From Land to Sea: Model for the Documentation of Land-Sourced Plastic Litter

Stephanie Cieplik

Contents

1 Global Challenge 274
2 Background/Motivation 274
3 Plastic Waste in Germany 275
4 Improperly Disposed-of Plastics and Littering in Germany 276
5 Subject of the Investigation of the Model 279
6 Methodology of the Model 280
7 Assumptions Made in the Model 280
8 Overview of the Discharge Pathways 281
9 Special Report: Compost and Digestate 282
10 Special Report: Littering 283
11 Data Basis 284
12 Limitations of the Model 284
13 Main Results 286
14 Conclusions 288
References 288

Abstract The model "From Land to Sea – Model for the documentation of land-sourced plastic litter" was developed on behalf of BKV GmbH, Frankfurt, Germany. This model systematically records for the first time discharges of improperly disposed-of plastic litter from Germany that gets into the North Sea, the Baltic Sea, and the Black Sea. All discharge pathways and sources are taken into account. A distinction is made between discharges of microplastic and macroplastic.

Keywords Discharge pathways/discharge sources, Germany's contribution, Microplastic/macroplastic, New methodology, Volume estimate

S. Cieplik (✉)
BKV GmbH, Frankfurt am Main, Germany
e-mail: stephanie.cieplik@bkv-gmbh.de

Friederike Stock, Georg Reifferscheid, Nicole Brennholt, and Evgeniia Kostianaia (eds.), *Plastics in the Aquatic Environment - Part I: Current Status and Challenges*, Hdb Env Chem (2022) 111: 273–288, DOI 10.1007/698_2021_781,

1 Global Challenge

Since the 1950s, plastics have achieved unparalleled growth. Because of their enormous variety of potential uses and outstanding technical properties, they have become established in numerous fields of application. We encounter plastics in all areas of our life. They have successfully taken over from conventional materials, for example, in car production, in household appliances, in the building sector, in sports and leisure articles, in medicine, and in packaging.

Because of their wide range of application, plastics have become indispensable in our day-to-day lives. They are valuable resources that bring people benefits in many areas, and they also make a valuable contribution to sustainable solutions. Having said this, the obvious question is of course what happens to the plastics at the end of their useful life. Established and well-functioning waste management systems can provide for the recycling and, if necessary, disposal of the plastics. Regional circumstances, as well as the responsible action and behaviour of the public and institutions also play a decisive role.

Often, however, plastics turn up in the environment, and marine litter in particular is a much-discussed topic at present. Plastics naturally do not belong in the environment. Plastics are useful materials and thus much too valuable to end their life floating as litter unused in the sea. However, it is currently estimated that between 4.8 and 12.7 mt of plastic waste end up in the world's seas every year [1].

Whether and how the litter already present in the seas can be collected for orderly disposal is one of the challenges of our age. Another is avoiding the creation of litter in the first place. Only cooperation between all the parties involved – science, research, politics, administration, NGOs, trade and industry – at all possible levels can lead to a solution to the marine litter problem.

2 Background/Motivation

The Marine Strategy Framework Directive came into force in Europe on 15 July, 2008. Its aim is to encourage the sustainable use of the seas and to conserve marine ecosystems. Based on this directive, the member states of the European Union are obliged to take the necessary measures to achieve or retain a healthy state of the marine environment at the latest by the year 2020. An important criterion for evaluating a good environmental status of the seas is marine litter. Whenever there is any talk of marine litter, plastics are always at the focus of discussion because of their long life, the additives they contain, and their decomposition into microplastics.

Against this background, the BKV GmbH wants to contribute to the necessary fact-oriented clarification of the true situation – by providing the required information and carrying out corresponding projects. Here, the BKV focuses its attention on the so-called land-sourced littering, in other words, the plastics that get from the land into the water. The main emphasis of this project is on the collection, compilation,

and processing of facts and data, especially with regard to mass flows and the routes by which the plastics are transported into the sea.

On behalf of BKV GmbH the Conversio Market & Strategy GmbH has presented for the first time a model approach for the documentation of land-sourced plastic litter with regard to its discharge pathways and discharge sources into the seas. The model was supported by the Association of the Austrian Chemical Industry (FCIO), the Germany's Plastics Packaging Industry Association (IK), PlasticsEurope Deutschland, and the German Engineering Federation (VDMA), here the Association of Plastics and Rubber Machinery.

In the first step, the methodology was applied to the discharges of improperly disposed-of plastic waste from Germany into the North Sea, and subsequently supplemented by the discharges into the Baltic Sea and the Black Sea. This provides an overall picture of discharges into the sea of improperly disposed-of plastic litter that can be attributed to Germany.

