PlasticFreeDanube

MATERIAL-FLOW-ANALYSIS

Of Macro-Plastic Pollution in the Danube River

DOCUMENT INFORMATION	
Work Package	3 Material Flow and Transport Modelling
Activity	3.4 Material-Flow-Analysis
Detail Output	3.4.1 Material-Flow-Analysis
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1. INTRODUCTION

1.1. Aim and structure

Deliverable of this report is a Material-Flow-Analysis (MFA) to systematically identify, structure and quantify the main sources and pathways of plastics in the PlasticFreeDanube project region between Vienna and Gabčíkovo. The system boundaries consider the geographical boundaries and content- related limitations (like data limitations). The developed MFA diagram assigns the potential sources of riverine pollution to the respective entry and discharge sources in the balance area and highlights hotspots of the plastic litter. Furthermore, a methodology for the data collection has been developed and listing of the necessary data has been started (D4.1.2, D4.2.1).

The MFA includes the flow of plastic materials consumed annually related to the project area, the amount of plastic waste collected through official collection systems and voluntary cleaning activities, and subsequently recycled or disposed of properly. Finally, an estimation of the quantities of plastic waste entering the Danube and the identification of the main sources of pollution is carried out.

The first part of the report summarizes the development process of the material-flow-analysis (MFA) model that should highlight and visualise the most important sources and paths of plastic pollution in the considered Danube region. Based on the *report on available data concerning plastic pollution* (D3.3.1) a register containing all relevant and available information for the evaluation of plastic pollution in the project area is described in the second chapter. This part deals also with the defined scenarios concerning littering and the potential plastic input in the PFD system. The last chapter deals with the data processing and input in the MFA-model. The main identified plastic pollution sources, sectors and pathways are discussed afterwards.

2. THE PFD MATERIAL FLOW MODEL

MFA connects the sources, the pathways and the intermediate and final sinks of a material. Because of the law of conservation of matter, the results of an MFA can be controlled by a simple mass balance comparing all inputs, stocks, and output of a process. An MFA delivers a complete and consistent set of information about all flows and stocks of a particular material over timer within a spatially defined system (Brunner and Rechberger, 2016). A detailed description of MFA terms, definitions as well procedures are given in Mayerhofer et al. 2021a.

2.1. MFA objective

Objective of this MFA is to visualize the main sources and pathways of plastics in Danube river for the project region between Vienna and Gabčíkovo. The material flow diagram includes information on quantities produced by different sources, disposal routes, as well as entry points for plastic waste into the Danube, which are indicators for major sources and pollution hotspots. The results of the material flow analysis are partly included in the action plan (D 6.2.2) and communicated to the stakeholders as well as decision makers in the conferences for strategic partners.

2.2. System boundaries

2.2.1. Geographical boundaries

Concerning the emergence of (littered) plastic waste, the project area has been defined as the territory of the Danube river and wetlands, as well as adjacent river banks between the metropolitan areas of Vienna and Bratislava down to hydropower plant Gabčíkovo in Slovakia (downstream border of the project area). As catchment area for direct plastic pollution within the cities a uniform distance of 250 m from the shoreline was defined, in rural areas (e.g. farmland etc.) a distance of 500m. The width of the study area was chosen as compromise between manageable effort of investigations and necessary accuracy and aims to cover relevant pollution sources. Along the Danube Canal the distance is chosen to be only 100m, because that is the distance to the residential areas (Figure 1). Within this distances, transportation of plastics by wind, strong rain or floods seems to be likely although no figures about transportation pathways and distances of plastics by wind and runoffs exist. We assume, it cannot be ruled out that, especially during single events such as heavy rain or storms, plastic waste may be carried into Danube river from a long distance and is not considered in this MFA. The chosen study area in general does not reflect the contribution of indirect plastic pollution by e.g. waste water treatment plants, as this would include for example total Vienna or tributaries.



Figure 1: GIS-Map of project area (Austria) (HQ100 overlap with 500m area)

2.2.2. *Content-related boundaries*

MFA is limited in terms of content, starting with the use phase of plastics. Although the "new" plastics brought onto the market can be related to the inhabitants of the study area, however, it is not possible to determine all plastics currently in use (installed, used, stored, etc.). Consequently, the MFA can only include the end-of-life phase in the modelling, where at least a reasonably well documented database is available.

2.2.3. Data limitations

Possible data limitations include a precise breakdown of how many plastics are actually in the use phase or what types and quantities of plastic products are brought to market in the project area (in the literature, for example, only the plastics demand of the domestic industry is given). Furthermore, there is a lack of detailed information and assessments on national littering quantities that actually remain in the environment. In this respect, only very inaccurate estimates of the collected litter amounts are available. Data gaps can also remain if existing data from e.g. authorities may not be used for this investigation. The report on available data concerning plastic pollution (D3.3.1) summarized all data limitations in more detail.

