TEXTE
198/2020

Kunststoffe in der Umwelt – Erarbeitung einer Systematik für erste Schätzungen zum Verbleib von Abfällen und anderen Produkten aus Kunststoffen in verschiedenen Umweltmedien

Abschlussbericht

Für Mensch & Umwelt

Umwelt Bundesamt

Kurzbeschreibung

Der Eintrag und Verbleib von Kunststoffen in die Umwelt ist seit einigen Jahren ein viel beachtetes und viel diskutiertes Thema. In diesem Vorhaben wurde eine Abschätzung des quantitativen Verbleibs von Kunststoffen in der Umwelt aus dem Bereich der achtlos weggeworfenen oder liegen gelassenen Kunststoffabfälle („Littering“) sowie der Kunststoffprodukte, die umweltoffen eingesetzt werden und aus denen Einträge in Form von Kunststoffpartikeln in die Umwelt hervorgehen können, vorgenommen. Auf dieser Basis wurden zum einen relevante Quellen für Kunststoffeinträge identifiziert und Handlungsmöglichkeiten diskutiert. Die größten Einträge ergeben sich aus dem Verkehrsbereich mit dem Reifenabrieb als größter Quelle. Daneben tragen der Baubereich und der Landwirtschafts- und Gartenbaubereich relevant zu den Gesamtmengen bei. Zum anderen ist eine kritische Betrachtung der Datenlage erfolgt und besonders zentrale Aspekte für eine Verbesserung der Datenlage wurden identifiziert. Die Berechnungsergebnisse wurden mit aktuellen einschlägigen Studien abgeglichen und eingeordnet.

Abstract

Plastic entries into the environment are an increasingly discussed issue. In this project, a first estimation of plastic entries into the environment from littered plastic items as well as plastic applications has been made. Based on this, the most relevant sources could be identified and possible mitigation actions have been discussed. Major emissions result from the transportation sector with tyre wear as key source. In addition, the construction sector as well as the agriculture and horticulture sectors contribute significantly. Besides the quantification of entries from various sources, the data situation has been critically assessed and key points for improving the data situation have been identified. Finally, results from this study have been cross-checked with findings from related recent studies.

Summary

Plastics are used in a variety of applications. From many of these applications as well as from improperly disposed plastic waste, plastic entries into the environment may result.

While, recently, the input of plastics into the environment has received broad attention and has been a widely discussed topic for some time now, the actual state of knowledge on the subject is, so far, fragmentary. Only few estimations quantifying plastic entries from different sources are available to date. Against this background, it was the goal of this study to obtain a first structured estimation of the quantitative entries of plastics from different sources into the environment for Germany. In this regard, littered plastics (plastic items thrown away or left behind in places not intended or designated for such a purpose) as well as the sector of plastic products used in the environment were considered. From the plastic products used in the environment, plastic inputs can result both during the usage and after the end of use span.

Many of the plastics entering the environment through different pathways are removed by cleaning and removal measures.

The project particularly aims at estimating the share of plastic entries which remain in the environment after such measures.

Methodical approach

The scope of this study is the environment in Germany. The approach differentiates between two basic emission pathways:

- Emission from littering of plastic waste
- Emissions from plastic products and plastic containing products intended to be used in the environment.

For both pathways, models were built, allowing an estimation of the plastics remaining in the environment based on available information and expert assumptions.

The modelling of the pathway from littering is based on information on the plastics found in the environment. Here the main sinks have been differentiated according to their use (roads, service stations, parking lots, pedestrian zones, coasts, river sides and inland swimming areas).

For the pathway of plastic products and plastic containing products intended to be used in the environment, the modelling is based on the quantities placed on the market (POM) for 63 product groups and assumptions on the share remaining in the environment after the end of the use-phase.

From plastic products used in the environment, emissions often occur over a long time span (up to multiple decades) and also the permanent remain of entire products or product parts in the environment partly occurs only after long-time usage. In the developed model these emissions occurring in the future are counted “back” to the period of “the placing on market”. For an even more exact depiction of the yearly emissions, time series analyses of the POM as well as the variance of the respective usage lengths over time would have to be considered in the modelling. For both aspects, so far no consistent databases are available.

The calculation results of both emission pathways were brought together and structured according to the following sites:

- Streets
- Rivers and river sides
- Settlement areas
- Agricultural areas

- Coastlines

Thus, for each of these sites/ land use types a quantification of plastic emissions can be found in the results.