The aim of the project is, based on the methodical approach, to systematically record, structure, and quantify the main discharge pathways and sources for plastics. Only if the discharge pathways and sources as well as the corresponding mass flows of the plastics into the sea are identified and analysed, it will be possible to make a useful contribution to the prevention of further input of litter into the seas.

3 Plastic Waste in Germany

Worldwide, approximately 348 million metric tonnes of plastic (The term "plastics" here covers thermoplastics, polyurethanes, thermosets, elastomers, adhesives, coatings, sealants and PP fibres. It does not include PET-, PA- or polyacrylic fibres) were produced in 2017 (Fig. 1). Of this, around 7% or over 20 million tonnes came from Germany and 18% from Europe, equivalent to over 64 million tonnes. According to current forecasts, a period of consolidation will be expected in the following years [2].

In Germany, around 14.4 mt of plastic were used in 2017 for the production of plastic goods. Of this, 12.6 mt were virgin material and 1.8 mt were recyclate (Fig. 2). Taking the export surplus into account, 11.8 mt remained in Germany for private and industrial consumption [3].

In 2017, 11.8 mt of plastic products were used in Germany as new products. In the same year, around 6.2 mt of plastic products became waste that was correctly disposed of. This volume was made up of 5.2 mt of post-consumer waste and 0.95 mt of production and processing scrap. This means that the volume of waste has risen by approximately 1.9% a year since 2015 [4].

Depending on the particular application, plastic products are used for a different length of time before they are sent for disposal. More than 95% of packaging material – generally very short-lived products – returns as waste in the same year as it was produced. On the other hand, only 19% of building products become waste in the same year because of their much longer useful life. For example, plastic pipes

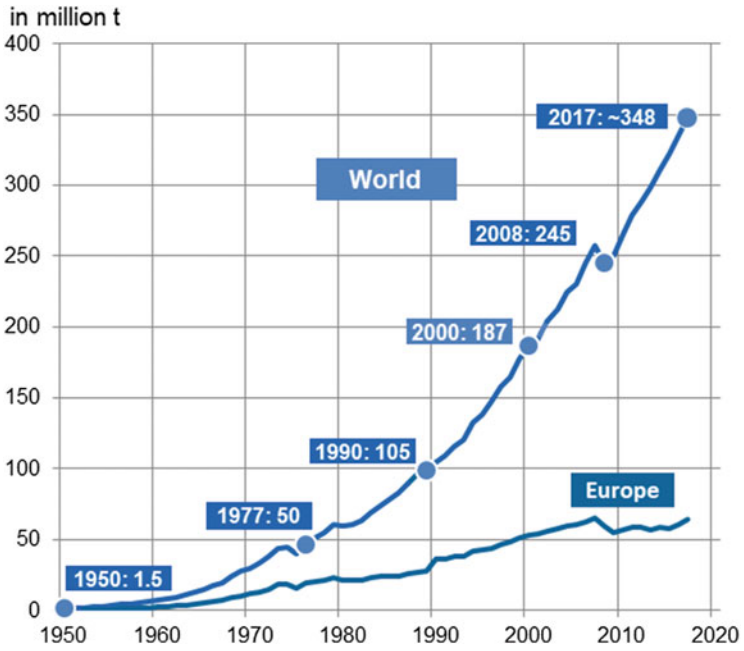

Fig. 1 World plastics production 1950–2017. © PlasticsEurope Market Research Group (PEMRG)/Consultic Marketing & Industrieberatung GmbH, 2016

remain in use for an average of 80 years and plastic window frames for 50–60 years before they are disposed of. The same applies to plastic products in vehicle construction. The average service life of a vehicle in Germany is 10–12 years, followed by an continued use of older vehicles abroad. As a consequence of this plastics from the automotive segment account for around 21% of the waste.

4 Improperly Disposed-of Plastics and Littering in Germany

Plastics enter the environment in various ways. During the manufacture of products, for example, plastic granules can be released in the form of microplastics. Microplastic in the environment also arises through the actual use of the products for their intended purpose. This includes, for example, abrasion of synthetic fibres during the wearing or washing of garments, and the use of detergents and cleaning products by private and commercial consumers [5].

In addition to the properly disposed-of waste, Germany also registers a certain amount of improperly disposed-of waste: the so-called littering. Littering is understood here to mean the contamination of the public sphere by people carelessly or irresponsibly discarding or leaving behind litter on roads, rivers in public places or in