Data uncertainties also exist in the extrapolation of the collected and analysed samples along the banks, in the hinterland or the measurements in the water. Furthermore, many of the analysed plastic parts cannot be directly attributed to a specific source.

2.3. MFA-model

As mentioned above, the material flow model (Figure 5) starts with the **end-of-life phase** of plastic products. This level (**waste collection**) is essentially divided between the properly collected and managed plastic waste, which is then treated in an appropriate way (e.g. recycling or thermal utilisation → level **treatment & disposal**) and plastic debris that enter and remain in the environment due to littering, illegal waste disposal or "mismanaged or improper" handling of waste (e.g. sewage-related debris, etc.) In some cases, it will be possible to assign certain plastic debris to a specific source sector while other quantities are summarized as "general waste" because it is simply not feasible to identify the origin. The latter plastic waste is considered in more detail in the MFA: With regard to the input of plastic waste into the system, a distinction is made between **direct input** into water bodies (**Danube river**) and **indirect** input (**shore area**).

Various processes (wind, flood, etc.) influence the input and output of plastic litter into the system or the exchanges between the considered balance areas (river & shore area). Starting from the "pollution stock" (orange and blue boxes), the individual plastic flows are assigned to the land-based (yellow lines) or river-based (blue lines) input and discharge sources (red arrows). It can be assumed that most of the analysed plastic wastes (in course of sampling and sorting activities) cannot be assigned to a specific or individual source, so these debris were broadly summarized in the model.

The MFA-model was created with the software STAN (subSTance flow ANalysis).

The following pictures show MFA models in in varying degrees of detail.