Parallel to this project commissioned by the German Environment Agency (Umweltbundesamt), a quantification of the plastic emissions into to the environment in Germany has been subject to two other recent studies:

- Bertling, Jürgen; Hamann, Leandra; Bertling, Ralf (2018): Kunststoffe in der Umwelt. Unter Mitarbeit von Tatiana Bladier, Rodion Kopitzky, Daniel Maga, Nils Thonemann und Torsten Weber. Fraunhofer Umsicht. Oberhausen.
- Conversio (2018): Vom Land ins Meer - Modell zur Erfassung landbasierter Kunststoffabfälle. Unter Mitarbeit von Christoph Lindner und Thomas Jäger. Hg. v. Conversio und BKV. Frankfurt.

Considering the high environmental and political relevance of the subject, a systematic cross check with these other two studies has been performed. This check was done based on the published reports and documentation of the above-mentioned parallel studies with the present preliminary results of this project as well as in intensive expert discussions between the involved authors. For this purpose, a workshop between the authors of Fraunhofer Umsicht, Conversio and Ökopol was held in September 2018 in Hamburg.

Here, fundamental differences became apparent regarding the subject in question (from primary microplastics to secondary microplastics to large plastic products), the emission pathways considered (from careless littering to inevitable emissions from usage to tolerated remain in the environment) as well as the sinks in question (from the focus on the final emission into the sea to the entire environment of Germany). The knowledge about these differences is very important in order to interpret the respective conclusions and statements of the studies correctly. For this reason the present report includes a systematic comparison of central assumptions and limits of the three studies.

The three studies consistently show that all data and findings available to this date do not suffice to build a continuously valid framework for the quantitative plastic emissions into the environment. The current results are therefore based to a relevant extent on extrapolations of single data points as well as expert assumptions, which from a scientific point of view, leads to high uncertainties of the results.

Regardless of the systematic differences and the challenges concerning missing data, the differentiated analysis of the results of all three studies showed in many cases high accordance in the magnitude of emissions from different sources.

In those cases where relevant differences in the calculated emissions between the parallel studies and the preliminary results of this project were identified, the calculations, underlying data and assumptions made were examined in more detail. As far as viable these aspects were considered in the sensitivity analysis of the results presented in this report.

Results: Plastic emissions into the environment

The plastic waste identified in the project, which is introduced by littering into the various types of land use (roads, rest areas, parks, pedestrian zones, coasts, river sides and inland swimming areas) and remains permanently in the environment, amounts to 650 to 2,500 t/a. Without differentiation between littering and non-littering waste (i.e. waste from illegal deposition) this amount increases up to 3,750 t/a. If the assumptions are adjusted in consideration of the other current studies, the mass increases to about 13,100 t/a. This exemplifies the existing data uncertainties because of the lack of systematic statistical data regarding littered waste which is suited for extrapolation.

From plastic applications, plastic emissions amount from 150,540 t/a to 235,045 t/a. Of these, 132,790 t/a to 165,440 t/a originate from the transport sector with tyre abrasion as main source. Next to this the building sector (8,875 – 60,425 t/a) and the agricultural and horticultural sector (6,200 – 21,500 t/a) relevantly contribute to the total emissions. Here again the result ranges show considerable uncertainties. In addition to uncertainties in the distinction between the quantities of products used in an environmentally open manner and the total quantities placed on the market in many product areas, uncertainties exist in particular in the area of assumptions about the proportions of products used in an environmentally open manner that will remain in the environment in the long term even after the end of use.

With regard to the outlined uncertainties, the most relevant emissions of plastics remaining in the environment are summarized in the following table.