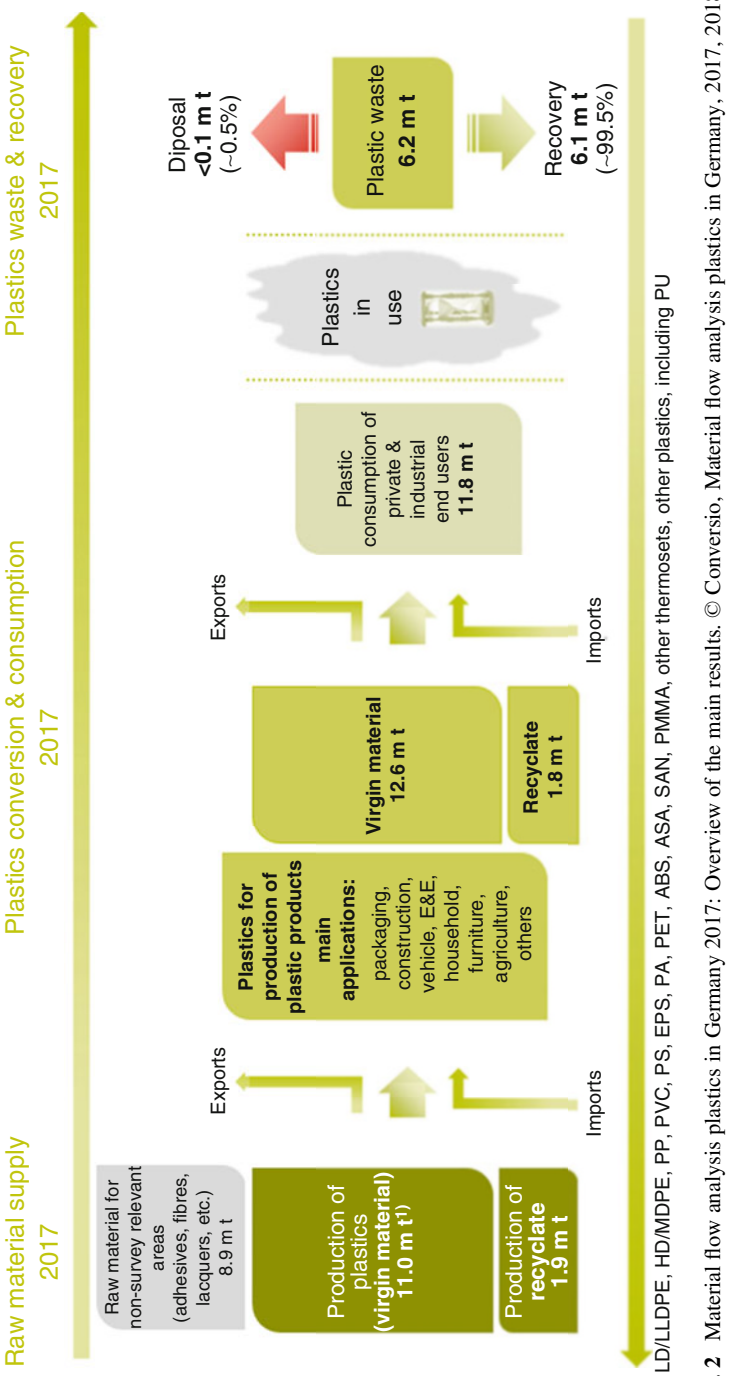

Fig. 2 Material flow analysis plastics in Germany 2017: Overview of the main results. © Conversio, Material flow analysis plastics in Germany, 2017, 2018

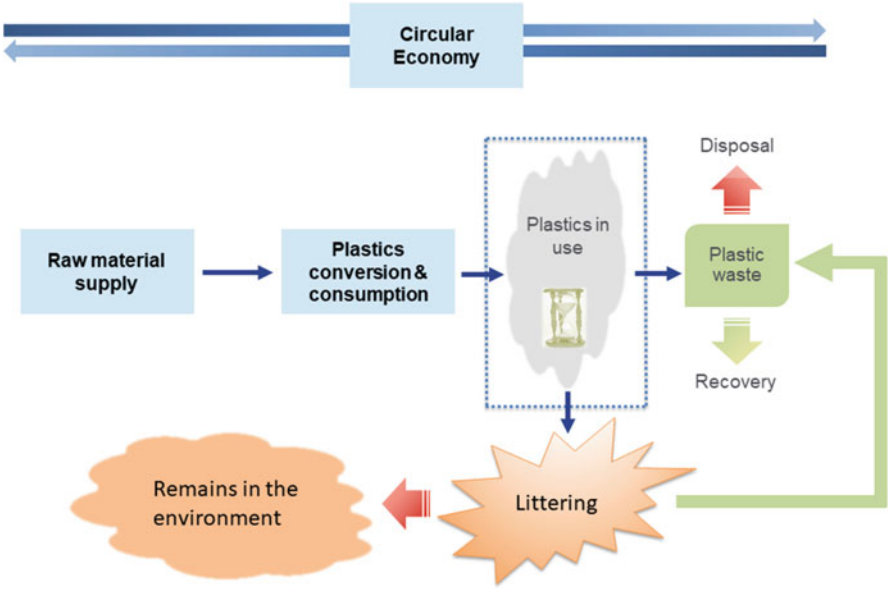

Fig. 3 Plastic waste in Germany and littering

the countryside. Littering involves all kinds of materials, whether metals, glass, paper, or plastics.