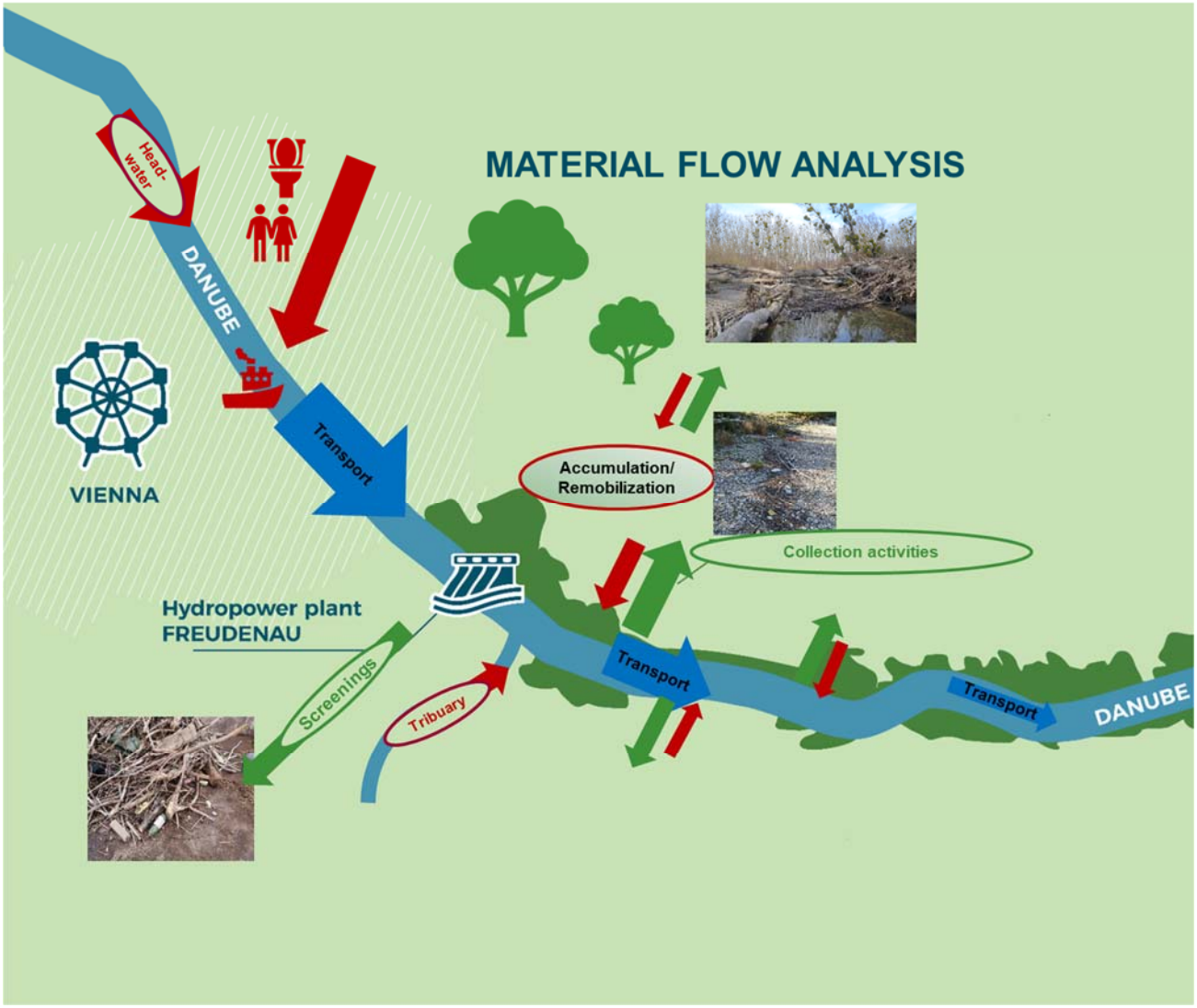
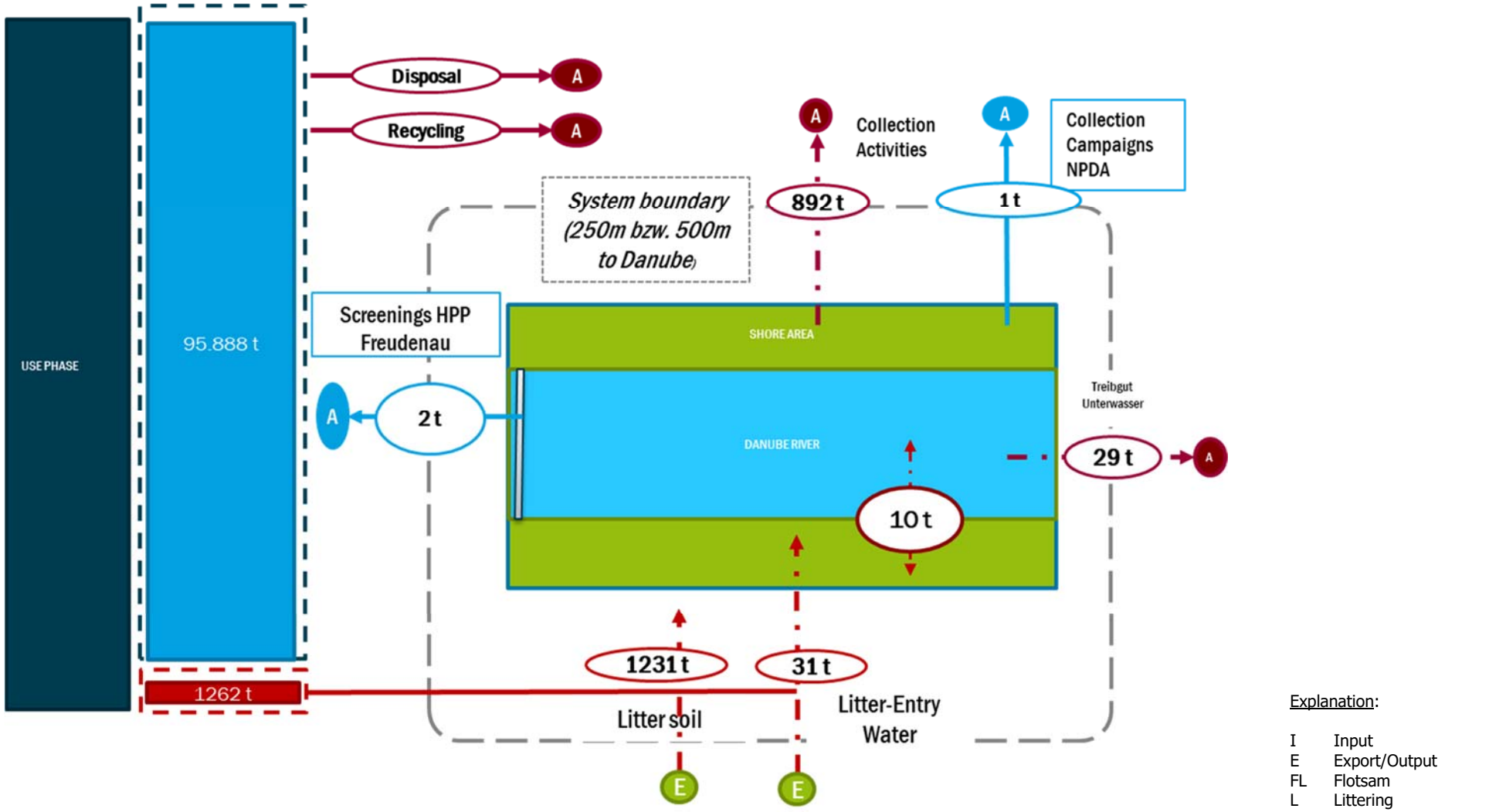