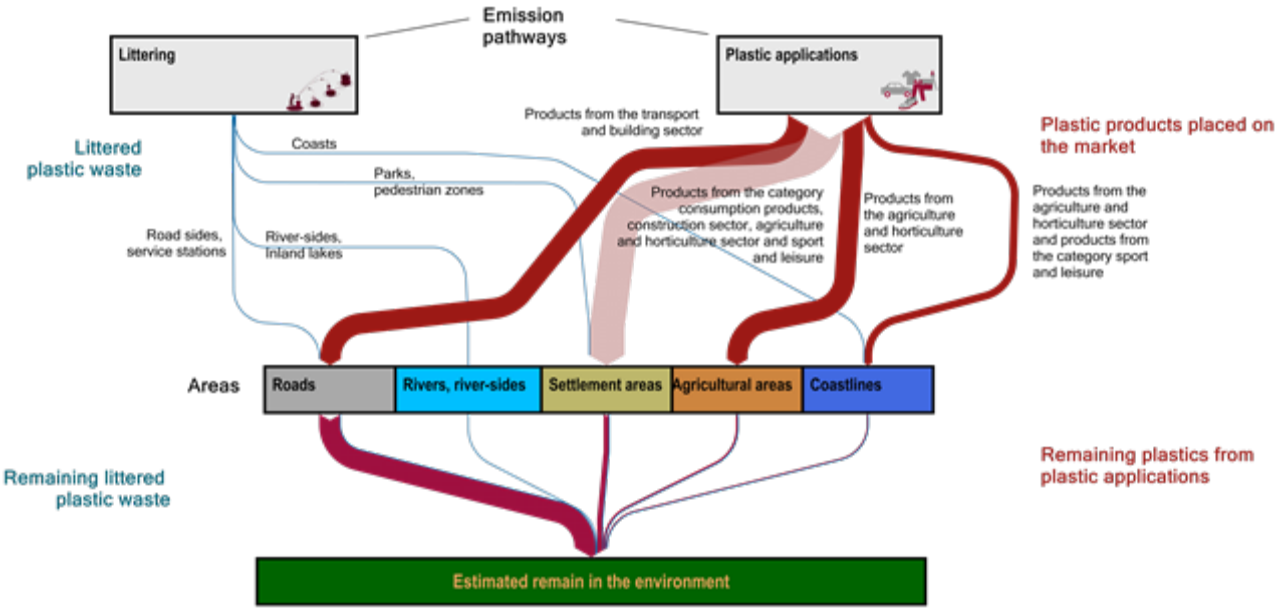
Table 1: The estimated yearly emissions of plastics permanently remaining in the environment for the 30 most mass-relevant emission sectors

Emission pathway	Source / Emission sector	Plastic emission [t/a]
Emission from intended use of plastic products or plastic containing products	Tyres, motor vehicle (abrasion)	143,260 (129,000-158,000)
	Pipes	25,410 (4,620-46,200)
	Geotextiles	3,500 (2,500-4,500)
	Shoes (abrasion)	2,400 (1,600-3,200)
	Planting pots	2,285 (415-4,150)
	Sewage sludge	2,250 (1,500 – 3,000)
	Compost	2,230 (1,090 – 3,340)
	Fertilizers	2,025 (1,970-2,075)
	Granulate for artificial pitches	1,930 (1,545 – 2,315)
	Grass paver	1,790 (325 – 3,250)
	Road markings	1,760 (1,130-2,390)
	Agricultural foils	1,650 (300-3,000)
	Bicycle tyres	1,095 (820-1,370)
	Drainage channel (rain channel)	895 (165 – 1,625)
	Cigarette filters (butts)	890 (165 – 1,620)
	Agricultural nets, tubes, fleeces	880 (160 – 1,600)
	Seepage blocs	825 (150 – 1,500)
	Baler twines	825 (150 – 1,500)
	Construction paints	700 (350 – 1,049)
	Palisades	650 (325-975)
	Base plates	500 (250-759)
	Toys / play equipment	500 (250-75)
	Cosmetics	490 (475-500)
	Silage films	460 (230-690)
	Pond liners	460 (83-830)
	Cable coatings	395 (200-590)

Emission pathway	Source / Emission sector	Plastic emission [t/a]
	Browsing protection	275 (50-500)
	Drainage	230 (40-415)
	Construction foil	200 (100—300)
Emissions from littering of plastic products	Carelessly disposed of ("littered") plastics including waste from illegal disposal, lost products, etc,	1,500 (650-13,100)

The mass flows of plastic emissions are furthermore depicted in the following graph structured by emission pathways. Here also an allocation to the emission site is made.

