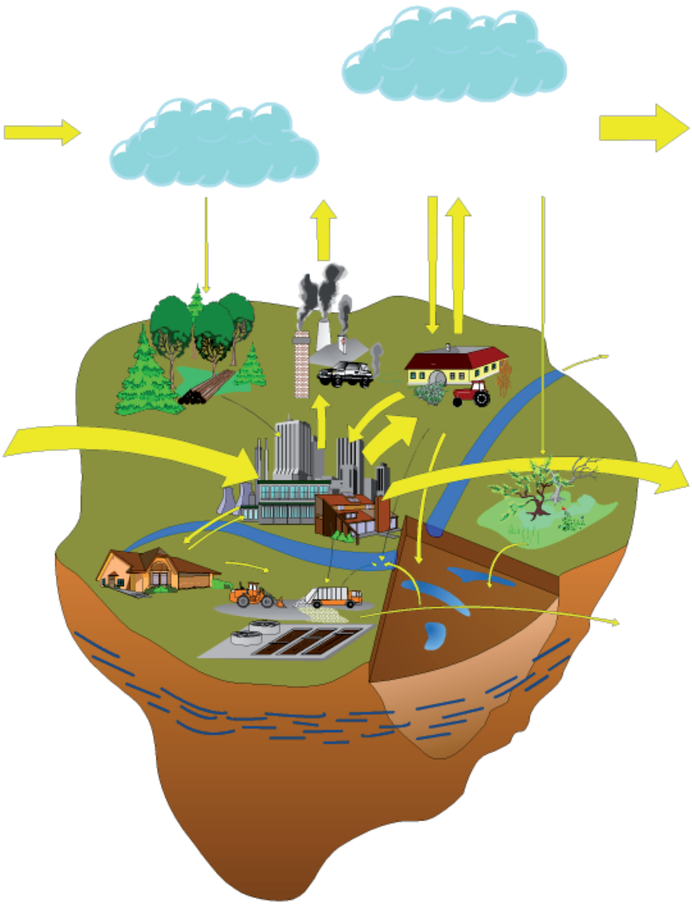
EC Programme Environment and Climate 1994-1998 ENV4_CT96_0230
April 1998 Final Report

EC ENVIRONMENTAL RESEARCH PROGRAMME
Research Area III - Economic and Social Aspects of the Environment

Materials Accounting as a Tool for Decision Making in Environmental Policy

Case Study Report 1

Urban Metabolism
The City of Vienna



Vienna University of Technology
Institute for Water Quality and Waste Management
Department of Waste Management

EC ENVIRONMENTAL RESEARCH PROGRAMME
Research Area III - Economic and Social Aspects of the Environment

Materials Accounting as a Tool for Decision Making in Environmental Policy

Case Study Report 1

Urban Metabolism
The City of Vienna

Richard Obernosterer
Paul H. Brunner
Hans Daxbeck
Tracey Gagan
Emmanuel Glenck
Carolyn Hendriks
Leo Morf
Renate Paumann
Iris Reiner

Vienna University of Technology
Institute for Water Quality and Waste Management
Department of Waste Management

This project was financed within the 4th European Commission Programme for Environment and Climate. It involved five partners from The Netherlands, Sweden, Switzerland and two groups from Austria.

Contact: Dipl.-Ing. Richard Obernosterer
Email: robernos@awsunix.tuwien.ac.at
Telephone: +43 1 58801 226 51
FAX: +43 1 58801 226 66

EC ENVIRONMENTAL RESEARCH PROGRAMME: Research Area III
Economic and Social Aspects of the Environment

Contract n°: ENV-CT96-0230 **Reporting period: 1/5/96 - 30/4/98**

CASE STUDY REPORT
OF TUW.IWAG

URBAN METABOLISM

The City of Vienna

Materials Accounting as a Tool for Decision Making in Environmental Policy

(MAcTEmPo)

April 1998

This project was financed within the 4th European Commission Programme for Environment and Climate [Brunner et al. 1998]. It involves five partners from The Netherlands, Sweden, Switzerland and two groups from Austria.

Obernosterer et al. 1998

CASE STUDY REPORT OF TUW.IWAG

URBAN METABOLISM

The City of Vienna

Materials Accounting as a Tool for Decision Making in Environmental Policy

Leading researcher: Dipl. Ing. Richard Obernosterer

Research staff:

First name	Family name	email
Richard	Obernosterer	robernos@awsunix.tuwien.ac.at
Paul H.	Brunner	pbrunner@email.tuwien.ac.at
Hans	Daxbeck	jdaxbeck@email.tuwien.ac.at
Tracey	Gagan	aws@awsunix.tuwien.ac.at
Emmanuel	Glenck	aws@awsunix.tuwien.ac.at
Carolyn	Hendriks	aws@awsunix.tuwien.ac.at
Leo	Morf	lmorf@awsunix.tuwien.ac.at
Renate	Paumann	aws@awsunix.tuwien.ac.at
Iris	Reiner	aws@awsunix.tuwien.ac.at

Institution: Vienna University of Technology
Institute for Water Quality and Waste Management
(**TUW.IWAG**)
Waste Management Group

Address: Karlsplatz 13/226.4
A-1040 Vienna
Austria

Contact: Dipl. Ing. Richard Obernosterer
Telephone: +43 1 58801 226 51, FAX: +43 1 58801 226 66
email: robernos@awsunix.tuwien.ac.at

ABSTRACT

The main objective of this study was to examine the metabolism of the City of Vienna by means of **Material Flow and Stock Analysis** (MFSA) and to explore the use of MFSA in the decision making process in view of environmental protection and resource conservation.

