment of the amount of floating litter or the plastic content within its water and sediments exceeded the scope of this study. It is however likely that the river transports some extent of unmanaged plastic waste from its journey through populated and industrial areas. Other forms of water pollution from industrial activities along the river without wastewater treatment have been described in literature.[137]

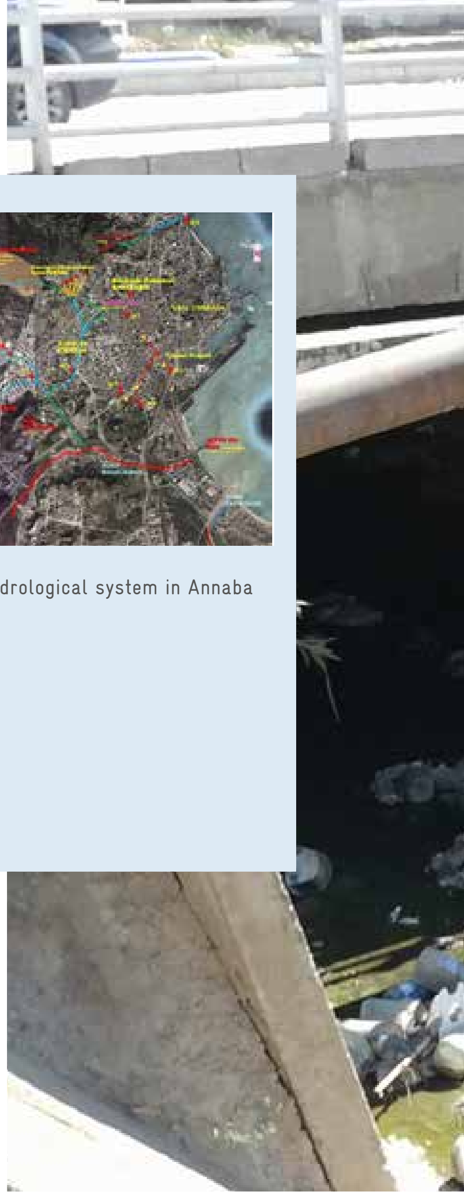


Fig. 17 River Seybouse[138] and hydrological system in Annaba (Source: DHW)

Waste in the Belt canal, Annaba

Waste in the Belt canal, Annaba

Fly-tipping of plastic waste exists along smaller rivers and within Annaba City's open drainage canal, the 'Belt canal' ***('Canal de ceinture').*** The Belt canal system exists since 1988, is underpinned by cement and about 24 km long, including its tributary drainage canals. It flows directly into the sea without passing through wastewater treatment facilities. Parts of the unmanaged plastic waste of the province's urban areas are likely to enter into these open river and drainage systems through wind and rain at one point or the other. PET bottles are particularly visible, but also other forms of packaging and plastic bags. (A large amount of plastic bags is consumed as shops hand them out with every purchase, even for small items.) During the field visits in September and October 2017, the Belt canal system had a low water tablet, which increases however significantly during the winter months and thereby its ability to transport plastics into the Mediterranean Sea. During the field visit, the canal was partly covered by vegetation, which might act as a temporary barrier to plastic waste transportation into the Mediterranean Sea. At parts of the Belt canal, maintenance works took place to remove vegetation and waste in order to allow the drainage canal to fulfil its purpose and to avoid inundations.

Waste in the Belt canal, Annaba

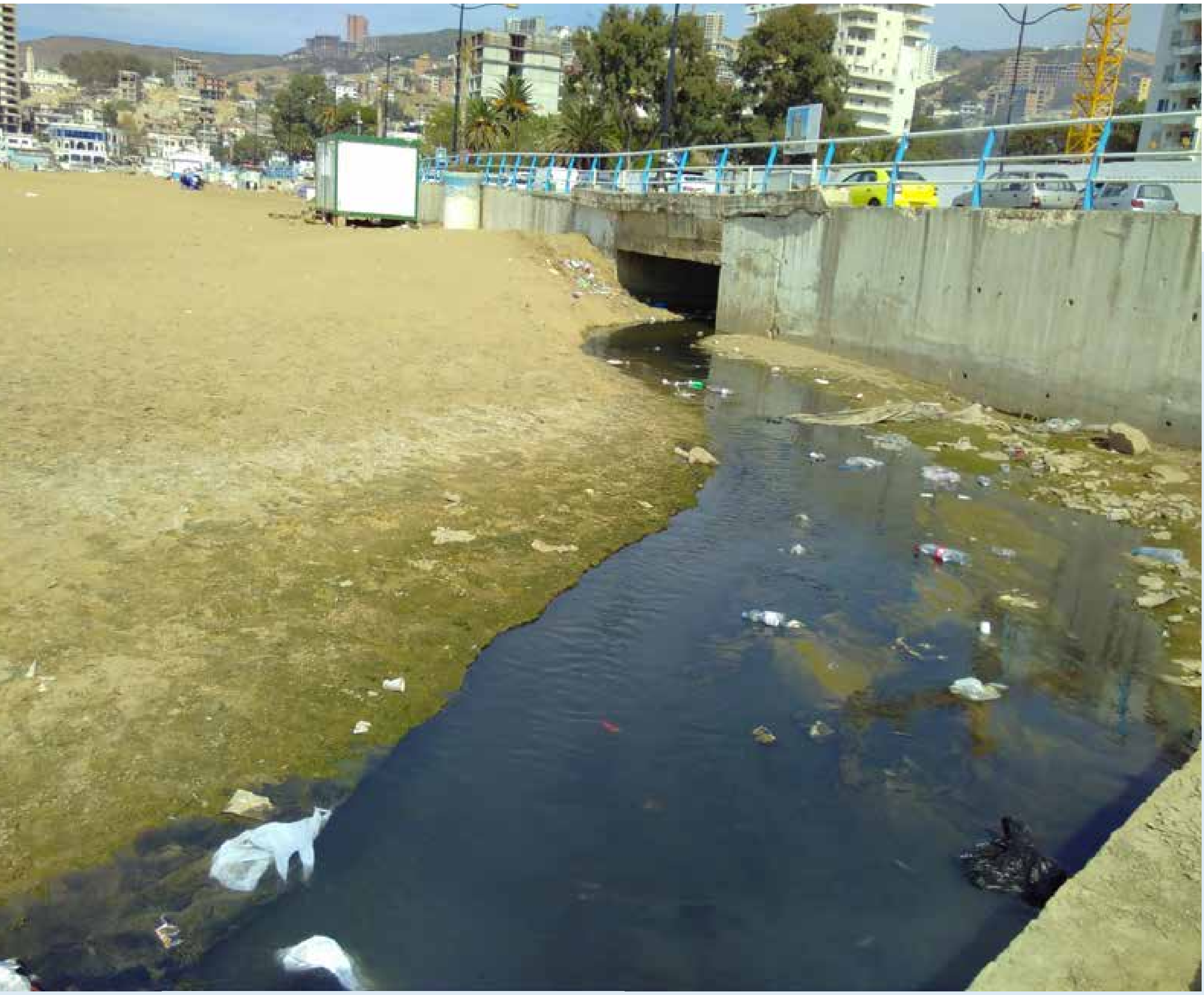
Wastewater entering the sea, Annaba

Fly-tipping of plastic waste in a river, Annaba

Waste accumulation next to river, Annaba

Waste at riverside, Annaba

Leakage of street litter into the underground sewage water and rain drainage system represents another potential pathway for marine litter generation. Plastics in the streets can easily enter through open gullies. Since 2010, Annaba Province has a wastewater treatment facility at Lallelik, which is located about 5 km south of Annaba City. This facility also filters out waste through a grid of 20 mm, as could be observed during a site visit. Other grids with wider mesh sizes for filtering waste exist at preceding pumping stations. The capacity of the wastewater treatment facility is however still underused. According to data of the National Office in charge of sewage treatment (*Office National de l'Assainissement* – ONA), about 90% of the province's population are connected to the wastewater treatment system. While wastewater generation accounts for about 120 litres per inhabitant and day, the wastewater treatment facility only treats 37.7 litres per inhabitant and day.[139] It means that only 32% of wastewater is treated, which is a bit lower than the national average of 34%. The rest enters the open water system and the sea without treatment.



Wastewater entering the sea, Annaba

4.3.3. PLASTIC WASTE AT BEACHES AND ALONG THE COASTLINE

Annaba has several beaches and shores that attract considerable amounts of tourists during summer holidays. Beach access is direct and easy in Annaba City but also outside of the city centre within a forested natural site. During the field visits in September and October 2017 just after the holiday season, large amounts of waste at beaches and rocks were observed. It consisted especially of plastic bottles but also of other types of waste such as cans, glass bottles, cigarette butts, packaging and plastic bags. According to legislation, beach access is free of charge. In fact, however, communes give concessions to private operators who provide parasols and chairs to visitors and take care of the beach's cleanliness. Parking slots are partly improvised and also provided through concessions to private operators. In the absence of showers, beach visitors use plastic bottles to wash their feet and often do not sufficiently care for their environmentally sound disposal, even though waste containers have been installed. In the case of a beach outside of Annaba City (Djenen el Bey), regular waste collection faces the additional difficulty of access in terms of distance and slope, which has led to insufficient collection.

Plastic waste at coastline, Annaba

Waste at coastline, Annaba

Plastic waste not only accumulates at beaches but all along the coastline. Waste density is particularly prevalent at spots along the cliff road where people spend leisure time. Plastic waste in form of bottles and other packaging, as well as cans and glass bottles, are omnipresent at cliffs and between plants. Eventually, wind and rain transport them into the Mediterranean Sea. Some waste collection containers are installed along the coastline. Obviously, they are not sufficient, which might foster a lack of environmentally sound waste disposal behaviour amongst tourists and inhabitants.

Parking at Djenen El Bey beach, Annaba

Plastic waste at coastline, Annaba

Plastic waste at coastline, Annaba

4.4. Quantitative estimation of marine plastic litter generation in Annaba

4.4.1. ESTIMATION FOR THE SITUATION IN 2017

In order to estimate plastic leakage into waterways and the sea within Annaba Province, the methodological approach described in chapter 2 was applied. In 2017, the province's population comprised about 715'654 inhabitants. On average, each inhabitant produced 0.9 kg of municipal solid waste per day – in total about 235'092 t per year. There is no recent data about the share of plastic waste within municipal solid waste. A study of 2012 for Annaba City suggests a share of 10% of plastics.[140] However, this study only considers municipal solid waste from households and excludes waste from commercial entities. An estimate of 17% plastic waste within municipal solid waste in Annaba Province is therefore used. It is based upon the results on waste characterisation in different Algerian regions recently communicated by the AND.[141] In the case of Annaba Province, hygienic waste and its plastic content was not considered in a separate manner.

