Resource-oriented wastewater management scenarios for urban areas: Material Flow Analysis for the city of Hamburg

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Many approaches and technologies aiming at the recovery of nutrients from wastewater exist or are under way. However, there is a need to assess and evaluate those technologies from a systems analysis point of view in order to be able to support decisions regarding the implementation of resource-oriented water systems in urban areas.

This study presents the application of a Material Flow Analysis (MFA) in order to evaluate different wastewater management scenarios and technologies with regard to their resource efficiency. MFA is a tool that allows identifying potentials for efficient resource management by analysing substance fluxes e.g. in regions. The city of Hamburg, Germany, was used as a case study including not only sanitation but also water supply and organic waste in the analysis. For the study the software SIMBOX was used in order to analyse nitrogen, phosphorus, potassium and sulphur flows.

Five different wastewater management scenarios were developed for the city of Hamburg. The scenarios were developed in such a way that a wide variety of technical options for nutrient recovery was included ranging from a centralised system to cluster and decentralised treatment units. Table 1 shows an overview of the scenarios highlighting their different degree of source control measures.

Table 1 Scenarios for the urban water system of Hamburg including nutrient recovery

<table>
<tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>Urine</td><td rowspan="2">Vacuum toilets, anaerobic digesters in clusters, transport of slurry</td><td>Separated, stored, transported</td><td>Separated, transport to central nutrient recovery</td><td rowspan="3">To central WWTP, centralised nutrient recovery from sludge</td><td rowspan="2">Vacuum sewer to cluster storage, transport to WWTP and anaerobic treatment</td></tr>
<tr><td>Faeces</td><td>Dry toilets, decentralised treatment</td><td rowspan="3">To central wastewater treatment plant (WWTP)</td></tr>
<tr><td>Greywater</td><td rowspan="2">Treatment and use as process water</td><td rowspan="2">Treatment and use as drinking and process water</td><td>To WWTP</td></tr>
<tr><td>Rainwater</td><td>Decentralised treatment</td></tr>
<tr><td>Organic waste</td><td>Anaerobic digestion with faeces</td><td>Composted together with faeces</td><td>Co-digestion in WWTP</td><td>Composting</td><td>Co-digestion in WWTP</td></tr>
<tr><td>Water supply</td><td>Grey-and rainwater supplemented by bottled water</td><td>Grey- and rainwater</td><td>Central water supply</td><td>Central water supply</td><td>Central water supply</td></tr>
</table>

The scenarios were transferred into material flow models. Please refer to figure 1 for an example of the structure of the material flow model showing the current situation of water and wastewater management in Hamburg. The material flow models were used to show the potential for water saving as well as recovery of N, P, K and S for agriculture for the different scenarios. In addition other advantages and drawbacks like nutrient emissions to surface and groundwater could be analysed with the help of the material flow model.