Although littering is a problem affecting many kinds of material, plastics receive an above-average amount of criticism. One reason for this is the comparatively long-life expectancy of plastics in nature. Furthermore, plastics – especially plastic bags and packaging – tend to attract more attention because of their size and appearance. Also, the fact that plastics are very light in weight has consequences with regard to their importance for littering: plastic articles – especially plastic bags – are very easily picked up by the wind and distributed over a wide area. They float on rivers, lakes, and seas and thus become distributed worldwide. Furthermore, microplastics are produced through the weathering and fragmentation of plastic articles. Removing such microplastics from the environment or from the sea is virtually impossible.

In Germany, a relevant cause of littering is the careless behaviour of people who simply throw such products away – out of laziness, convenience, indifference, lack of responsibility, provocation, or simply ignorance. In many places, a lack of waste bins contributes to the increase of littering. Only a change in behaviour of everyone involved will, in the long run, be able to solve this problem [6].

A large proportion of the improperly disposed-of waste in Germany is returned by one way or another to the intended collection systems (Fig. 3). Examples of this include the uncontrolled disposal of waste that is collected by the relevant authorities at big public events or at tourist destinations. Such refuse is also often collected by tram or railway maintenance depots, and also, for example, at motorway service

areas. According to estimates, around 75% of the improperly disposed-of waste is returned at some time to the waste management system [7].

Despite this, not all uncontrolled disposed-of waste can be subsequently collected. Reasons for this include gaps in the documentation of the disposal infrastructure and accumulations of waste at remote areas in the wild. Accordingly, the risk exists with such waste that it will end up in the sea by one route or another.

5 Subject of the Investigation of the Model

The focus of the model is on improperly disposed-of plastic litter. The term plastic is taken to mean polymer materials. Tyre and brake abrasion are at present not taken into account, nor are polymers in paints and other surface coatings. This is attributable to conventional definitional classifications (Tyres are made from rubber. According to the official statistics, tyres thus count as "rubber goods". Tyre abrasion can therefore not be counted as plastic waste. In the case of brake abrasion, the focus here is primarily on the fine dust pollution. Fine dust does not count as plastic waste either. In the study, by definition, primarily plastic products are taken into account as moulding compounds, i.e. polymers in surface coatings are not included. Resins are also taken into account only as moulding compounds).

In the model, a distinction is made between microplastic and macroplastic. There is no uniform definition for the term "microplastic". Within the framework of the model, plastics that are <5 mm when discharged into one of the discharge pathways or discharge sources count as microplastics (primary microplastics). Plastics that are >5 mm on discharge are recorded as macroplastics.

There is one special aspect in the model when distinguishing between primary and secondary microplastic. For designing the model, the plastic discharge via the various discharge pathways must be separated analytically from the discharge of plastic into the seas. The key factor for the classification as microplastics or macroplastics is thus their size at the moment of discharge into the discharge pathway. They are regarded as primary microplastics if, at the time of discharge into one of the discharge pathways, the plastics are <5 mm. Secondary microplastics are created by decomposition processes. Plastics that are >5 mm when entering a discharge pathway and do not decompose until they are in the discharge pathway (secondary microplastics) are recorded within the model calculation as macroplastics. Consequently, secondary microplastics are also taken into account in the model, but, in line with the assumptions made in the model, are shown as macroplastics. The "development" from macroplastic to microplastic is not a subject of the model.

A differentiation of the microplastics covered by the model according to the particle size has not so far been carried out because of the available data. Within the framework of the model, the particle size on entering one of the discharge pathways is decisive. According to this, the classification as microplastics or macroplastics is made. In contrast, previous studies have so far relied on results based on

measurements from one of the discharge pathways. Although these measurements provide a differentiation of the microplastics according to the particle size, it is not possible – or only to a limited extent – to draw conclusions about the particle size on entering the discharge pathway, about the place of origin (e.g. household, compost/digestate and industry/trade) of the plastic waste, or about its discharge pathway.

6 Methodology of the Model

The model serves primarily to estimate more reliably the origin, quantity, and nature of the plastic litter ending up in the sea. It presents individually the possible discharge pathways of plastic waste (micro- and macroplastics) that finds its way into the sea. It examines the land-sourced litter that gets into the North Sea, Baltic Sea, and Black Sea that can be attributed to Germany. Litter from marine shipping, cruise ships, and the fishing industry (sea-sourced litter) and discharges from other regions into the seas are not yet taken into account in the model.