Furthermore, there are no specific numbers on collection coverage through the two public companies and the communes for Annaba Province. According to observations and interviews, collection coverage of households and commercial entities can be estimated at 90%. It takes into account that areas without or with partial collection still exist, like the area of Sidi Salem for instance. Amongst these 90% of households and commercial entities, it can be estimated that about 94% of municipal solid waste is effectively collected. The estimate of 94% is based on the previously described ratio between total waste generation and waste entering the disposal sites of the public company CET Annaba. About 84% of generated waste is collected and goes to the disposal sites of the public company CET Annaba (90% of collection coverage multiplied with 94% collection efficiency).

There is no waste separation at source in Annaba Province. Only marginal reuse and recycling of plastic waste at household and commercial level exists and accounts for an estimated 1% of total plastic waste generation. Concerning formal recycling, partially organised activities take place at the landfill and to some extent at controlled dumpsites. As there are no specific treatment facilities, it is assumed that 100% of waste goes into treatment, which is in this case equivalent to the disposal sites. However, only about 1% of total plastic waste generation (PET, PEHD, films) is separated at the disposal sites for further recycling. This estimate is based upon data by CET Annaba on plastic waste separation. Furthermore, a certain level of unauthorised waste segregation takes place during collection by garbage collectors and drivers, a kind of informal separation within the formal system, which is not considered in quantitative estimates in this study. Energy recovery from plastic waste or its use as refuse-derived fuel in cement plants do not take place in Annaba Province. Figure 18 provides a summary on the above-mentioned data.

Analysis of the solid waste management (SWM) system in Annaba Province			
General parameters	**Unit**	**Value**	**Comment**
Total population in area	Inhabitants	715'654	Census of 2008, annual growth of 1.8%
Per capita waste generation	Kg/day	0.90	National average for urban areas
Plastic fraction	Weight-%	17%	AND
SWM system parameters			
Collection coverage (population with access to service)	% of population	90%	Estimation
Collection efficiency (quantity collected vs generated)	% of plastic waste of covered population	94%	Calculation
Additional collection by informal systems	% of total plastic waste	0%	Estimation
Waste treatment parameters			
At source recycling and reuse	% of total plastic waste	1%	Estimation
Collected waste entering treatment	% of formally and informally collected plastic waste	100%	All waste goes to disposal sites where some treatment takes place
Formal recycling	% of collected plastic waste entering treatment	1%	Data of "CET Annaba" used for estimation
Formal RDF/ energy use	% of collected plastic waste entering treatment	0%	Does not exist in Annaba Province
Informal recycling	% of informally collected plastic waste	0%	Estimation

Fig. 18 Solid waste management parameters with focus on plastic waste, Annaba, 2017

Figure 19 provides an overview for the transmission factors used for the case study in Annaba Province. As no data is available for such transmission factors, they are based on estimates related to field observations and interviews. Concerning waste that cannot enter waterways [14-16], an estimated 20% of uncollected plastic waste is burned. Further 30% are buried or end up at dumpsites without potential leakage into waterways. About 10% are disposed of in another manner, which make leakage unlikely.

Leakage of plastic waste into waterways arises through several pathways in Annaba Province [17-22]. About 30% of uncollected plastic waste is burned or disposed of at wild dumpsites close to waterways. Out of this waste, about 70% probably enter waterways. Due to the presence of street litter and the situation of the drainage system, an estimated 10% of uncollected plastic waste enters the drainage system of which 50% end up in waterways. Directly throwing plastic waste into waterways is marginal in Annaba and therefore appears in the calculation of this study with 0%. Most likely, there are additional plastics entering waterways through the wastewater system, e.g. micro-plastics from textiles, cosmetics or hygienic products. It is however very difficult to estimate this amount and an indicative value of 0.01% of total plastic waste generation is therefore used.

With regards to leakage from the waste management system [23-26], an estimated 1% of collected plastic waste enters waterways during collection. An additional 1% of plastic waste entering treatment probably also leaks into waterways. As all treatment takes place at the landfill, there is no further transport between treatment and landfill and the corresponding transmission factor is 0%. As the landfill is located far from waterways, leakage from this point in the waste management chain is also 0%.

Parts of plastic waste in waterways are probably retained [27-29]. An estimated 20% of plastic waste in waterways does not enter the ocean due to technical and natural barriers such as clean-up activities and vegetation. An additional 15% of plastic waste in waterways might stay there through sedimentation processes. As plastics degrade slowly into smaller pieces, 0% is retained through degradation.

Direct littering at beaches and along cliffs from tourism and leisure activities further contributes to marine plastic litter generation. During the summer holidays, there are about 3 million visits of beaches. To calculate a rough number, it is estimated that each visit is linked to the consumption of one PET bottle of 1.5 L, of which about 30% do not end up in collection bins but in the environment. If each bottle has a weight of 30 g, there are about 27 t of plastic beach litter per year or 74 kg per day (3 million * 30% * 30 g). Another approach to estimate numbers would be to conduct beach clean-ups combined with scientific protocols for analysing the collected waste items. Such an approach would however also require an idea about time spans within which waste accumulates as well as a potential distinction between land-based and sea-based sources of waste at beaches and cliffs.

Transmission factor	Unit	Value	Comments on assessment
Uncollected plastic waste burned (no leakage)	% of uncollected plastic waste	20%	Site visits, expert interviews, existing assessments
Uncollected plastic waste buried or openly dumped (no leakage)	% of uncollected plastic waste	30%	Site visits, expert interviews, existing assessments
Uncollected plastic waste – other treatment (no leakage)	% of uncollected plastic waste	10%	Site visits, expert interviews, existing assessments
Uncollected plastic disposed of close to waterways	% of uncollected plastic waste	30%	Site visits, expert interviews, existing assessments
Percentage of potential leakage of uncollected plastic waste close to waterways	% of uncollected plastic waste close to waterways [17]	70%	Estimate of how much unaccounted uncollected waste will eventually enter waterways
Uncollected plastic waste directly entering waterways	% of uncollected plastic waste	0%	Calculation as difference of sum of all other unmanaged waste streams to total unmanaged waste
Leakage of plastic waste into waterways through the waste-water system	% of total plastic waste (additional)	0.01%	Based on site visits and composition analysis, further research needed
Uncollected plastic waste entering drainage system	% of uncollected plastic waste	10%	KfW feasibility study
Plastic waste in drainage system entering waterways	% of plastic waste entering the drainage system	50%	Site visits, expert interviews, existing assessments
Plastic waste leakage into waterways during collection	% of collected plastic waste	1%	Site visits, expert interviews, existing assessments
Plastic waste leakage into waterways during recycling, energy recovery and RDF	% of collected plastic waste entering treatment	1%	Site visits, expert interviews, existing assessments
Plastic waste leakage into waterways during transport	% of plastic waste transported from treatment to landfill	0%	Site visits, expert interviews, existing assessments
Plastic waste leakage into waterways during landfilling	% of landfilled plastic waste	0%	Site visits, expert interviews, existing assessments
Retention factor: technical and natural barriers in waterways	% of plastic waste in waterways	20%	Estimation
Retention factor: sedimentation of plastic waste in waterways	% of plastic waste in waterways	15%	Estimation
Retention factor: degradation of plastic waste in waterways	% of plastic waste in waterways	0%	Estimation
Direct beach& coastal littering	kg/day	74	Beaches in Sidoarjo are not used for recreational activities, insignificant littering

Fig. 19 Transmission factors for plastic waste, Annaba, 2017

Based on these estimates, total marine plastic litter generation in Annaba Province amounted to about 1'494 t in 2017. It represents about 3.7% of total plastic waste production in Annaba Province. In total, about 39'966 t of plastic waste was produced in 2017. About 32'475 t ended up at the landfill and controlled disposal sites, corresponding to 81% of plastic waste generation. An additional 731 t were reused, recycled or otherwise treated through waste management and at source. The numbers show that the coverage and efficiency of waste collection are a key element for preventing marine pollution in Annaba. About 6'093 t of plastic waste were not collected corresponding to 15.2% of total plastic waste production. About 2'254 t of plastic waste entered waterways in 2017, 5.6% of produced plastic waste. Of the plastic waste that has entered waterways, about 789 t were retained before they could enter the ocean.

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in tonne/year

Total plastic waste production	39'966	Formal collection of plastic waste	33'473	Recycling of plastic waste	331	Transportation of plastic between treatment and landfill	32'475		
Reuse and recycling at source	400	Informal collection of plastic waste	-	Energy recovery & RDF of plastic waste	-	Landfilling of plastic waste	32'475		
Total uncollected plastic waste	**6'039**			**Total plastic waste entering waterways**	**2'254**			**Total marine plastic litter**	**1'494**
Uncollected plastic waste burned (no leakage into waterways)	1'219	Uncollected plastic waste burned or dumped close to waterways	1'828	Uncollected plastic waste entering waterways from wild dumpsites	1'280	Plastic waste leakage into waterways during waste collection	335	Direct beach and coastal littering (through tourism, leisure) entering into the ocean	27
Uncollected plastic waste buried or dumped (no leakage into waterways)	1'828	Uncollected plastic waste entering the drainage system	609	Uncollected plastic waste entering waterways through drainage system	305	Plastic waste leakage into waterways during recycling and energy recovery & RDF	331	Retention of plastic waste in waterways through technical and natural barriers (no leakage into the ocean)	451
Uncollected plastic waste with other treatment (no leakage into waterways)	609	Uncollected plastic waste directly dumped into waterways	-	Additional entry of plastic waste into waterways through wastewater system	4	Plastic waste leakage into waterways during transportation	-	Retention of plastic waste in waterways through sedimentation (no leakage into the ocean)	338
						Plastic waste leakage into waterways during landfilling	-	Retention of plastic waste in waterways through degradation (no leakage into the ocean)	-

Fig. 20 Results for estimated marine plastic litter generation, Annaba, 2017

4.4.2. COMPARISON WITH THE PRIOR SITUATION IN 2014

While additional initiatives to prevent marine litter will be necessary, several measures have already been implemented during the last years in Annaba Province. It invites to compare between 2017 and the prior situation in 2014. Only some of the entry data will be modified for this purpose (Fig. 21). It is assumed that the population in 2014 amounted to about 681'000 inhabitants and that the share of plastic waste was 15%. Furthermore, it is estimated that waste coverage accounted for about 80% of households in 2014 and that the efficiency of waste collection was at 88%. All other entry data and transmission factors remain the same.

	2014	2017
Population	681'000	715'654
Share of plastic waste	15%	17%
Collection coverage	80%	90%
Collection efficiency	88%	94%

Fig. 21 Comparison of changed input data for 2014 and 2017, Annaba

Fig. 22 compares the results for 2014 and 2017 (see also Annex 3). As the total population and the share of plastic waste within the composition of municipal solid waste was lower in 2014, total plastic waste production was about 33'556 t in 2014 compared to 39'966 t in 2017. At the same time, lower waste collection performance in 2014 signifies that about 9'833 t of plastic waste (29.3%) were uncollected instead of 6'093 t (15.2%) in 2017. The estimated marine plastic litter generation was 1'995 t in 2014, 5.9% of total plastic waste production, compared to 1'494 t (3.7%) in 2017. Thus, an estimated reduction of marine litter generation of about 500 t took place between 2014 and 2017 due to enhanced collection performance.