Material Flow and Stock Analysis (MFSA) is based on a holistic approach which examines the materials flowing into a given system (nation, region, city, private household, company, etc.), the stocks and flows within this system, and the resulting outputs from this system to other systems. MFSA is a complementary tool to traditional environmental and resource management approaches. It provides the necessary links between anthropogenic activities and their impacts on the environment.

MFSA is based on a regional approach and therefore allows for regionally adapted environmental protection and resource management strategies. Such strategies are needed because the dilution potential of environmental sinks (e.g. sediments) and conveyor belts (e.g. rivers), as well as the availability of resources are regionally variable.

The discussion of the policy use of MFSA is based on the investigation on the flows and stocks of goods (such as drinking water, construction materials or energy sources) and of the substances Aluminium, Lead, Iron, Zinc, Nitrogen and Carbon through and within the City of Vienna. Urban regions typically induce high energy and material flows, due to their high population densities and their huge and relatively dense material stocks. Knowledge about the metabolism of cities allows decision makers to prepare for and react to present and future issues regarding materials flows and materials stocks of a city.

All data used in this study was collected from existing data sources. No new analytical determinations were performed. In most, but not all cases, this procedure yielded information which was sufficiently accurate to be used as a base for policy decisions. The following major results and conclusions were obtained:

- The City of Vienna is essentially a “flow through” reactor with 200 tons of goods flowing through the city per capita and year. Approximately 90% of the flow of goods consists of water and air and are primarily due to „cleaning“ and secondarily to „transportation“ and „heating“ purposes. Due to the high throughput of materials through Vienna, the city is dependent on its „Hinterland“ for supply (e.g. fresh water and air), as well as for disposal of its residuals (water and air are the most important disposal conveyor belts for the City of Vienna). In contrast to a „pure“ service city, Vienna has a rather large material flow and stock due to the industry and trade sector. However, the material import into the city by far exceeds the export, and hence there is a stock build up within the city of 350 t/c, which is still growing.
- The Carbon flows of Vienna (3 t/c.y) are dominated by the consumption of fossil fuels. The key to control these substance flows is within the heating and transportation sectors. The Nitrogen flows through the City (30-40 kg/c.y) are due to the activities „to nourish“ and again to „heating /transportation“. The Nitrogen flows induced by city activities in the „Hinterland“ are larger than those in Vienna itself. The ratio of stock to

total import is twice as large for Lead, Iron and Aluminium than for Nitrogen and Carbon. This confirms that there is a long residence time of most metal containing goods in a city.

- Between 70 to 90 % of the stock is located in the cities buildings and infrastructure and 10 % - 30 % in the city's landfills. In the future, the buildings and infrastructure stock will be either a potential resource or pollutant which will need to be recycled or disposed of in some way. If today's consumption pattern continues, in 2 to 4 generations the people of Vienna will have to maintain and manage double the current amount of materials. Comprehensive information and knowledge is needed on the type and composition of these stocks, the dynamics of their changes, and about how to control and manage them.
- Today's anthropogenic Carbon, Nitrogen and Lead loadings into the air and water are 25 - 800 times higher than comparable past loadings from a „geogenic“ Vienna (past environmental conditions prior to human settlement).
- The link between the anthroposphere and the environment highlights that anthropogenic activities are significantly altering current environmental conditions. Therefore, environmental assessment should consider not only concentration limits but total loadings and final sinks, especially in relation to long-term environmental effects.
- The relationship between an urban region and its „Hinterland“ reveals that in some cases, the induced flows in the „Hinterland“ into the environment can be more significant than those in the city itself.

The current investigations into the use of MFSA have been primarily academically focused. The MAcTEmPo project has been a bridging step linking the „technical“ MFSA with it's potential policy uses. Following conclusions and recommendations of the potential use of MFSA in the policy world could be highlighted:

- In order to reduce resource depletion and environmental harm, materials must be used within the anthroposphere in an optimum manner. MFSA provides a guiding tool for efficient resource management within the anthroposphere. For instance MFSA has a high potential to be implemented as a guiding tool on the regional level, e.g. as part of a Regional Environmental Management and Audit System (regional-EMAS) or as a part of a Local Agenda 21 Process. Using this tool, one can link various resource strategies with potential environmental impacts. Decision makers responsible for a given system, here the City of Vienna, can use the results from MFSA studies to examine the potential effectiveness of their policies both within the anthroposphere and in relation to the environment and as a basis for designing improvements.
- MFSA is a complementary tool to traditional environmental and resource management strategies. Today's environmental monitoring systems measure the current state of the environment and tend to focus on single issues with little consideration of the total system. In many cases this approach can be highly in-efficient since it may only address a small portion of the total flows and stocks. MFSA should be used as a environmental decision making tool since it can present a holistic picture of the system linking current information and data bases. Furthermore, MFSA focuses on short and long-term loadings and highlights current and potential stocks.