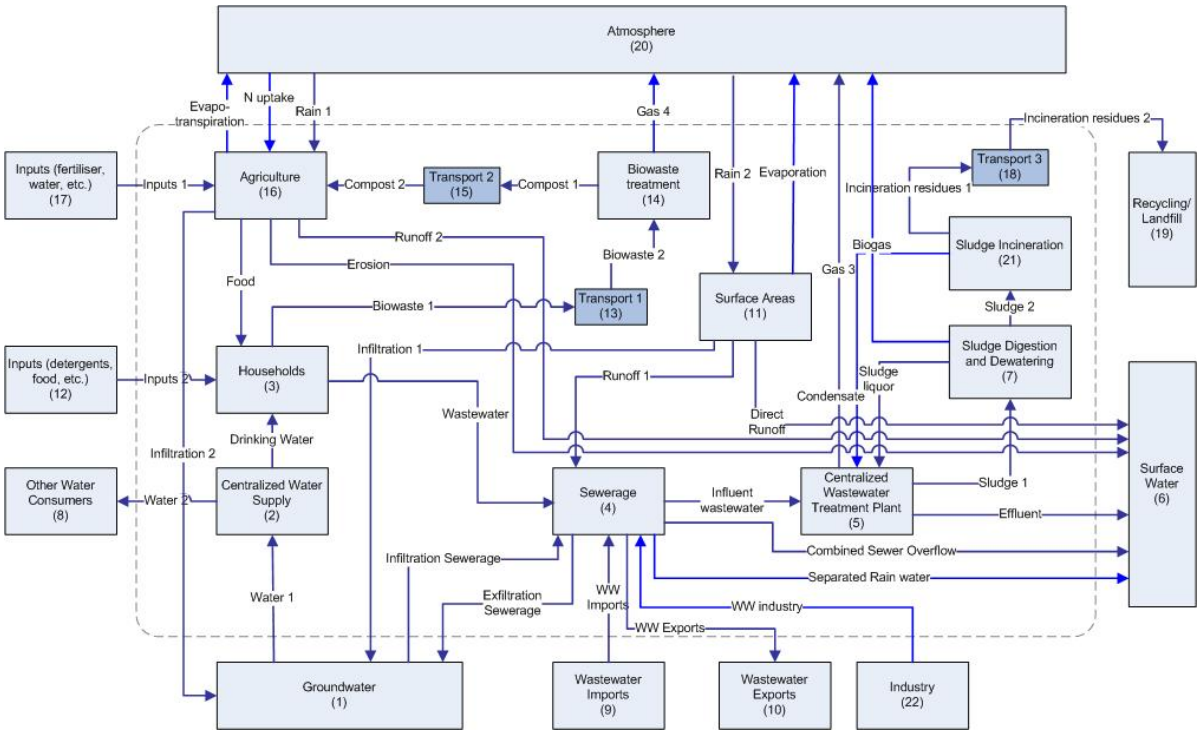

Figure 1: Material flow model for the current situation

The results of the analyses showed that in the more decentralised scenarios (in particular scenario 1) a generally higher nutrient recovery in terms of total nitrogen, phosphorus, potassium and sulphur could be achieved as compared to the more centralised systems. However, if the focus is only on phosphorus recovery also centralised systems can achieve a high recovery rate which would allow reducing the consumption of mineral fertiliser. Figure 2 summarises the potential for nutrient recovery for the different scenarios.

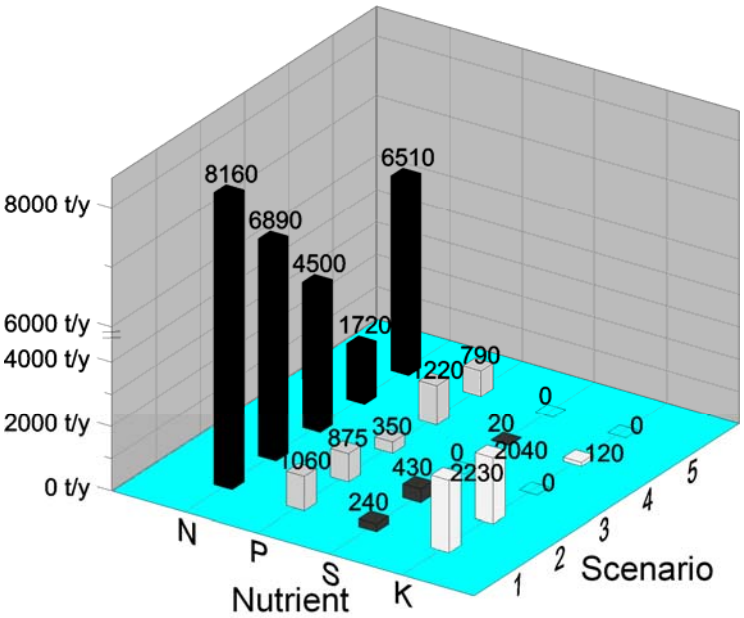

Figure 2: Summary of the potential nutrient recovery [in t/y for the city of Hamburg]

MFA proved to be a valuable tool for assessing environmental effects and resource efficiency of urban water systems. In conjunction with tools for the evaluation of socio-economic criteria alternative treatment and nutrient recovery options can thus be compared from a systems perspective to allow for a paradigm shift in urban wastewater management.