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in tonne/year

	2017	2014	
Total plastic waste production	**39'966**	**33'556**	–
Reuse and recycling at source	400	336	–
Recycling, energy recovery & RDF	331	232	–
Landfilling of plastic waste	32'475	22'690	–
Total uncollected plastic waste	**6'093**	**9'833**	–
Total plastic waste entering waterways	**2'254**	**3'025**	–
Retention in waterways	789	1'059	–
Direct beach and coastal littering	27	27	–
Total marine plastic litter	**1'494**	**1'995**	–

Fig. 22 Comparison of results for 2017 (baseline) and 2014 (scenario 1), Annaba

In 2017, there were about 2.09 kg of marine plastic litter per inhabitant in Annaba Province. It is equivalent to each inhabitant throwing 70 plastic bottles of 30g per bottle into the Mediterranean Sea, one bottle every 5 days. It corresponds to 140 plastic bags of 15g per bag. In 2014, marine plastic litter generation by inhabitant was even higher at about 2.93 kg. It was equivalent to 98 plastic bottles – one bottle every 4 days.

4.5. Conclusions and recommendations based on the case study of Annaba

Marine plastic litter represents a serious issue in Annaba Province. Several activities have already been conducted by different stakeholders, which contributed to marine plastic litter prevention. In order to further reduce marine plastic litter generation, additional efforts will be necessary in Annaba as well as in other coastal cities and regions of Algeria and Northern Africa. The following recommendations based on the context of Annaba seek to provide ideas for potential measures at regional and local level.

» **Recommendation 1: Promote separate collection of plastic bottles**
Awareness raising and the extension of waste collection go hand in hand. The separate collection of plastic bottles could serve as a tangible example for marine litter prevention. Waste collection operators could sign voluntary agreements with commercial entities, hotels, restaurants, university entities and others to separate plastic bottles. In the case of Annaba, the two public companies Annaba Propre and CET Annaba could take over this role. After their separate collection, plastic bottles could be directly sold to existing recycling intermediaries in order to reduce costs for transport and access to the landfill. To increase awareness raising and sensibility for waste as a resource, municipalities and waste management operators can install permanent public communication units. Cooperation with Environment Centres, NGOs, private initiatives and also Imams can be envisaged for sensitisation towards waste and resource management rather than littering the environment. At national level, the creation of a deposit-refund system for plastic bottles and other beverage packaging can be considered.

» **Recommendation 2: Further improve waste collection**
While waste collection has been significantly improving, it is not yet ideal. In some areas, waste collection coverage and efficiency still need to increase drastically and wild dumpsites need to be closed to protect public health and prevent marine litter. In Annaba, this is for instance the case for Sidi Salem where an open dumpsite is located close to the beach. Waste management operators need to provide sufficient collection containers, especially for larger housings, and ensure their protection and maintenance. In order to achieve a sustainable collection system, they should strive for improving cost recovery, e.g. through payments from markets, shops, hotels, restaurants, universities etc. for waste collection services (initiating the polluter-pays principle). Realistic financial contributions from households would also be necessary. Extended producer responsibility mechanisms should also be used as an instrument for financing efficient and sustainable waste management.

» **Recommendation 3: Cooperate with local fishermen**
One option would be to organise awareness raising campaigns or to provide incentives for fishermen to bring back by-catch waste to the port for environmentally sound disposal instead of throwing them back into the sea. Cooperation between fishermen and divers could also be further encouraged to recover lost fishing gear where it is feasible – some examples of such interactions exist in Annaba. Furthermore, municipalities and waste management operators could enhance their cooperation with harbour administrations in terms of waste collection at port and its transport to landfills. It should include information to fishermen to increase their trust in the performance of waste collection and treatment services.

» **Recommendation 4: Encourage scientific research on environmental and economic impacts of marine litter**
In order to increase scientific knowledge on marine litter, it would be useful to offer master or doctoral theses at universities. Economy related topics would be for instance: costs for cleaning, lost revenues from deterred tourism (opportunity costs), costs for fishermen for cleaning nets and through dangers for motors, damage to material such as pumps in the wastewater system. Other topics could include toxicological impacts on individual species, microplastics spreading through food chains, assessment of plastic accumulation and transport in different layers of the riverine and marine environment, systematic quantification and characterisation of plastics at beaches. Cooperation with Mediterranean networks such as the consortium 'Plastic Busters' of the University of Siena and the UN Sustainable Development Solutions Network are an option in this regard.

» **Recommendation 5: Raise awareness by organising clean-up campaigns**

Several clean-up initiatives exist already in Annaba Province and other areas in Algeria and Northern Africa. They are, however, not sufficient. After their implementation, as could be observed during a site visit. Initiatives such as the project 'Eco-Gardes' in Annaba could be expanded to other beaches and sponsoring by tourism stakeholders like hotels and travel agencies could be envisaged, e.g. for producing information material. Voluntary clean-up activities are also important in housing areas along canals and rivers, which can be organised by district committees, environmental organisations and mosques. Municipalities or Environment Centres might take a coordinating role, also contributing to public communication and outreach. Clean-up campaigns should not only take part before and during but also after the holiday season in order to avoid waste leakage into the Mediterranean Sea through winter rains.

» **Recommendation 6: Reduce plastic waste leakage into the drainage and wastewater system**

Besides improving street sweeping, the coverage of gullies and sewers should be improved. It would reduce plastic waste leakage into the canalisation and thereby the risk of inundations and marine litter generation. Existing efforts by offices in charge of sewage treatment should continue and lead to a phasing out of all forms of wastewater arriving at beaches and the coast. Waterways, as well as their surroundings, should be regularly cleaned in order to avoid plastic waste transport into the Mediterranean Sea.

» **Recommendation 7: Develop recycling value chains and controlled landfills**

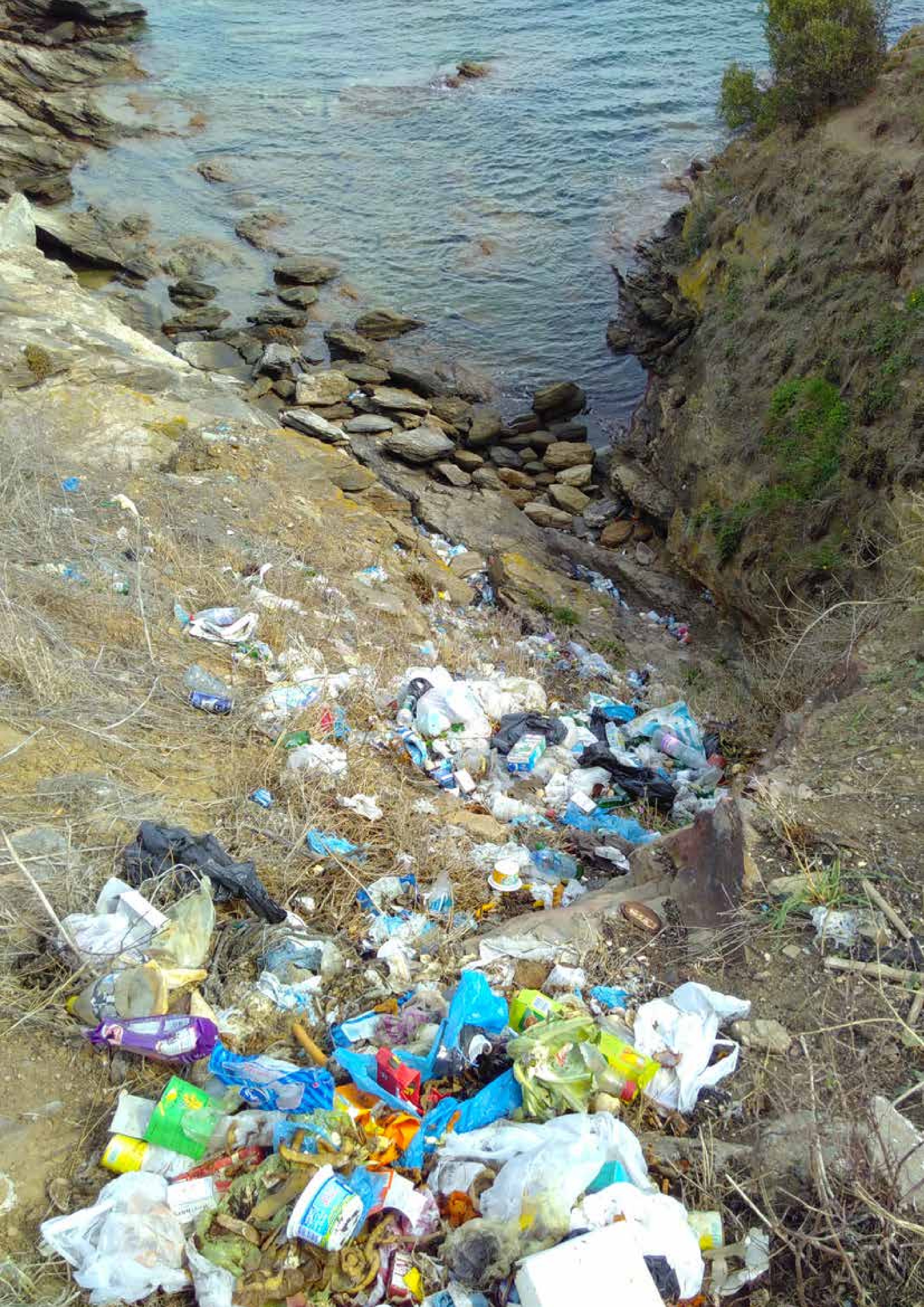
In order to increase recycling, installing separation centres at landfills or prior to landfills would be an option to follow-up. Where not yet the case, integrating informal waste collectors into waste separation is necessary. Concluding agreements with small-scale businesses who buy recyclables is an option, as it is practiced in Annaba. It needs to include measures for occupational health and safety standards as well as the prohibition of child labour.

» **Recommendation 8: Install a regular monitoring system**

Regular monitoring should assess the evolution of marine plastic litter generation over time and space. It could go deeper into analysing the composition and volumes of waste and its distribution over the different entry pathways. It could also involve an assessment of economic and ecological impacts. The effect of mitigation measures could also be evaluated. For quantitative estimations, approaches such as the one used in this study could be applied. Clean-up campaigns can contribute to useful data gathering if they apply standardised protocols.[142]

» **Recommendation 9: Create a roundtable on marine litter**

The various stakeholders who are already active in the field of waste management, environmental education and other areas at regional and local level could create a roundtable or working group for regular exchange on marine litter. They could describe problems and identify potential solutions as well as opportunities for cooperation. It would not be an additional institution but rather a network that could be based on existing collaborations. Stakeholders of public administration on environment and the economy, tourism, the communes, public companies for waste and wastewater treatment, NGOs, shops, plastic recyclers, fishermen and port representatives, universities and radio channels could take part in such a roundtable.