In the first step, the main discharge pathways and discharge sources were identified and a data model established. Based on this data model, a database was drawn up. In the second step, an analysis was made of the discharge volumes based on secondary and primary data. Alongside scientific studies and investigations, statistical data, among other things from EUROSTAT and the German Statistical Office, were used and primary data were generated in the form of expert discussions. The process of evaluating other literature and sources and their potential subsequent utilisation in the model consistently continues.

7 Assumptions Made in the Model

The model subdivides land-sourced litter according to particular discharge pathways or discharge sources, namely “rivers”, “river shipping”, “coastal regions”, “ports”, and “landfills” (Fig. 4).

The model refers consistently to discharge pathways even if, for example, a landfill or a port is more a source than a pathway. Other point sources, such as wastewater treatment plants, or diffuse sources, such as discharges from agriculture, are assigned to the discharge pathways, and are included in the calculation of the discharge volume of the respective pathway into the sea. Depending on the relevance, certain sources are shown in the model separately and in more detail.

Only one part of the litter that gets into the environment also ends up in the sea, after a certain delay. Some of it remains in the countryside, becomes deposited in riverbeds and wetlands, or is collected again and disposed of (e.g. with the help of screens or sieves on weirs and wastewater treatment plants). In addition to discharges of litter into the environment, different “loss factors” therefore have to be taken into account when calculating the transport into the sea.

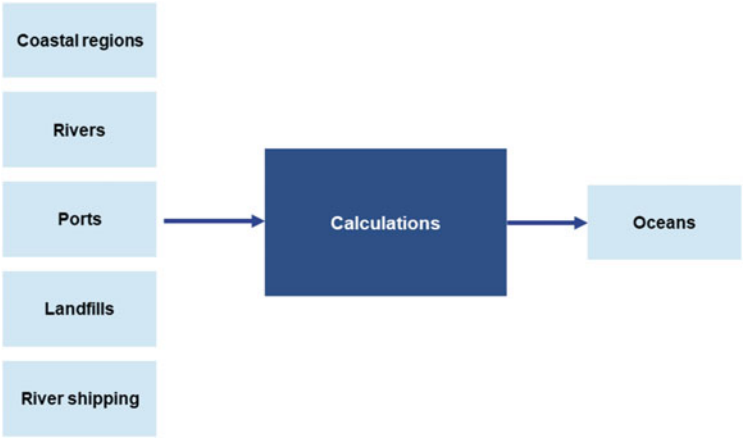

Fig. 4 Discharge sources and pathways

8 Overview of the Discharge Pathways

In the model, five main discharge pathways or discharge sources are identified.

Microplastics and macroplastics can get into the sea via rivers. What is unclear, however, is at what point the plastic enters the rivers. To ensure that the model takes into account not only the main rivers that flow directly into the sea but also other smaller rivers, it also covers the catchment areas of the rivers as defined by "river basin districts". River basin districts comprise one or several neighbouring river catchment areas. They encompass rivers from their source to their mouth (at the point where they flow into the sea) as well as all their tributaries and streams plus the groundwater in this district. The study focuses on river basin districts in Europe in which the main river flows into the North Sea, Baltic Sea, or Black Sea, or borders directly the North Sea, Baltic Sea, or Black Sea. Consequently, it covers not only the respective countries bordering these seas, but also countries that are part of an international river basin district and are thus of importance for discharges into the North Sea, Baltic Sea, or Black Sea.

In the study, the discharge pathway labelled as "rivers" covers waste that, in some way or other, gets from the land into a river. For example, microplastics in effluent can either find their way directly into the receiving water via the waste water from a treatment plant or can be blown or leached out from the sewage sludge that has been spread over fields. Improperly disposed-of macroplastics can get into streams and rivers through the wind, rainwater, or illegal dumping.

In the system used here, the discharge pathway "rivers" includes only plastic litter that enters the discharge pathway inland. The discharge of plastic litter into streams and rivers near the coast falls under the discharge pathway "coastal regions". The reason for this is that the transport losses are smaller with waste that is discharged near the coast.

Because of their proximity to the sea, coastal regions must be regarded separately. Here, plastic litter can either get directly into the sea or can be carried into the sea via surface water. In contrast to the discharge pathway "rivers", the loss factors here for plastic litter are much smaller because of the proximity to the sea. The model takes into account both the coast and the coastal regions of the North Sea and Baltic Sea. The EUROSTAT definition of a coast is used here: "a coastal region in the European Union is a region of the NUTS 3 level, which has a coastline or in which more than half the population lives less than 50 km from the sea". When considering the discharge pathway covered by "coastal regions", tourism was also taken into account.

In river shipping, litter (macroplastics) can first find its way into a river and finally into the sea through the wind, drifting, careless/irresponsible disposal, or illegal dumping. The model includes inland shipping in all countries whose river basin districts are relevant for the discharge of plastic waste into the North Sea, Baltic Sea, or Black Sea.