Figure 2: Main input and output flows in the project area



Figure 3: Main plastic flow in the project area



Explanation:

I Input
E Export/Output
FL Flotsam
L Littering

Figure 4: MFA Model on plastic flows in the project area

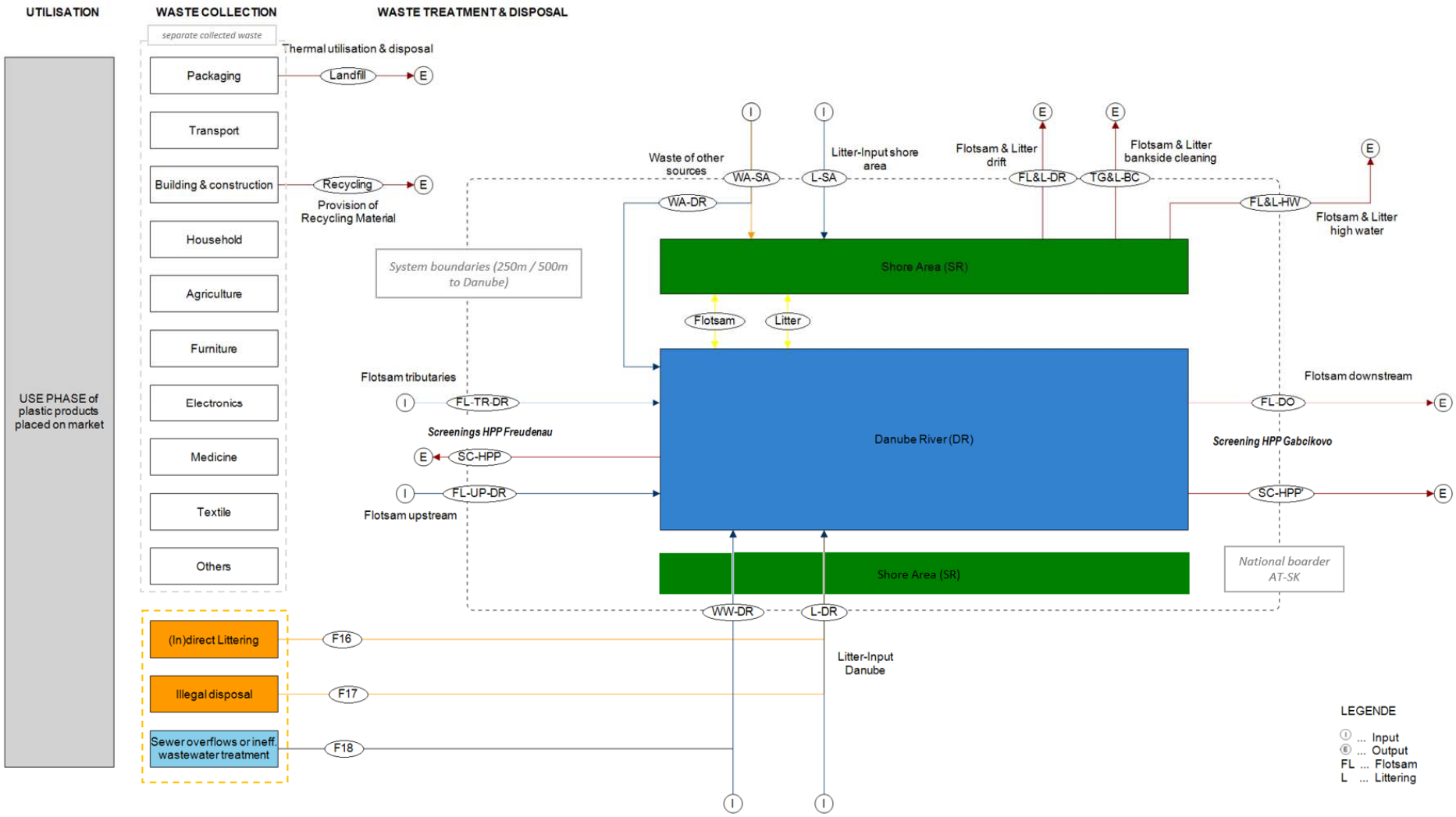


Figure 5: Detailed MFA-Model of the main plastic sources and entry paths in the project region of "PlasticFreeDanube" with software STAN