DISCUSSION AND OUTLOOK

Reducing plastic leakage into waterways and the ocean for protecting biodiversity and human livelihoods is a major challenge. However, suitable approaches to address this challenge exist, which would simultaneously bring needed improvements in municipal solid waste management services and support the transition towards a circular economy. Assessing plastic leakage into waterways and the ocean can represent a first step for municipalities and regions. It can serve as a basis for broader stakeholder dialogues and the identification of appropriate prevention measures. Further steps involve implementing these measures and monitoring their effects. Local action should also be accompanied by global exchange of experiences amongst committed municipalities and other stakeholders from public administration, the private sector, civil society and scientific institutions.

Some differences exist between the two study areas in Southeast Asia and Northern Africa. They are related to the geographical and socio-economic conditions as well as the respective level of waste management services. According to the estimates for 2017, Sidoarjo in Indonesia generated significantly more marine plastic litter (7'616 t, 3.17 kg per capita) than Annaba in Algeria (1'494 t, 2.09 kg per capita). The large variation in absolute numbers partly results from the difference in total population numbers as Sidoarjo Regency (2.4 million) has more than three times the population of Annaba Province (0.7 million). However, the waste generation rate per capita was lower in Sidoarjo (0.65 kg per capita/day) than in Annaba (0.90 kg per capita/day). Furthermore, the share of plastics in the municipal solid waste composition was lower in Sidoarjo (9% plastic waste) than in Annaba (17% plastic waste), although additional plastic content of hygienic waste forms part of the data in Sidoarjo but not in Annaba.

A major difference between Sidoarjo and Annaba consists in the level of waste collection. Collection coverage and efficiency were significantly higher in Annaba (90% and 94%) than in Sidoarjo (40% and 78%). This leads to significant differences in the amount and share of uncollected plastic waste. In Sidoarjo, an estimate 56'073 t of plastic waste were generated in 2017, of which about 31'390 t or 56% of the plastic waste were not collected or reused and recycled at household level. In Annaba, 39'966 t total plastic waste was generated, of which about 6'093 t or 15.2% of was uncollected. It is estimated that 9'066 t of plastic waste entered waterways in Sidoarjo Regency, representing 16.2% of the total plastic waste generated. Due to better collection coverage and efficiency in Annaba, a smaller proportion, 5.6% or 2'254 t, of the total plastic waste generated entered waterways. These amounts derive from part of the uncollected waste as well as leakage from the waste management system.

Reducing land-based marine plastic litter generation is possible. This is demonstrated through comparing changes to the waste management system in Annaba between 2014 and 2017 as well as the 5-year scenarios for Sidoarjo. Improvements require several efforts such as those suggested in the recommendations of this study. In contexts such as Sidoarjo, the primary need is to increase waste collection coverage and efficiency. Achieving such improvements requires, however, a set of actions by different stakeholders concerning operator models, financing schemes and public awareness amongst others. More detailed research and dialogue is necessary in this regard. In contexts such as Annaba, separate waste collection of plastic bottles and other packaging, the development of recycling value chains, awareness raising and regular beach clean-ups appear important. Together with other stakeholders, local waste management operators play a crucial in facilitating this. For both contexts, introducing and implementing extended producer responsibility mechanisms at national level would be a significant step forward.

Recommendations based on the case study in Sidoarjo Regency

1. Integrate riverine and marine litter prevention as an objective into efforts to improve solid waste management systems
2. Enhance collection services, including waste segregation at source, through support for the necessary institutional and legal framework
3. Promote institutional and individual capacity development
4. Raise awareness at the political level and among citizens
5. Improve service quality and frequency
6. Establish sustainable financing mechanisms for waste collection
7. Install waste traps or other means of removing plastics in strategic locations
8. Regularly assess plastic waste leakage into waterways and the ocean and monitor marine litter

Recommendations based on the case study in Annaba Province, Algeria

1. Promote separate collection of plastic bottles
2. Further improve waste collection
3. Cooperate with local fishermen
4. Encourage scientific research on environmental and economic impacts of marine litter
5. Raise awareness by organising clean-up campaigns
6. Reduce plastic waste leakage into the drainage and wastewater system
7. Develop recycling value chains and controlled landfills
8. Install a regular monitoring system
9. Create a roundtable on marine litter

Fig. 23 Recommendations based on the two case studies

The issue of marine litter still requires awareness raising among local decision-makers. Assessing the current situation and future scenarios for different implementation measures can be helpful for this. The methodological approach for assessing plastic leakage used in this study provided qualitative descriptions as well as quantitative estimates for two distinct regions. It displays plastic waste flows within the waste management system and outside of it. It estimates the amount of plastic waste leaking into waterways from uncollected waste and from the waste management system. Furthermore, it estimates how much of the plastic waste is retained in waterways before entering the ocean and how much additional marine plastic litter arises from littering at beaches and coastlines. This approach complements existing approaches to monitoring which measure the extent of litter found within rivers, at the seafloor or at beaches. The approach is similar to modelling approaches conducted by Jambeck et al. (2015) but focuses on a local and regional level instead of national and global data.

Assessing plastic leakage requires the collection of data as well as the evaluation of several transmission factors. Conducting such studies requires the involvement of experienced solid waste management experts who are already familiar with the local situation or have sufficient time for field visits. The results are only a tentative approximation to the chaotic reality of plastic waste flows, relying on assumptions and expert judgements, observations and interviews, as well as waste management data from local authorities and international development cooperation projects. If such waste management data are not available, a general assessment of the solid waste management system should be undertaken, for instance with the help of the 'Wasteaware' benchmark indicators, before assessing plastic leakage.[143]

In a next step, this assessment approach can be developed into a tool for municipalities and regional administrative bodies. Applying the approach in different settings is necessary to fine-tune the estimation of transmission factors, which may enable the development of default transmission factors for different world regions or contexts. The graphic visualisation of plastic waste flows can be improved. Following this, the tool may support regular monitoring in local areas in addition to other monitoring approaches for marine litter. Linking this methodology to financial data would also enable cost-effectiveness assessment and comparison of different measures for preventing marine plastic litter. Such a tool could thereby support multi-stakeholder processes, planning and decision-making. While focussing on plastics, such a tool could also be helpful for taking into account other types of waste going into waterways or being managed in an uncontrolled manner (e.g. open burning) and causing negative environmental and health effects.

Further research is needed on the marine litter prevention measures mentioned in this study. These questions must be addressed in the local context in the coming years if we are to stem the ever-increasing tide of plastics. For instance, what kind of plastic recycling technologies can present a viable business model in different contexts, whilst also complying with environmental and social standards? What is the best way to integrate informal sector workers into improved plastic recycling value chains? How can sufficient awareness and environmentally sound behaviour be achieved? How can source-to-sea approaches be applied for marine litter prevention? How to mobilise political commitment and endurance to successfully introduce and implement extended producer responsibility mechanisms and deposit-refund systems for packaging? How to incentivise design for recycling and the use of recycled materials at scale? To answer these questions, cooperation between multiple actors with partly conflicting interests will be necessary. There is a chance to learn from successful approaches in other countries, however in many instances countries must forge ahead with locally adapted solutions to their waste management problems.

ANNEX

Annex 1: Calculations used in the methodological approach for assessing plastic leakage

The following list provides an overview of the calculations used in the methodological approach. The calculation sheets are hidden in the Excel table to make its application easier. As all values are first calculated on a kg/day basis, the results sheets transform them into t/year numbers (through multiplication with 365 days/year and division by 1000kg/t). The calculations generally combine plastic waste and plastic content within hygienic waste. The calculations below display within square brackets the corresponding entry data.

MANAGED PLASTIC WASTE

Total plastic waste production
Population [1] * Municipal solid waste generation per capita [2] * Share of plastic waste within municipal solid waste composition [3.3.2]
+ Special factor for plastic content in hygienic waste [3.3.a] * Population [1] * Municipal solid waste generation per capita [2] * Share of hygienic waste within municipal solid waste composition [3.3.5]

Reuse and recycling at source
Total plastic waste production * Transmission factor for reuse and recycling at source [9]
+ Special factor for plastic content in hygienic products [3.3.a] * Generated hygienic waste * Transmission factor for reuse and recycling at source [9])

Formal collection of plastic waste
(Total plastic waste production - Reuse and recycling at source of plastic waste) * Transmission factor for collection coverage [4] * Transmission factor for collection efficiency [5]
+ Special factor for plastic content in hygienic products [3.3.a] * (Total production of hygienic waste - Reuse and recycling at source of hygienic waste) * Transmission factor for collection coverage [4] * Transmission factor for collection efficiency [5]

Informal collection of plastic waste
Total plastic waste production * Transmission factor for informal collection [6] * (1 – Transmission factor for unmanaged waste in the informal sector [8])
+ Special factor for plastic content in hygienic products [3.3.a] * Hygienic waste production * Transmission factor for informal collection [6] * (1 - Transmission factor for unmanaged waste in the informal sector [8])

Recycling of plastic waste
((Formal collection of plastic waste + Informal collection of plastic waste) * Transmission factor for collected waste entering treatment [10] – (Leakage of plastic waste from waste collection * Transmission factor for collected waste entering treatment [10])) * Transmission factor for formal recycling [11]
+ Special factor for plastic content in hygienic products [3.3.a] * ((Formal collection of hygienic waste + Informal collection of hygienic waste) * Transmission factor for collected waste entering treatment [10] – Leakage of hygienic waste from waste collection * Transmission factor for collected waste entering treatment [10])) * Transmission factor for formal recycling [11]

Energy recovery and refuse derived fuel (RDF) of plastic waste

(Formal collection of plastic waste + Informal collection of plastic waste) * Transmission factor for collected waste entering treatment [10] - Leakage of plastic waste from waste collection * Transmission factor for collected waste entering treatment [10]) * Transmission factor for energy recovery and RDF [12]
+ Special factor for plastic content in hygienic products [3.3.a] * (Formal collection of hygienic waste + Informal collection of hygienic waste entering formal system) * Transmission factor for collected waste entering treatment [10] – Leakage of hygienic waste from waste collection * Transmission factor for collected waste entering treatment [10]) * Transmission factor for energy recovery and RDF [12]

Transportation of plastic waste between treatment and landfill

(Plastic waste entering treatment – Recycling of plastic waste – Energy recovery and RDF of plastic waste – Plastic waste leakage from treatment – Plastic waste treatment by informal activities)
+ Special factor for plastic content in hygienic products [3.3.a] * (Hygienic waste entering treatment – Recycling of hygienic waste – Energy recovery and RDF of hygienic waste – Hygienic waste leakage from treatment – Hygienic waste treatment by informal activities)