Waste disposed in landfills near to the coast can get into the seas by the wind or by drifting. The discharge of plastic litter from landfills into the sea can be selectively documented. This model covers active landfills near the coast with a maximum distance of 5 km to the North Sea or Baltic Sea. For discharges into the Black Sea attributable to Germany, the discharge pathway of "landfills" does not play a role because of the lack of a coastline.

Litter occurring in ports can end up in the sea through the wind, drifting, careless disposal, or illegal dumping. The model covers ports in countries with direct access to the North Sea and Baltic Sea that are on the coast or near to the coast. This discharge pathway is not relevant for discharges into the Black Sea.

9 Special Report: Compost and Digestate

Composts and digestates can contain microplastics to a differing extent. As a rule, plastics get into the recycling of biowaste through the collection of biowaste from households and trade and commerce. Especially in the collection of biowaste from private households, incorrect consumer behaviour plays a decisive role. Through carelessness, plastics and other foreign substances find their way into the organic waste bin. In the commercial sector, it is, above all, incorrectly disposed-of plastic packaging that plays the largest part in the amount of plastics found in compost and digestate. When compost and digestate are spread on the land in agriculture, forestry, landscaping, and private households, it is quite possible that microplastic particles will get into rivers or directly into the sea through the wind, through drifting, or by being leached out.

In the model, compost and digestate from household and commercial sources are shown as a potential discharge source for plastics into the seas. Every year, composts and digestates, with approximately three metric tonnes, account for less than 1% of the total discharges into the North Sea, Baltic Sea, and Black Sea attributable to

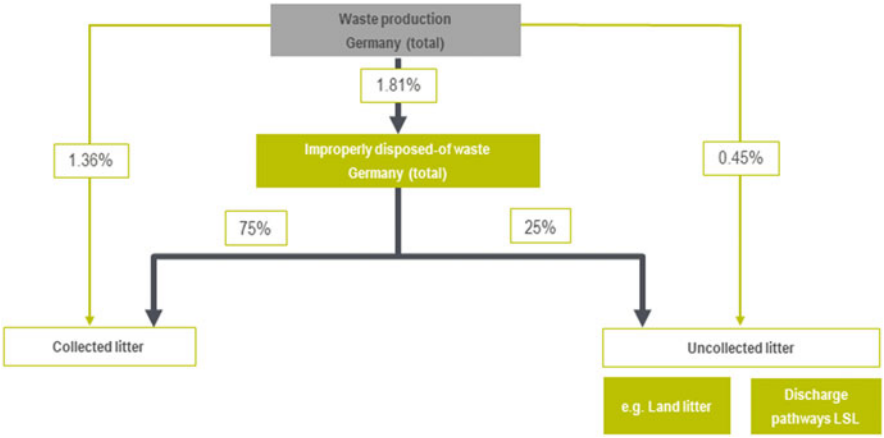

Fig. 5 Littering in Germany – Calculation approach. © Conversio, From Land to Sea – Model for the documentation of land-sourced plastic litter, 2018

Germany (The calculations are based on data from the RAL quality assurance of the Federal Compost Association (BGK) and on data from the Federal Statistical Office).

For discharges into the North Sea, the Baltic Sea, and the Black Sea, a special report on compost/digestate has been compiled as a supplement to the model. It describes the individual calculation steps in detail [8].

10 Special Report: Littering

To determine the percentage of macroplastic in marine litter, a calculation based on improperly disposed-of plastic waste – litter – is being carried out because there is a lack of adequate data and information (Fig. 5). Although a direct correlation between the quantity of correctly recorded waste and incorrectly recorded waste is only possible to a certain extent, it can, in view of the lack of available data, serve as an initial aid.

There have been few studies regarding the proportion of litter in the total amount of waste in Germany. To date, no countrywide study of improperly disposed-of waste has been carried out. The basis for the calculation in the model is therefore a study by the Bavarian Office for Environmental Protection (Bayerisches Landesamt für Umwelt – LfU) In 2001, a report entitled "Special assessment of the waste figures for 2001 – Illegal waste disposal" was published.

The assumptions made in the model about littering were examined in more detail and verified in a separate study in 2018. Especially the assumptions made on the basis of the LfU study from 2001 were checked with the aid of additional sources

and methods. To this end, literature research and expert discussions were held. Furthermore, a sensitivity analysis was carried out to coordinate the obtained results.

The results of the special report on littering show that only minor changes need to be made to the assumptions made in the model with regard to littering. These will be undertaken in the course of the next update of the report and handbook in 2019.

11 Data Basis

The model is based on the data and information obtained and forwarded by third parties (Fig. 6). The absolute discharge quantities determined here should be seen as an estimate based on the existing study situation and discussions with relevant market experts. Against this background it is understandable that the quality and quantity of the available data considerably vary between the studied areas of microplastics and macroplastics.