Figure 1: Plastic emissions to the environment - Summary of estimations



In conclusion based on this data basis the following observations can be made:

- The emissions from various plastic applications dominate the overall picture. Next to the transport sector, which is dominated by tyre abrasion, particularly the construction sector is a relevant source for plastic emissions.
- Tyre abrasion represents the quantitatively largest (single) source for plastic emission. The uncertainties (or differences in the assumed abrasion factors) are below 30 %. There is strong consensus among experts on the quantitative relevance of this source.
- Next to the abrasion from the intended use of tyres, the source contributing the most to emissions remaining in the environment is the incomplete removal of plastic products after their use.
- Littering of mostly small plastic objects such as packaging is also a relevant source of plastic emissions into the environment. Regarding the total emissions, however, this source is one amongst many similarly important sources. In many areas, cleaning measures can reduce the permanent presence in the environment. Changes in the nature and intensity of such cleaning measures are reflected in the developed model as a change of the captured share of waste or rather as slippage. Main uncertainties and questions exist regarding:

- The effectiveness of the existing cleaning measurements: Systematic data regarding cleaning measures, accounting for amounts with regard to different land use types, efficacy / slippage are missing here. The influence of the assumptions made on slip and plastic proportion has been depicted using the example of littering along roads. Parameter variations in line with the assumptions made in other studies can influence the results of the estimations by up to a factor of 10.
- The differentiation between littering and non-littering: because this distinction cannot be made for the plastic products found in the environment, this differentiation brings an additional uncertainty into the total estimations, which according to expert's valuation is not countered by an added value regarding the conclusions.

Derivation of recommended actions

Based on the results of the modelling of the plastic emissions into the environment, recommendations for actions can be derived on two levels.

Firstly, the research as well as the analysis of the currently available data on plastic emissions into the environment showed that in many areas the data availability is insufficient. Here, need for action exists to improve the knowledge on the status quo and also improve the analysis of future developments.

Secondly, the estimations on plastic emissions already show quite clearly which sectors of emission are relevant with regard to future mitigation measurements.

These are:

- Emissions from sewage sludge and composts
- Emissions from roads: tyres, road markings, shoes
- Emissions from agriculture and horticulture: geotextiles, pipes, architectural paints, artificial grass, grass paver
- Emissions from the agricultural industry; foils etc.

Additionally the sector of waste water treatment is of importance because of its cross divisional function and the area of littered cigarette filters because of its attention in the media.

In the course of the project, these sectors were looked at in more detail with regard to existing mitigation measurements and approaches for future action.

Waste water treatment

Emissions of plastic parts and particles into waste water (sewage water and rainwater) are to be expected from various plastic applications. Findings on the quantity of plastic emissions in the different output streams and the resulting plastic emissions into the environment are only sparsely available. Multiple research projects with the focus on "plastics in the environment" are currently underway which could improve the state of knowledge. The results of these research projects should be systematically evaluated and taken into account when updating the overall emission model.

Emissions from roads

In the sector of road use, a closer look has been taken at tyre abrasion, road markings and shoe abrasions. For tyres a prospective adjustment of the regulation (EC) No 1222/2009 or 661/2009 may be an option for the reduction of the plastic emissions. Additionally, from the current research project "RAU – tyre abrasions into the environment" valuable findings on the emission and mitigation possibilities of tyre abrasions can be expected.

With regard to road markings the expert are of the opinion that there are currently no concise and reasonable approaches to action. In principle the kind of used road markings could be regulated via the

public invitation for tender, however regarding the missing alternatives this remains a theoretical approach.

In the area of shoe abrasions an approach could be to make binding standards on abrasion resistance. Corresponding standards are to date available for the area of safety footwear and in voluntary eco labels (Blue Angel and EU-Ecolabel).

Construction and landscaping

Especially in the sector of civil engineering and road construction but also in buildings plastic products are increasingly being installed directly in the ground. These products are on the one hand plastic foils or plastic textiles which are being used as insulation, sealing or compensating membranes and on the other hand a broad variety of moulded plastic parts such as pipes, wastewater channels and cable ducts. Also supporting elements for terrain levels, road attachments and more are by now increasingly made out of plastic.

All of these plastic products are designed for long term use in their respective area of application. However, with regard to plastic emissions into the environment three main questions arise:

1. To which extent can emissions of plastic particles or parts be expected from the different conditions of installation and from the intended use?
2. To which extent can emissions of plastic be expected due to either damage from the use phase or from the installation or in the course of renovation and reconstruction measures?
3. Which share of the initially installed plastic products can be expected to remain in the environment permanently after their use phase, either because they remain entirely in the ground or because they are damaged during the dismantling of the building and remain partly in the ground?

Regarding to the total quantities especially questions 1 and 2 are relevant. For these sectors however, to date no systematically suitable basic information is available.