Landfilling of plastic waste

(Transportation of plastic waste between treatment and landfill – Leakage of plastic waste from transportation) + (Formal collection of plastic waste + Informal collection of plastic waste – Leakage of plastic waste from collection) * (1 – Transmission factor for collected waste entering treatment [10])
+ Special factor for plastic content in hygienic products [3.3.a] * (Transportation of hygienic waste between treatment and landfill – Leakage of hygienic waste from transportation) + (Formal collection of hygienic waste + Informal collection of hygienic waste – Leakage of hygienic waste from collection) * (1 – Transmission factor for collected waste entering treatment [10])

UNMANAGED PLASTIC WASTE

Total uncollected plastic waste

Total plastic waste production – Reuse and recycling at source of plastic waste – Formal collection of plastic waste – Informal collection of plastic waste
+ Special factor for plastic content in hygienic products [3.3.a] * (Hygienic waste generation – Reuse and recycling at source of hygienic waste – Formal collection of hygienic waste – Informal collection of hygienic waste)

Uncollected plastic waste burned (no leakage into waterways)

Uncollected plastic waste * Transmission factor for burning of uncollected plastic waste without leakage into waterways [14]
+ Special factor for plastic content in hygienic products [3.3.a] * Uncollected hygienic waste * Transmission factor for burning of uncollected plastic waste without leakage into waterways [14]

Uncollected plastic waste buried or dumped (no leakage into waterways)

Uncollected plastic waste * Transmission factor for burying and umping of uncollected plastic waste without leakage into waterways [15]
+ Special factor for plastic content in hygienic products [3.3.a] * Uncollected hygienic waste * Transmission factor for burying and umping of uncollected plastic waste without leakage into waterways [15]

Uncollected plastic waste with other treatment (no leakage into waterways)

Uncollected plastic waste * Transmission factor for other treatment of uncollected plastic waste without leakage into waterways [16]
+ Special factor for plastic content in hygienic products [3.3.a] * Uncollected hygienic waste * Transmission factor for other treatment of uncollected plastic waste without leakage into waterways [16]

Uncollected plastic waste burned or dumped close to waterways

Uncollected plastic waste * Transmission factor for burning or dumping of uncollected plastic waste close to waterways [17]
+ Special factor for plastic content in hygienic products [3.3.a] * Uncollected hygienic waste * Transmission factor for burning or dumping of uncollected plastic waste close to waterways [17]

Uncollected plastic waste entering the drainage system

Uncollected plastic waste * Transmission factor for uncollected plastic waste entering drainage systems [21]
+ Special factor for plastic content in hygienic products [3.3.a] * Uncollected hygienic waste * Transmission factor for uncollected plastic waste entering drainage systems [21]

Uncollected plastic waste directly dumped into waterways

Uncollected plastic waste - Uncollected plastic waste burned (no leakage into waterways) - Uncollected plastic waste buried or dumped (no leakage into waterways) - Uncollected plastic waste with other treatment (no leakage into waterways) - Uncollected plastic waste burned or dumped close to waterways - Uncollected plastic waste entering the drainage system

PLASTIC WASTE ENTERING WATERWAYS

Total plastic waste entering waterways

Uncollected plastic waste directly dumped into waterways + Uncollected plastic waste entering waterways from wild dumpsites + Uncollected plastic waste entering waterways through drainage system + Additional entry of plastic waste into waterways through wastewater system + Plastic waste leakage into waterways during waste collection + Plastic waste leakage into waterways during recycling and energy recovery & RDF + Plastic waste leakage into waterways during transportation + Plastic waste leakage into waterways during landfilling

Uncollected plastic waste entering waterways from wild dumpsites

Uncollected plastic waste burned or dumped close to waterways * Transmission factor for potential leakage from waste close to waterways [18]
+ Special factor for plastic content in hygienic products [3.3.a] * Uncollected hygienic waste burned or dumped close to waterways * Transmission factor for potential leakage from waste close to waterways [18]

Uncollected plastic waste entering waterways through drainage system

Uncollected plastic waste entering the drainage system * Transmission factor for plastic waste in drainage systems entering waterways [22]
+ Special factor for plastic content in hygienic products [3.3.a] * Uncollected hygienic waste entering the drainage system * Transmission factor for plastic waste in drainage systems entering waterways [22]

Additional entry of plastic waste into waterways through wastewater system

Production of plastic waste * Transmission factor for leakage of plastic waste into waterways through wastewater systems [20]
+ Special factor for plastic content in hygienic products [3.3.a] * Production of hygienic waste * Transmission factor for leakage of plastic waste into waterways through wastewater systems [20]

Plastic waste leakage into waterways during waste collection

(Formal collection of plastic waste + Informal collection of plastic waste) * Transmission factor for plastic waste leakage into waterways during waste collection [23]
+ Special factor for plastic content in hygienic products [3.3.a] * (Formal collection of hygienic waste + Informal collection of hygienic waste) * Transmission factor for plastic waste leakage into waterways during waste collection [23]

Plastic waste leakage into waterways during recycling and energy recovery & RDF
Plastic waste entering treatment * Transmission factor for plastic waste leakage into waterways during recycling, energy recovery & RDF [24]
+ Special factor for plastic content in hygienic products [3.3.a] * Hygienic waste entering treatment * Transmission factor for plastic waste leakage into waterways during recycling, energy recovery & RDF [24]

Plastic waste leakage into waterways during transportation
Transportation of plastic waste between treatment and landfill * Transmission factor for plastic waste leakage into waterways during waste transportation [25]
+ Special factor for plastic content in hygienic products [3.3.a] * Transportation of hygienic waste between treatment and landfill * Transmission factor for plastic waste leakage into waterways during waste transportation [25]

Plastic waste leakage into waterways during landfilling
Landfilling of plastic waste * Transmission factor for plastic waste leakage into waterways during landfilling [26]
+ Special factor for plastic content in hygienic products [3.3.a] * Landfilling of hygienic waste * Transmission factor for plastic waste leakage into waterways during landfilling [26]

MARINE PLASTIC LITTER GENERATION

Total marine plastic litter
Total plastic waste entering waterways – Retention of plastic waste in waterways through technical and natural barriers, sedimentation and degradation + Direct beach and coastal littering (through tourism, leisure) entering into the ocean

Direct beach and coastal littering (through tourism, leisure) entering into the ocean
Value for direct beach and coastal littering [30]

Retention of plastic waste in waterways through technical and natural barriers (no leakage into the ocean)
Total plastic waste entering waterways * Retention factor for technical and natural barriers in waterways [27]

Retention of plastic waste in waterways through sedimentation (no leakage into the ocean)
Total plastic waste entering waterways * Retention factor for sedimentation of plastic waste in waterways [28]

Retention of plastic waste in waterways through degradation (no leakage into the ocean)
Total plastic waste entering waterways * Retention factor for degradation of plastic waste in waterways [29]

Annex 2: Input data and result sheets for Sidoarjo Regency, Indonesia

Input data sheet, Sidoarjo

1. General waste management information				Baseline	Scenario 1	Scenario 2	
No.	Item	Description	Unit	Value	Value	Value	Notes
1	Population	How many people live in the area (city, urban district, region) you want to model?	Persons	2'400'000	2'605'925	2'605'925	Please use an estimate based on the last census or other official data and consider population growth rates
2	Municipal solid waste generation per capita	How much municipal solid waste does the population produce on average per person and per day during one year?	Kg/day	0,65	0,65	0,65	If values are not available for the area, please use values from comparable areas or national averages
3	Municipal solid waste composition	Average waste composition for the following waste fractions in weight-%					
.3.1		Paper	Weight-%	8%	8%	8%	The simplified model calculates only with plastics (plastic waste and plastic content in hygienic waste). The results show these aspects together as "plastic waste".
.3.2		Plastics	Weight-%	9%	9%	9%	
.3.3		Glass	Weight-%	3%	3%	3%	
.3.4		Metals	Weight-%	2%	2%	2%	
.3.5		Hygienic products	Weight-%	13%	13%	13%	
.3.6		Other non-organic	Weight-%	10%	10%	10%	
.3.7		Organic	Weight-%	55%	55%	55%	
.3.a		Special factor for plastic content in hygenic products	Weight-%	6%	6%	6%	Please use this predefined value if you do not have more specific data

2. Waste management system				Baseline	Scenario 1	Scenario 2	
No.	Item	Description	Unit	Value	Value	Value	Notes
4	Waste collection coverage	How many people do receive formal and regular municipal solid waste collection services in the area?	% of population	40%	50%	60%	Estimate or official number for all municipal solid waste
5	Waste collection efficiency for covered households	How much of the municipal solid waste is collected from the households that are covered by the collection system?	% of waste produced by covered areas	78%	81%	93%	Estimate or official number for all municipal solid waste
6	Informal collection	How much of the plastic waste is collected by the informal sector (not including specific picking of valuable materials which is covered by no. 9)?	% of plastic waste	5%	5%	5%	Estimation, total formal and informal collection cannot exceed 100%
7	Informal recycling	How much of the informally collected plastic waste is recycled?	% of the informally collected plastic waste	20%	20%	20%	Estimation
8	Unmanaged waste in the informal sector	How much of the informally collected plastic waste ends up unmanaged (e.g. wild dumpsites, burning, in waterways) instead of being reinserted into formel collection?	% of the informally collected plastic waste	50%	50%	50%	Estimation

3. Plastic waste treatment				Baseline	Scenario 1	Scenario 2	
No.	Item	Description	Unit	Value	Value	Value	Notes
9	Reuse and recycling at source	How much of the generated waste is adequately reused or recycled at household level or through buy-back centers, door-collections by the informal sector, etc. before reaching the formal or informal collection systems?	% produced plastic waste	15%	15%	15%	Estimation (please distinguish from no. 6)
10	Collected Waste entering treatment	How much of the formally and informally collected waste is entering formal treatment facilities (e.g. transfer stations, sorting, recycling, RDF, composting, etc.)	% formally & informally collected plastic waste	75%	80%	90%	Capacity of treatment facilities, to distinguish from collected waste directly disposed of at the final disposal site
11	Formal recycling	How much of the formally collected waste is recycled?	% plastic waste entering treatment	30%	55%	80%	Recycling rate within the formal waste management system or estimation
12	Energy recovery and co-processing/ refuse-derived fuel (RDF)	How much of the formally collected waste is energetically recovered or prepared to be used as refuse-derived fuel (RDF) in cement factories?	% of plastic waste entering treatment	0%	0%	0%	Estimation or numbers from cement factories or waste incinerators
13	Composting and biogas	How much of the formally collected waste is composted or used in anaerobic digestion (biogas)?	% of plastic waste entering treatment	0%	0%	0%	Estimation / not relevant for plastic waste