In the microplastics segment, the model is based on a broad set of data, as many studies and investigations have already been carried out on this subject. Nevertheless, because a large number of variables are used for the calculation of individual factors, there are also some individual data gaps in the field of microplastics. For this reason, the decision was taken to work with estimates from experts.

For some factors that extend over several discharge pathways and also several applications (e.g. transport losses), only rudimentary data is so far available. Consequently, when looking at the volumes involved in the discharge of plastics into the sea, an assessment of the data accuracy according to the application or discharge pathway is only possible to a limited extent.

In the macroplastics segment, hardly any studies so far exist that can be integrated into the model. For this reason, the figures have so far been derived from the amount of improperly disposed-of waste in Germany.

12 Limitations of the Model

A model is always a simplified representation of the reality. For this reason, not all factors can be taken into account in the model "From Land to Sea – Model for the documentation of land-sourced plastic litter".

As already described, the limitations to the model result, on the one hand, from the frame of reference and the definitional classifications, and, on the other hand, from the frequent lack of the necessary data and information on relevant issues, which prevents them from being included in the model. This leads, for example, to a situation in which a differentiated classification according to the type and size of plastic in the model is currently not possible. Also, the importance of tourism, the discharges of plastic particles through the air, the effects of natural phenomena such as floods, and special events such as music festivals cannot be taken into account

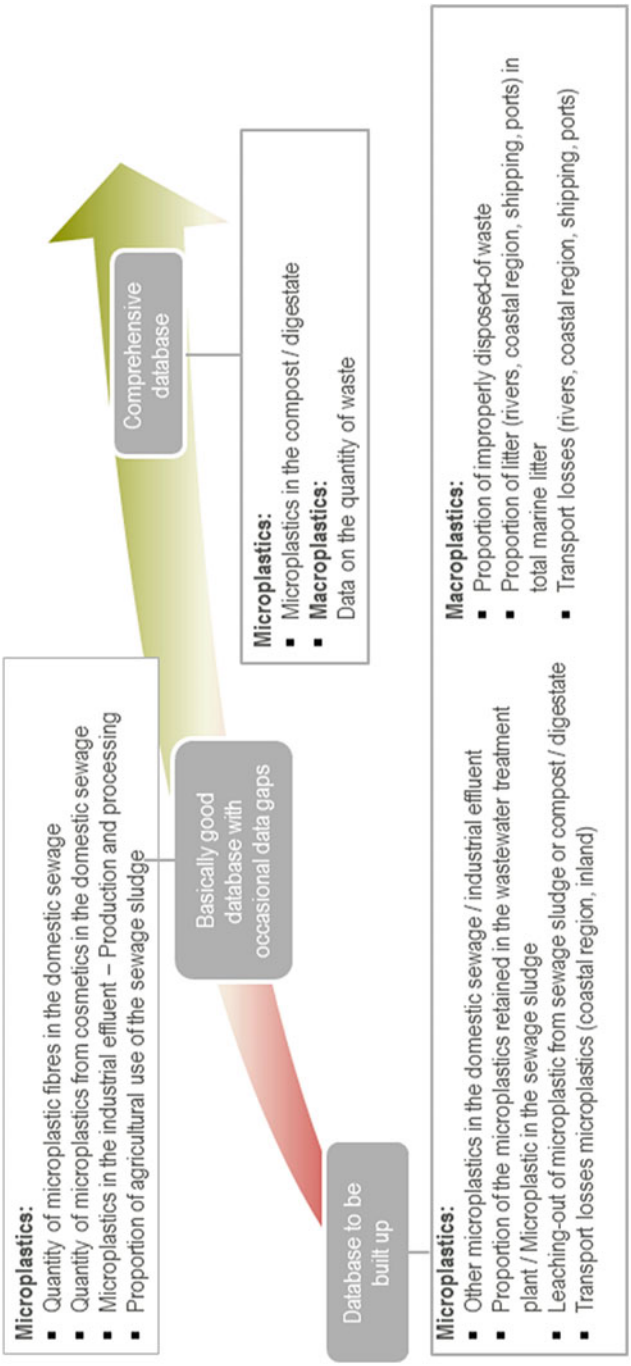

Fig. 6 Evaluation of the data. © Conversio, From Land to Sea – Model for the documentation of land-sourced plastic litter, 2018

separately in the model at the present time due to a lack of usable information. However, all this information also goes wherever possible into the model via the factors that were established for calculating the discharge of plastics into the sea attributable to Germany.

13 Main Results

Most of the plastics discharged into the sea from Germany are macroplastics (Fig. 7). This result must always be considered taking into account the distinction used in the model between microplastics and macroplastics, as well as the given definition of "plastics". Furthermore, the proportion of macroplastics in the total discharges differs from one sea to another. By far the highest proportion of macroplastics is discharged into the Baltic Sea. This is explained by the high percentage of the coastline of the river basin districts that are connected with the Baltic Sea. The majority of the population which has to be considered within the calculations for the Baltic Sea live on the coast. Because of the proximity to the sea and the partial direct discharge into the sea, the transport losses are lower. Consequently, more macroplastics get into the sea and are not, en route, permanently eliminated again from the discharge pathway.