With respect to question 2 the challenge is the lack of routine maintenance for the plastic parts in question. Therefore damages of plastic parts and plastic emissions related to those are usually not detected or are accepted as long as they do not compromise the function of the building and are usually not recorded in a structured manner.

With respect to question 3 this is due to the fact that the intended overall usage time is not yet reached for the majority of the plastic products and that even if the plastic parts are removed during dismantling, no comparison is made of the initially installed parts and those plastic parts removed during dismantling of the building.

Because of the high quantitative relevance of this emission sector, in the experts' opinion it is indispensable to carry out detailed investigations on the current state of management and dismantling of plastic products used in an environmentally open manner in the building sector.

Sewage sludge and compost

Possible mitigation measures for the plastic quantities emitted with the sewage sludge output are either a reduction of the plastic quantities introduced into the waste water treatment plant (WWTP) or a reduction of the plastic content of the sewage sludge or a further reduction/total ban of the application of sewage sludge on land for agricultural purposes. The first measure would be desirable, however it requires changes in many other areas. A reduction of the plastic content in sewage sludge would only be feasible through an improved screening. To achieve this, either the legal threshold for sewage sludge intended for agricultural application could be strengthened or extended to particles smaller than 2 mm. It is however questionable whether it is possible to technically remove plastics from

sludge to a sufficient degree, as the plastic particles in the sludge can be expected to be particularly small (from tyre abrasion, plastic fibres etc.). A further reduction or total ban of sewage sludge application on agricultural land is rather unlikely, as this regulation has only just been adopted for large WWTPs and has to be implemented now. Furthermore, an improvement of the data base is an important measure for action. A number of currently ongoing research projects are devoted to this topic.

Two fundamental mitigation measures can be distinguished for the reduction of plastic contents in composts: firstly the reduction of plastic contents in the input into composting facilities (in particular waste from the organic waste bin and garden waste), secondly the reduction of plastic contents in the output product (compost) through improved technology, stricter thresholds or enforcement. On the input side it would be useful to expand and develop consumer information tools, whereby an evaluation of the effectiveness of such campaigns is still pending. Further possible measures could be a polluter-pays pricing for biological waste as well as an adaption of the standards EN 13432 and EN 14995, which define conditions for the degradability of plastics, to the actual conditions in composting plants.

On the side of the treatment and outputs a possible measure could be to tighten the legal thresholds. In September 2018, at the request of a number of federal states, the Federal Council expressed its support for this. Today, most of the facilities are already significantly below the thresholds, however the thresholds do not cover particles smaller than the size of 2 mm. Whether it is technically and economically feasible to remove plastics more thoroughly (including smaller particles) during the biological treatment has to be clarified in detail with the composting plant operators and further experts. Moreover, the German bio waste ordinance as well as quality monitoring of fertilizers could be strengthened with regard to the foreign substance thresholds. This monitoring is the responsibility of the federal states and is done randomly, the situation however differs from state to state. Whether the monitoring with regard to plastic contents in composts is sufficient cannot be evaluated with the current information available.

On top of this, the improvement of the data base on plastic contents in compost is reasonable because most surveys and studies only record plastic particles larger than 2 mm thus the content of smaller particles remains unknown.

Agricultural industry

The range of agricultural films includes films intended for earlier harvesting and for fodder preservation. The emission into the environment results from remainders of entire foils or smaller foil parts in the soil due to drift or incomplete removal after usage. The main challenge is to guarantee a wide removal and recycling of the films. With the initiative ERDE of the RIGK GmbH such a collection and recycling and system already exists. The initiative ERDE (Erntekunststoffe Recycling Deutschland) is a collection system for agricultural films, initiated by the Industrievereinigung Kunststoffverpackungen e. V (IK) . The system is currently financed by ten participating producers of agricultural plastics (RIGK 2018) in order to offer farmers a cost-effective service for collection of the films. Users of agricultural films (farmers) can bring the used films to collection points or have them collected.

Planting pots

The emission of plastic from planting pots stems from abrasion or chipping off of small plastic parts during the use or from remainders of the product in the environment i.e. by leaving the pots outside and blowing them away with the wind. The emission of plastic from this source could be entirely avoided if the pots were not made of plastic but of material that is degradable under given conditions. Such pots made of biologically degradable and compostable materials like straw, cork, sawdust and corn starch are available on the market.