4. Transmission factors (estimations based on expert assessment)				Baseline	Scenario 1	Scenario 2	
No.	Item	Description	Unit	Value	Value	Value	Notes
14	Uncollected plastic waste: Burning (no leakage into waterways)	How much of the uncollected plastic waste is openly burned at household or roadside level, which cannot leak into waterways?	% of uncollected plastic waste	45%	45%	45%	"All values are estimates. The transmission factors no. 14, 15 and 16 display in the calculation uncollected plastic waste that cannot enter waterways and the ocean.
15	Uncollected plastic waste: Burying and dumping (without leakage into waterways)	How much of the uncollected plastic waste is buried or openly dumped at household or roadside level, which cannot leak into waterways?	% of uncollected plastic waste	20%	20%	20%	
16	Uncollected plastic waste: other treatment (no leakage into waterways)	How much of the uncollected plastic waste is dealt with in a different way at household or roadside level and cannot leak into waterways?	% of uncollected plastic waste	0%	0%	0%	
17	Uncollected plastic waste: burning or dumping close to waterways	How much of uncollected plastic waste can enter waterways (different to no. 13 to 15) but is not directly disposed into waterways (differnt to no. 18)?	% of uncollected plastic waste	20%	20%	20%	Transmission factors no. 17 and 18 need to be considered together
18	Potential leakage from waste close to waterways (no. 17)	How much of the uncollected plastic waste burned or dumped close to waterways does enter waterways?	% of uncollected plastic waste in no. 17	60%	60%	60%	
19	Uncollected plastic waste directly disposed into waterways	Calculated value: all unmanaged waste not accounted for by no. 13, 14, 15, 16 and 20 is assumed to enter directly the water system.	% of uncollected plastic waste	10%	10%	10%	The sum of no 14, 15, 16, 17, 19 and 21 is 100%.
20	Leakage of plastic waste into waterways through wastewater systems	How much waste is leaked additionally into waterways through the wastewater system (e.g. through sanitation, microplastics from washing and cosmetics, etc.)?	% of produced plastic waste	0,01%	0,01%	0,01%	Results in additional quantities of waste entering waterways and the ocean. Estimates should be prudent as the transmission factor refers to total plastic waste production.
21	Uncollected plastic waste entering drainage systems	How much of the uncollected plastic waste enters the drainage system (washing in, dumping, etc.), considering the characteristics of the system, the quality of street sweeping, etc.?	% of uncollected plastic waste	5%	5%	5%	No. 21 and no. 22 need to be considered together
22	Plastic waste in drainage systems entering waterways	How much plastic waste is not retained by traps, sinks, technical barriers or other installations (serviced and cleaned in a regular fashion) in the drainage system and thus enters waterways?	% of plastic waste entering the drainage system (no. 21)	90%	90%	90%	

4. Transmission factors (estimations based on expert assessment)				Baseline	Scenario 1	Scenario 2	
No.	Item	Description	Unit	Value	Value	Value	Notes
23	Plastic waste leakage into waterways during waste collection	How much plastic waste leaks into waterways during collection (untidy collection points, littering around collection points, uncovered open collection vehicles, etc)?	% of collected plastic waste	2,5%	2,5%	2,5%	"The transmission factors 23, 24, 25 and 26 display in the calculation plastic waste leakage from formal waste collection. Factor 23 considers collection activities including moving collected waste to treatment facilities or directly to final disposal. Factor 25 refers only to waste transported from treatment or between treatment stages. Factor 10 defines how much waste is entering treatment stages and has to be transported."
24	Plastic waste leakage into waterways during recycling, energy recovery & RDF	How much plastic waste entering treatment stages leaks into waterways during recycling, energy recovery and RDF (e.g. untidy facility management, windblown litter, etc.)?	% plastic waste entering treatment	1,5%	1,5%	1,5%	
25	Plastic waste leakage into waterways during waste transportation	How much plastic waste leaks into waterways during waste transportation (e.g. uncovered verhicles, untidy transfer stations, etc.) from treatment to disposal	% of plastic waste transported from treatment to landfill	0,5%	0,5%	0,5%	
26	Plastic waste leakage into waterways during landfilling	How much plastic waste leaks into waterways from landfills (e.g. lack of coverage (windblown), untidy site management, informal activities, etc.)	% of landfilled plastic waste	1,0%	1,0%	1,0%	
27	Retention factor: technical and natural barriers in waterways	How much waste is retained in waterways actively (e.g. waste traps) or passively (e.g. natural or technical barriers)	% of plastic waste in waterways	1%	1%	1%	The transmission factors no. 27, 28 and 29 display in the calculation the retention of plastic waste in waterways, which hinders plastics from entering into the ocean.
28	Retention factor: sedimentation of plastic waste in waterways	How much plastic waste is retained in waterways by sedimentation processes (the estimate of 15% can be used if more specific data is missing)	% of plastic waste in waterways	15%	15%	15%	
29	Retention factor: degradation of plastic waste in waterways	How much plastic waste is retained in waterways through degradation (the estimate of 0% can be used if more specific data is missing)	% of plastic waste in waterways	0%	0%	0%	

5. Additional values (estimations based on expert assessment)				Baseline	Scenario 1	Scenario 2	
No.	Item	Description	Unit	Value	Value	Value	Notes
30	Direct beach and coastal littering	How much marine litter stems from disposal of plastic waste at beaches and along the coastline (e.g. from touristic or recreational activities)	kg/day	0	0	0	Estimation unrelated to waste management system (e.g. based on tourist visits, consumption of bottles, beach samplings, etc.)

RESULTS SHEET FOR 2017 (BASELINE), SIDOARJO – ABSOLUTE NUMBERS

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in tonne/year

Total plastic waste production	56'073	Formal collection of plastic waste	14'871	Recycling of plastic waste	3'570	Transportation of plastic between treatment and landfill	7'871		
Reuse and recycling at source	8'411	Informal collection of plastic waste	1'402	Energy recovery & RDF of plastic waste	–	Landfilling of plastic waste	11'798		
Total uncollected plastic waste			**31'390**	**Total plastic waste entering waterways**			**9'066**	**Total marine plastic litter**	**7'616**
Uncollected plastic waste burned (no leakage into waterways)	14'125	Uncollected plastic waste burned or dumped close to waterways	6'278	Uncollected plastic waste entering waterways from wild dumpsites	3'767	Plastic waste leakage into waterways during waste collection	407	Direct beach and coastal littering (through tourism, leisure) entering into the ocean	–
Uncollected plastic waste buried or dumped (no leakage into waterways)	6'278	Uncollected plastic waste entering the drainage system	1'569	Uncollected plastic waste entering waterways through drainage system	1'413	Plastic waste leakage into waterways during recycling and energy recovery & RDF	178	Retention of plastic waste in waterways through technical and natural barriers (no leakage into the ocean)	91
Uncollected plastic waste with other treatment (no leakage into waterways)	–	Uncollected plastic waste directly dumped into waterways	3'139	Additional entry of plastic waste into waterways through wastewater system	6	Plastic waste leakage into waterways during transportation	39	Retention of plastic waste in waterways through sedimentation (no leakage into the ocean)	1'360
						Plastic waste leakage into waterways during landfilling	118	Retention of plastic waste in waterways through degradation (no leakage into the ocean)	–

RESULTS SHEET FOR 2017 (BASELINE), SIDOARJO – IN PERCENTAGES

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in % of total plastic waste production

Total plastic waste production	100%	Formal collection of plastic waste	27%	Recycling of plastic waste	6%	Transportation of plastic between treatment and landfill	14%		
Reuse and recycling at source	15%	Informal collection of plastic waste	3%	Energy recovery & RDF of plastic waste	-	Landfilling of plastic waste	21%		
Total uncollected plastic waste			56,0%	**Total plastic waste entering waterways**			**16,2%**	**Total marine plastic litter**	**13,6%**
Uncollected plastic waste burned (no leakage into waterways)	25,2%	Uncollected plastic waste burned or dumped close to waterways	11,2%	Uncollected plastic waste entering waterways from wild dumpsites	6,7%	Plastic waste leakage into waterways during waste collection	0,7%	Direct beach and coastal littering (through tourism, leisure) entering into the ocean	-
Uncollected plastic waste buried or dumped (no leakage into waterways)	11,2%	Uncollected plastic waste entering the drainage system	2,8%	Uncollected plastic waste entering waterways through drainage system	2,5%	Plastic waste leakage into waterways during recycling and energy recovery & RDF	0,3%	Retention of plastic waste in waterways through technical and natural barriers (no leakage into the ocean)	0,2%
Uncollected plastic waste with other treatment (no leakage into waterways)	0,0%	Uncollected plastic waste directly dumped into waterways	5,6%	Additional entry of plastic waste into waterways through wastewater system	0,0%	Plastic waste leakage into waterways during transportation	0,1%	Retention of plastic waste in waterways through sedimentation (no leakage into the ocean)	2,4%
Total marine plastic litter in kg per person/year	**3,17**	Total marine plastic litter per person/year equivalent to no. of PET bottles of 30g/bottle	**106**			Plastic waste leakage into waterways during landfilling	0,2%	Retention of plastic waste in waterways through degradation (no leakage into the ocean)	0,0%

RESULTS SHEET FOR CONSERVATIVE 5 YEARS DEVELOPMENT SCENARIO (SCENARIO 1), SIDOARJO – IN ABSOLUTE NUMBERS

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in tonne/year

Total plastic waste production 60'844	Formal collection of plastic waste 20'959	Recycling of plastic waste 9'645	Transportation of plastic between treatment and landfill 7'324	
Reuse and recycling at source 9'133	Informal collection of plastic waste 1'425	Energy recovery & RDF of plastic waste –	Landfilling of plastic waste 11'671	
Total uncollected plastic waste 29'270		**Total plastic waste entering waterways 8'741**		**Total marine plastic litter 7'342**
Uncollected plastic waste burned (no leakage into waterways) 13'171	Uncollected plastic waste burned or dumped close to waterways 5'854	Uncollected plastic waste entering waterways from wild dumpsites 3'512	Plastic waste leakage into waterways during waste collection 562	Direct beach and coastal littering (through tourism, leisure) entering into the ocean –
Uncollected plastic waste buried or dumped (no leakage into waterways) 5'854	Uncollected plastic waste entering the drainage system 1'463	Uncollected plastic waste entering waterways through drainage system 1'317	Plastic waste leakage into waterways during recycling and energy recovery & RDF 263	Retention of plastic waste in waterways through technical and natural barriers (no leakage into the ocean) 87
Uncollected plastic waste with other treatment (no leakage into waterways) –	Uncollected plastic waste directly dumped into waterways 2'927	Additional entry of plastic waste into waterways through wastewater system 6	Plastic waste leakage into waterways during transportation 37	Retention of plastic waste in waterways through sedimentation (no leakage into the ocean) 1'311
			Plastic waste leakage into waterways during landfilling 117	Retention of plastic waste in waterways through degradation (no leakage into the ocean) –

RESULTS SHEET FOR CONSERVATIVE 5 YEARS DEVELOPMENT SCENARIO (SCENARIO 1), SIDOARJO – IN PERCENTAGES

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in % of total plastic waste production