As regards the discharge pathways, the two pathways "rivers" and "coastal regions" dominate. The majority (approx. 80%) of the total discharge gets into the seas, i.e. North Sea, Baltic Sea, and Black Sea via these two pathways.

Virtually all the litter entering the Black Sea that is attributable to Germany is transported via the discharge pathway "rivers". Because Germany does not directly border the Black Sea, only the "rivers" and "river shipping" pathways are of relevance here, but not the "coastal regions" pathway.

Discharges via landfills are of no relevance in Germany, because in Germany it is forbidden to dump carbon-containing waste – and thus plastic-containing waste – on landfills of classes I, II, and III (Definition and descriptions according to German law: § 2 Number 7 and 8 of the German "Verordnung über Deponien und Langzeitlager (Deponieverordnung – DepV)" and Annex 3 of the German "Verordnung über Deponien und Langzeitlager (Deponieverordnung – DepV)". Waste can only be deposited on landfills of classes I, II or III if it fulfils the criteria according to law). Only a neglectable amount of plastics end up on landfills of classes IV – an underground landfill for hazardous waste. For this reason, an account of the discharge pathway "landfills" has been dispensed with in the report on the model.

Total discharge from Germany into the seas

Germany 2014			Discharge pathways								Total	
			River		River shipping		Coastal region		Ports			
Miroplastic	Household	Fibers	79 t	14%	-	-	14 t	2%	-	-	93 t	7%
		Consumer products	39 t	7%	-	-	7 t	1%	-	-	46 t	3%
		Other	24 t	4%	-	-	4 t	1%	-	-	27 t	2%
	Household/ trade	Compost/digestate	3 t	<1%	-	-	<1 t	<1%	-	-	3 t	<1%
	Industry/ trade	Production and processing waste	7 t	1%	-	-	1 t	<1%	-	-	8 t	1%
		Other	2 t	<1%	-	-	1 t	<1%	-	-	3 t	<1%
Total miroplastics			153 t	27%	-	-	27 t	5%	-	-	181 t	13%
Macroplastic		Packaging	247 t	44%	23 t	61%	322 t	58%	149 t	61%	741 t	53%
		Agricultural	22 t	4%	-	-	28 t	5%	-	-	50 t	4%
		Other	140 t	25%	15 t	39%	182 t	33%	97 t	39%	434 t	31%
Total macroplastics			408 t	73%	38 t	100%	532 t	95%	246 t	100%	1224 t	87%
Total			561 t	100%	38 t	100%	559 t	100%	246 t	100%	1405 t	100%

Fig. 7 Results of the calculations of the discharge. © Conversio, From Land to Sea – Model for the documentation of land-sourced plastic litter, 2018

14 Conclusions

The report and handbook belonging to the model are continuously updated and further revised. In addition to continuously adapting the above-mentioned framework conditions, the model parameters are also checked and, wherever necessary, modified. The evaluation of the model is accompanied by consultations with external experts.

The open structure of the methodology makes it possible to also apply it to other regions or countries and to incorporate further discharge pathways. The advantage of the model lies, in particular, in the easy and flexible adaptation of variables and calculations. The aim is, therefore, to transfer the model to other regional conditions. The report and handbook for the model are available in German and English and can be obtained free of charge via the BKV website. Like the model, the "Special study on littering" and the "Special study on compost/digestate" can be ordered free of charge on the BKV website (https://www.bkv-gmbh.de/studies.html).

References

1. Jambeck et al (2015) Plastic waste inputs from land into the ocean
2. PlasticsEurope Market Research Group (PEMRG) and Conversio Market & Strategy GmbH (2018) Plastics – the facts 2018
3. Conversio Market & Strategy GmbH (2018) Material flow analysis plastics in Germany 2017
4. Conversio Market & Strategy GmbH (2017) Post-consumer plastic waste management in European countries 2016 – EU 28 + 2 countries
5. Fraunhofer UMSICHT (2018) Kunststoffe in der Umwelt: Mikro- und Makroplastik, Kurzfassung der Konsortialstudie
6. Öko-Institut e.V. and ZEUS-GmbH (2020) Status Quo, Handlungspotentiale, Instrumente und Maßnahmen zur Reduzierung des Litterings
7. Conversio Market & Strategy GmbH (2018) Verification of the factor 0.3% within the model "From Land to Sea – Model for recording land-sourced plastic waste"
8. Conversio Market Strategy GmbH (2020) Sonderbetrachtung Kompost und Gärrückstände