The feasibility of this solution is however limited for plants offered for private use in retail markets. Suited and affordable alternatives are currently searched for. Another possible measure to reduce the emission is to give incentives to the consumers to collect the pots and return them (i.e. via a deposit system).

Cigarettes

For the avoidance of littering and remain of cigarette butts in the environment several measurements can be identified:

- Targeted information about the negative impacts on the environment of litter,
- Structured guidance for municipalities,
- Addressing the issue in "anti-litter campaigns",
- Provision of "mobile" ashtrays (either free of charge or against payment) and
- Punishment of littering through regulations.

In Germany, such activities have so far taken place only rarely. In the experts opinion it should be assessed which of the identified mitigation measures lead to a reduction of littered cigarettes to further develop effective and equally efficient action measurements for Germany. For this purpose it should be determined whether data on the impact of these measures are collected in selected municipalities that have implemented measures against littering. In principle, it should be examined along the further legislative process of the EU-plastic strategy which kind of awareness raising measures specifically are intended in the proposal of the EU commission and how the proposed new instrument of extended producer responsibility could be designed in concrete terms.

Systematic further development of the overall modelling

As part of the project, an overall model was developed for the first time for all areas of plastic discharge into the environment in Germany. In view of the problems with the data bases outlined above, only initial estimates with correspondingly high uncertainties could be made for some areas. Nevertheless, this modelling allows a first rational derivation of the overall relevance of the topic of entries and the fate of plastic in the environment.

According to the authors, however, the representatives of the plastics industry, environmental administration and specialist science involved in the final expert discussion in June 2019 see this as opening up the perspective of a stronger fact-based debate on the topic, which has so far been quite controversial and emotional.

In order to be able to fulfil this function in the future, however, in the opinion of the named actors, a consistent updating of the overall model is required, in which the existing uncertainties and remaining data gaps must be specifically minimised.

For this it is relevant that the structured representation of all entry areas created in the developed modelling allows to overwrite the currently used (estimated) values with updated and/or better substantiated detailed data at any time. This would make it possible in future to improve and update the database in a transparent and, if necessary, also work-sharing process.

The comparison with other partial models on environmental inputs of plastics developed in parallel carried out in the course of the project and the discussions conducted with the actors involved also showed, however, that it is important in the context of updating and further developing an overall model to re-examine the objective, i.e. the expected answers.

Basically, with a modelling both

- precautionary orientation
  by creating a systematic factual situation as a rational basis for targeted action in the case of newly identified risks and precautionary reduction strategies and
- risk management/reduction
  through the (focused) pursuit of environmental quality impairments derived from concrete risk considerations in defined environmental compartments

may be under laid. However, there are questions regarding the type of preparation of the information, i.e., among other things:

- Input quantity into the environment and/or quantity remaining in the environment?
  => Leads to the question: are e.g. sealed (urban) areas part of the "environment"?
- Accumulated stock and/or annual (entry/remaining) increase?
  => Leads to the question: Period of observation (whereabouts after x years ...)?
- Amount of macro and/or micro plastics
  => Is linked to the question of the time horizon and thus the formation of "secondary" microplastics.
- Accounting at the place of entry and/or whereabouts?
  => The questions of (permanent) retention relevant for precautionary and risk considerations make the integration of transport and degradation models necessary.
- Balancing of the basic polymer quantities and/or also the quantities of additives/functionalisation substances
  => Requires further knowledge/information on the material composition of different product groups

In view of these questions, which in some areas will presumably require longer discussion and coordination, the authors propose the following staged further procedure for the further development of the overall modelling.

Step 1: Update of the existing overall model as a uniform entry model on the basis of the product quantities used.

In this context

- result-related data references (i.e. the litter quantities currently found) are abandoned in favour of a uniform reference to usage quantities.
- a targeted invitation to the market players to participate in the improvement of the data base is issued. The focus is on those market players who (possibly) bring relevant products into use.

Step 2: Development and integration of transport and degradation models for plastics released into the environment.

Here

- such models have to be adapted systematically to the different entry pathways of plastic into the environment and the compartments where they are transported to.
- a targeted transfer of current research work and results will become necessary.

Step 3: Transparent performance of risk assessments and derivation of risk management measures for the identified environmental fate quantities.

This

- requires the combination of information on quantities with current findings on the (environmental and health-related) effects of (micro-)plastics in the various environmental compartments
- enables a targeted review of measures already taken (for precautionary reasons) with regard to risk management and their adjustment/update.