Total plastic waste production	100%	Formal collection of plastic waste	34%	Recycling of plastic waste	16%	Transportation of plastic between treatment and landfill	12%
Reuse and recycling at source	15%	Informal collection of plastic waste	2%	Energy recovery & RDF of plastic waste	-	Landfilling of plastic waste	19%

Total uncollected plastic waste			**48,1%**	**Total plastic waste entering waterways**			**14,4%**	**Total marine plastic litter**	**12,1%**
Uncollected plastic waste burned (no leakage into waterways)	21,6%	Uncollected plastic waste burned or dumped close to waterways	9,6%	Uncollected plastic waste entering waterways from wild dumpsites	5,8%	Plastic waste leakage into waterways during waste collection	0,9%	Direct beach and coastal littering (through tourism, leisure) entering into the ocean	-
Uncollected plastic waste buried or dumped (no leakage into waterways)	9,6%	Uncollected plastic waste entering the drainage system	2,4%	Uncollected plastic waste entering waterways through drainage system	2,2%	Plastic waste leakage into waterways during recycling and energy recovery & RDF	0,4%	Retention of plastic waste in waterways through technical and natural barriers (no leakage into the ocean)	0,1%
Uncollected plastic waste with other treatment (no leakage into waterways)	0,0%	Uncollected plastic waste directly dumped into waterways	4,8%	Additional entry of plastic waste into waterways through wastewater system	0,0%	Plastic waste leakage into waterways during transportation	0,1%	Retention of plastic waste in waterways through sedimentation (no leakage into the ocean)	2,2%
Total marine plastic litter in kg per person/year	2,82	Total marine plastic litter per person/year equivalent to no. of PET bottles of 30g/bottle	94			Plastic waste leakage into waterways during landfilling	0,2%	Retention of plastic waste in waterways through degradation (no leakage into the ocean)	0,0%

RESULT SHEET FOR BEST-CASE 5 YEARS DEVELOPMENT SCENARIO (SCENARIO 2), SIDOARJO – IN ABSOLUTE NUMBERS

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in tonne/year

Total plastic waste production 60’844	Formal collection of plastic waste 28’877	Recycling of plastic waste 21’340	Transportation of plastic between treatment and landfill 4’631	
Reuse and recycling at source 9’133	Informal collection of plastic waste 1’425	Energy recovery & RDF of plastic waste –	Landfilling of plastic waste 7’571	
Total uncollected plastic waste 21’352		**Total plastic waste entering waterways 6’923**		**Total marine plastic litter 5’816**
Uncollected plastic waste burned (no leakage into waterways) 9’608	Uncollected plastic waste burned or dumped close to waterways 4’270	Uncollected plastic waste entering waterways from wild dumpsites 2’562	Plastic waste leakage into waterways during waste collection 760	Direct beach and coastal littering (through tourism, leisure) entering into the ocean –
Uncollected plastic waste buried or dumped (no leakage into waterways) 4’270	Uncollected plastic waste entering the drainage system 1’068	Uncollected plastic waste entering waterways through drainage system 961	Plastic waste leakage into waterways during recycling and energy recovery & RDF 400	Retention of plastic waste in waterways through technical and natural barriers (no leakage into the ocean) 69
Uncollected plastic waste with other treatment (no leakage into waterways) –	Uncollected plastic waste directly dumped into waterways 2’135	Additional entry of plastic waste into waterways through wastewater system 6	Plastic waste leakage into waterways during transportation 23	Retention of plastic waste in waterways through sedimentation (no leakage into the ocean) 1’039
			Plastic waste leakage into waterways during landfilling 76	Retention of plastic waste in waterways through degradation (no leakage into the ocean) –

RESULT SHEET FOR BEST-CASE 5 YEARS DEVELOPMENT SCENARIO (SCENARIO 2), SIDOARJO – IN PERCENTAGES

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in % of total plastic waste production

Total plastic waste production 100%	Formal collection of plastic waste 47%	Recycling of plastic waste 35%	Transportation of plastic between treatment and landfill 8%	
Reuse and recycling at source 15%	Informal collection of plastic waste 2%	Energy recovery & RDF of plastic waste –	Landfilling of plastic waste 12%	
Total uncollected plastic waste 35,1%		**Total plastic waste entering waterways** 11,4%		**Total marine plastic litter** 9,6%
Uncollected plastic waste burned (no leakage into waterways) 15,8%	Uncollected plastic waste burned or dumped close to waterways 7,0%	Uncollected plastic waste entering waterways from wild dumpsites 4,2%	Plastic waste leakage into waterways during waste collection 1,2%	Direct beach and coastal littering (through tourism, leisure) entering into the ocean –
Uncollected plastic waste buried or dumped (no leakage into waterways) 7,0%	Uncollected plastic waste entering the drainage system 1,8%	Uncollected plastic waste entering waterways through drainage system 1,6%	Plastic waste leakage into waterways during recycling and energy recovery & RDF 0,7%	Retention of plastic waste in waterways through technical and natural barriers (no leakage into the ocean) 0,1%
Uncollected plastic waste with other treatment (no leakage into waterways) 0,0%	Uncollected plastic waste directly dumped into waterways 3,5%	Additional entry of plastic waste into waterways through wastewater system 0,0%	Plastic waste leakage into waterways during transportation 0,0%	Retention of plastic waste in waterways through sedimentation (no leakage into the ocean) 1,7%
Total marine plastic litter in kg per person/year 2,23	Total marine plastic litter per person/year equivalent to no. of PET bottles of 30g/bottle 74		Plastic waste leakage into waterways during landfilling 0,1%	Retention of plastic waste in waterways through degradation (no leakage into the ocean) 0,0%

Annex 3: Input data and results sheets for Annaba, Algeria

Input data sheet, Annaba

1. General waste management information				Baseline	Scenario 1	Scenario 2	
No.	Item	Description	Unit	Value	Value	Value	Notes
1	Population	How many people live in the area (city, urban district, region) you want to model?	Persons	715'654	681'000		Please use an estimate based on the last census or other official data and consider population growth rates
2	Municipal solid waste generation per capita	How much municipal solid waste does the population produce on average per person and per day during one year?	Kg/day	0,90	0,90		If values are not available for the area, please use values from comparable areas or national averages
3	Municipal solid waste composition	Average waste composition for the following waste fractions in weight-%					
.3.1		Paper	Weight-%				The simplified model calculates only with plastics (plastic waste and plastic content in hygienic waste). The results show these aspects together as "plastic waste".
.3.2		Plastics	Weight-%	17%	15%		
.3.3		Glass	Weight-%				
.3.4		Metals	Weight-%				
.3.5		Hygienic products	Weight-%	0%	0%		
.3.6		Other non-organic	Weight-%				
.3.7		Organic	Weight-%				
.3.a		Special factor for plastic content in hygenic products	Weight-%	6%	6%	6%	Please use this predefined value if you do not have more specific data

2. Waste management system				Baseline	Scenario 1	Scenario 2	
No.	Item	Description	Unit	Value	Value	Value	Notes
4	Waste collection coverage	How many people do receive formal and regular municipal solid waste collection services in the area?	% of population	90%	80%		Estimate or official number for all municipal solid waste
5	Waste collection efficiency for covered households	How much of the municipal solid waste is collected from the households that are covered by the collection system?	% of waste produced by covered areas	94%	88%		Estimate or official number for all municipal solid waste
6	Informal collection	How much of the plastic waste is collected by the informal sector (not including specific picking of valuable materials which is covered by no. 9)?	% of plastic waste	0%	0%		Estimation, total formal and informal collection cannot exceed 100%
7	Informal recycling	How much of the informally collected plastic waste is recycled?	% of the informally collected plastic waste	0%	0%		Estimation
8	Unmanaged waste in the informal sector	How much of the informally collected plastic waste ends up unmanaged (e.g. wild dumpsites, burning, in waterways) instead of being reinserted into formel collection?	% of the informally collected plastic waste	0%	0%		Estimation

3. Plastic waste treatment				Baseline	Scenario 1	Scenario 2	
No.	Item	Description	Unit	Value	Value	Value	Notes
9	Reuse and recycling at source	How much of the generated waste is adequately reused or recycled at household level or through buy-back centers, door-collections by the informal sector, etc. before reaching the formal or informal collection systems?	% produced plastic waste	1%	1%		Estimation (please distinguish from no. 6)
10	Collected Waste entering treatment	How much of the formally and informally collected waste is entering formal treatment facilities (e.g. transfer stations, sorting, recycling, RDF, composting, etc.)	% formally & informally collected plastic waste	100%	100%		Capacity of treatment facilities, to distinguish from collected waste directly disposed of at the final disposal site
11	Formal recycling	How much of the formally collected waste is recycled?	% plastic waste entering treatment	1%	1%		Recycling rate within the formal waste management system or estimation
12	Energy recovery and co-processing/ refuse-derived fuel (RDF)	How much of the formally collected waste is energetically recovered or prepared to be used as refuse-derived fuel (RDF) in cement factories?	% of plastic waste entering treatment	0%	0%		Estimation or numbers from cement factories or waste incinerators
13	Composting and biogas	How much of the formally collected waste is composted or used in anaerobic digestion (biogas)?	% of plastic waste entering treatment	0%	0%		Estimation / not relevant for plastic waste

4. Transmission factors (estimations based on expert assessment)				Baseline	Scenario 1	Scenario 2	
No.	Item	Description	Unit	Value	Value	Value	Notes
14	Uncollected plastic waste: Burning (no leakage into waterways)	How much of the uncollected plastic waste is openly burned at household or roadside level, which cannot leak into waterways?	% of uncollected plastic waste	20%	20%		"All values are estimates. The transmission factors no. 14, 15 and 16 display in the calculation uncollected plastic waste that cannot enter waterways and the ocean.
15	Uncollected plastic waste: Burying and dumping (without leakage into waterways)	How much of the uncollected plastic waste is buried or openly dumped at household or roadside level, which cannot leak into waterways?	% of uncollected plastic waste	30%	30%		
16	Uncollected plastic waste: other treatment (no leakage into waterways)	How much of the uncollected plastic waste is dealt with in a different way at household or roadside level and cannot leak into waterways?	% of uncollected plastic waste	10%	10%		
17	Uncollected plastic waste: burning or dumping close to waterways	How much of uncollected plastic waste can enter waterways (different to no. 13 to 15) but is not directly disposed into waterways (differnt to no. 18)?	% of uncollected plastic waste	30%	30%		Transmission factors no. 17 and 18 need to be considered together
18	Potential leakage from waste close to waterways (no. 17)	How much of the uncollected plastic waste burned or dumped close to waterways does enter waterways?	% of uncollected plastic waste in no. 17	70%	70%		
19	Uncollected plastic waste directly disposed into waterways	Calculated value: all unmanaged waste not accounted for by no. 13, 14, 15, 16 and 20 is assumed to enter directly the water system.	% of uncollected plastic waste	0%	0%	100%	The sum of no 14, 15, 16, 17, 19 and 21 is 100%.
20	Leakage of plastic waste into waterways through wastewater systems	How much waste is leaked additionally into waterways through the wastewater system (e.g. through sanitation, microplastics from washing and cosmetics, etc.)?	% of produced plastic waste	0,01%	0,01%		Results in additional quantities of waste entering waterways and the ocean. Estimates should be prudent as the transmission factor refers to total plastic waste production.
21	Uncollected plastic waste entering drainage systems	How much of the uncollected plastic waste enters the drainage system (washing in, dumping, etc.), considering the characteristics of the system, the quality of street sweeping, etc.?	% of uncollected plastic waste	10%	10%		No. 21 and no. 22 need to be considered together
22	Plastic waste in drainage systems entering waterways	How much plastic waste is not retained by traps, sinks, technical barriers or other installations (serviced and cleaned in a regular fashion) in the drainage system and thus enters waterways?	% of plastic waste entering the drainage system (no. 21)	50%	50%		

4. Transmission factors (estimations based on expert assessment)				Baseline	Scenario 1	Scenario 2	
No.	Item	Description	Unit	Value	Value	Value	Notes
23	Plastic waste leakage into waterways during waste collection	How much plastic waste leaks into waterways during collection (untidy collection points, littering around collection points, uncovered open collection vehicles, etc)?	% of collected plastic waste	1,0%	1,0%		"The transmission factors 23, 24, 25 and 26 display in the calculation plastic waste leakage from formal waste collection. Factor 23 considers collection activities including moving collected waste to treatment facilities or directly to final disposal. Factor 25 refers only to waste transported from treatment or between treatment stages. Factor 10 defines how much waste is entering treatment stages and has to be transported."
24	Plastic waste leakage into waterways during recycling, energy recovery & RDF	How much plastic waste entering treatment stages leaks into waterways during recycling, energy recovery and RDF (e.g. untidy facility management, windblown litter, etc.)?	% plastic waste entering treatment	1,0%	1,0%		
25	Plastic waste leakage into waterways during waste transportation	How much plastic waste leaks into waterways during waste transportation (e.g. uncovered verhicles, untidy transfer stations, etc.) from treatment to disposal	% of plastic waste transported from treatment to landfill	0,0%	0,0%		
26	Plastic waste leakage into waterways during landfilling	How much plastic waste leaks into waterways from landfills (e.g. lack of coverage (windblown), untidy site management, informal activities, etc.)	% of landfilled plastic waste	0,0%	0,0%		
27	Retention factor: technical and natural barriers in waterways	How much waste is retained in waterways actively (e.g. waste traps) or passively (e.g. natural or technical barriers)	% of plastic waste in waterways	20%	20%		The transmission factors no. 27, 28 and 29 display in the calculation the retention of plastic waste in waterways, which hinders plastics from entering into the ocean.
28	Retention factor: sedimentation of plastic waste in waterways	How much plastic waste is retained in waterways by sedimentation processes (the estimate of 15% can be used if more specific data is missing)	% of plastic waste in waterways	15%	15%		
29	Retention factor: degradation of plastic waste in waterways	How much plastic waste is retained in waterways through degradation (the estimate of 0% can be used if more specific data is missing)	% of plastic waste in waterways	0%	0%		

5. Additional values (estimations based on expert assessment)				Baseline	Scenario 1	Scenario 2	
No.	Item	Description	Unit	Value	Value	Value	Notes
30	Direct beach and coastal littering	How much marine litter stems from disposal of plastic waste at beaches and along the coastline (e.g. from touristic or recreational activities)	kg/day	74	74		Estimation unrelated to waste management system (e.g. based on tourist visits, consumption of bottles, beach samplings, etc.)

RESULTS SHEET FOR 2017 (BASELINE), ANNABA – IN ABSOLUTE NUMBERS

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in tonne/year

Total plastic waste production	39'966	Formal collection of plastic waste	33'473	Recycling of plastic waste	331	Transportation of plastic between treatment and landfill	32'475
Reuse and recycling at source	400	Informal collection of plastic waste	-	Energy recovery & RDF of plastic waste	-	Landfilling of plastic waste	32'475

Total uncollected plastic waste			**6'093**	**Total plastic waste entering waterways**			**2'254**	**Total marine plastic litter**	**1'494**
Uncollected plastic waste burned (no leakage into waterways)	1'219	Uncollected plastic waste burned or dumped close to waterways	1'828	Uncollected plastic waste entering waterways from wild dumpsites	1'280	Plastic waste leakage into waterways during waste collection	335	Direct beach and coastal littering (through tourism, leisure) entering into the ocean	27
Uncollected plastic waste buried or dumped (no leakage into waterways)	1'828	Uncollected plastic waste entering the drainage system	609	Uncollected plastic waste entering waterways through drainage system	305	Plastic waste leakage into waterways during recycling and energy recovery & RDF	331	Retention of plastic waste in waterways through technical and natural barriers (no leakage into the ocean)	451
Uncollected plastic waste with other treatment (no leakage into waterways)	609	Uncollected plastic waste directly dumped into waterways	-	Additional entry of plastic waste into waterways through wastewater system	4	Plastic waste leakage into waterways during transportation	-	Retention of plastic waste in waterways through sedimentation (no leakage into the ocean)	338
						Plastic waste leakage into waterways during landfilling	-	Retention of plastic waste in waterways through degradation (no leakage into the ocean)	-

RESULTS SHEET FOR 2017 (BASELINE), ANNABA – IN PERCENTAGES

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in % of total plastic waste production

Total plastic waste production	100%	Formal collection of plastic waste	84%	Recycling of plastic waste	1%	Transportation of plastic between treatment and landfill	81%		
Reuse and recycling at source	1%	Informal collection of plastic waste	0%	Energy recovery & RDF of plastic waste	–	Landfilling of plastic waste	81%		
Total uncollected plastic waste			15,2%	**Total plastic waste entering waterways**			5,6%	**Total marine plastic litter**	3,7%
Uncollected plastic waste burned (no leakage into waterways)	3,0%	Uncollected plastic waste burned or dumped close to waterways	4,6%	Uncollected plastic waste entering waterways from wild dumpsites	3,2%	Plastic waste leakage into waterways during waste collection	0,8%	Direct beach and coastal littering (through tourism, leisure) entering into the ocean	–
Uncollected plastic waste buried or dumped (no leakage into waterways)	4,6%	Uncollected plastic waste entering the drainage system	1,5%	Uncollected plastic waste entering waterways through drainage system	0,8%	Plastic waste leakage into waterways during recycling and energy recovery & RDF	0,8%	Retention of plastic waste in waterways through technical and natural barriers (no leakage into the ocean)	1,1%
Uncollected plastic waste with other treatment (no leakage into waterways)	1,5%	Uncollected plastic waste directly dumped into waterways	0,0%	Additional entry of plastic waste into waterways through wastewater system	0,0%	Plastic waste leakage into waterways during transportation	0,0%	Retention of plastic waste in waterways through sedimentation (no leakage into the ocean)	0,8%
Total marine plastic litter in kg per person/year	**2,09**	Total marine plastic litter per person/year equivalent to no. of PET bottles of 30g/bottle	**70**			Plastic waste leakage into waterways during landfilling	0,0%	Retention of plastic waste in waterways through degradation (no leakage into the ocean)	0,0%

RESULTS SHEET FOR 2014 (SCENARIO 1), ANNABA – IN ABSOLUTE NUMBERS

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in tonne/year

Total plastic waste production	33'556	Formal collection of plastic waste	23'387	Recycling of plastic waste	232	Transportation of plastic between treatment and landfill	22'690		
Reuse and recycling at source	336	Informal collection of plastic waste	-	Energy recovery & RDF of plastic waste	-	Landfilling of plastic waste	22'690		
Total uncollected plastic waste			**9'833**	**Total plastic waste entering waterways**			**3'025**	**Total marine plastic litter**	**1'995**
Uncollected plastic waste burned (no leakage into waterways)	1'967	Uncollected plastic waste burned or dumped close to waterways	2'950	Uncollected plastic waste entering waterways from wild dumpsites	2'065	Plastic waste leakage into waterways during waste collection	234	Direct beach and coastal littering (through tourism, leisure) entering into the ocean	27
Uncollected plastic waste buried or dumped (no leakage into waterways)	2'950	Uncollected plastic waste entering the drainage system	983	Uncollected plastic waste entering waterways through drainage system	492	Plastic waste leakage into waterways during recycling and energy recovery & RDF	232	Retention of plastic waste in waterways through technical and natural barriers (no leakage into the ocean)	605
Uncollected plastic waste with other treatment (no leakage into waterways)	983	Uncollected plastic waste directly dumped into waterways	-	Additional entry of plastic waste into waterways through wastewater system	3	Plastic waste leakage into waterways during transportation	-	Retention of plastic waste in waterways through sedimentation (no leakage into the ocean)	454
						Plastic waste leakage into waterways during landfilling	-	Retention of plastic waste in waterways through degradation (no leakage into the ocean)	-

Assessment of Marine Plastic Litter Generation: Results (estimations)

All values in % of total plastic waste production

Total plastic waste production	100%	Formal collection of plastic waste	70%	Recycling of plastic waste	1%	Transportation of plastic between treatment and landfill	68%		
Reuse and recycling at source	1%	Informal collection of plastic waste	0%	Energy recovery & RDF of plastic waste	-	Landfilling of plastic waste	68%		
Total uncollected plastic waste			29,3%	**Total plastic waste entering waterways**			**9,0%**	**Total marine plastic litter**	**5,9%**
Uncollected plastic waste burned (no leakage into waterways)	5,9%	Uncollected plastic waste burned or dumped close to waterways	8,8%	Uncollected plastic waste entering waterways from wild dumpsites	6,2%	Plastic waste leakage into waterways during waste collection	0,7%	Direct beach and coastal littering (through tourism, leisure) entering into the ocean	-
Uncollected plastic waste buried or dumped (no leakage into waterways)	8,8%	Uncollected plastic waste entering the drainage system	2,9%	Uncollected plastic waste entering waterways through drainage system	1,5%	Plastic waste leakage into waterways during recycling and energy recovery & RDF	0,7%	Retention of plastic waste in waterways through technical and natural barriers (no leakage into the ocean)	1,8%
Uncollected plastic waste with other treatment (no leakage into waterways)	2,9%	Uncollected plastic waste directly dumped into waterways	0,0%	Additional entry of plastic waste into waterways through wastewater system	0,0%	Plastic waste leakage into waterways during transportation	0,0%	Retention of plastic waste in waterways through sedimentation (no leakage into the ocean)	1,4%
Total marine plastic litter in kg per person/year	**2,93**	Total marine plastic litter per person/year equivalent to no. of PET bottles of 30g/bottle	**98**			Plastic waste leakage into waterways during landfilling	0,0%	Retention of plastic waste in waterways through degradation (no leakage into the ocean)	0,0%

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