- MFSA allows for a precautionary approach since it can anticipate future environmental problems and does not rely on signals of „environmental“ stress. Therefore, future environmental policies should be expanded from measuring how humans impact environmental media, to designing efficient resource management strategies within the anthroposphere. MFSA can be used for early recognition since it can identify actual and future stocks and their changes in both the anthroposphere and in the environment. This information can be used to discuss the potential of a stock as a future environmental risk or as a resource. The identification of key flows and stocks using MFSA can also serve as a base for efficient resource management strategies. It provides a basis for designing and optimising material flows and stocks in the anthroposphere e.g. for urban development and urban planing.
- MFSA requires further capacity building in order to broaden experiences and it’s potential. A number of controlled experiments on the enterprise, urban and regional scale should be conducted. This strategy is essential since new methods and additional data does not necessarily lead to improved policy making. With the experience of a number of controlled experiments the capacity of efficient implementation of MFSA in the policy world will rapidly increase.
- In order for MFSA to be broadly used in an efficient manner, a Material Accounting system (MAc) is required which involves periodically registering material data. However, the real potential of MFSA will be achieved when resource managers (MFSA-experts) work in conjunction with social scientists, policy makers and economists to determine the most efficient materials management scenarios. Then, the effects of social, technical, political and economic tools (education, taxes, legislation, materials accounting systems, cost benefit analysis etc.) on materials flows can be discussed in view of achieving sustainable materials management.

STRUCTURE OF THIS REPORT

ABSTRACT

INTRODUCTION *(Chapter 1)*

SCOPE AND OBJECTIVES *(Chapter 2)*

MFSA STUDIES ON THE METABOLISM OF VIENNA (*Chapter 4 & 5)*

This section, of the report contains detailed information on various MFSA studies on the metabolism of the City of Vienna.

MFSA and POLICY APPLICATIONS *(Chapter 6)*

This section discusses different possible uses of MFSA based on the experience of the metabolism of Vienna and other investigations for environmental and resource policy making.

CONCLUSIONS & RECOMMENDATIONS *(Chapter 7)*

SUMMARY *(Chapter 8)*

ADDITIONAL INFORMATION *(Chapter 9, 10, 11 & 12)*

This section provides background information on both, MFSA and policy; in particular MFSA tables and calculation and broadly outlines of the current environmental policy situation in Vienna, Austria and on the EU level. Furthermore, this section provides a policy related questionnaire on two MFSA studies, the references, acronyms, abbreviations, the glossary and the index of tables and figures.

Readers interested only in the policy applicability of MFSA could go directly to chapter 6 and 7 and using the summary (chapter 8) as a basis for background information on MFSA results.

Table of Contents

1 General Introduction

This project investigates the applicability of Material Flow and Stock Analysis (MFSA) to support the environmental and resource policy decision making process. Financed within the 4th European Commission Programme for Environment and Climate, the entire project involves five partners from The Netherlands, Sweden, Switzerland and two groups from Austria. Four case studies have been carried out in four different countries at various levels (local, national and European). In particular, the project allows various environmental management and policy strategies to be examined on different levels. The results of these and previous case studies are used to formulate general as well as specific conclusions on the use of MFSA in environmental and resource policy decision making.

Isolated studies of anthropogenic metabolism date back to the seventies. Their goal was to assess the present and future need for resources, and to investigate pollution problems caused by anthropogenic materials flows. In the eighties, regional MFSA was introduced by several research groups to study the environmental loadings of Polychlorinated Biphenyls (PCBs), of heavy metals such as Cadmium, Lead and Mercury, and also nutrient loading. These studies generally identified the most important source of a particular pollution and sought to design efficient and adequate protection measures. In the late eighties and early nineties, methods for the analysis of the metabolism of the anthroposphere were developed and applied to new fields.

One of the main conclusions of this studies is that future environmental protection measures will need to consider both anthropogenic and natural systems. The goal of future regional material management is the sustainable use of resources by optimising and controlling the input, the output, the stock as well as the use of materials and energy in the anthroposphere. It is suggested that this strategy should become a vital aim in future environmental protection, and that the focus of measures should gradually shift away from the environment towards measures within the anthroposphere itself. Today, methodological tools have to be developed to reach this goal; these tools must be made known and available to decision makers, so that they have a base for environmental policy decisions and interventions. The MAcTEmPo project introduces the possible links between material flow analysis and its implementation into the policy world.

The following investigation is a part of the entire project MAcTEmPo [Brunner et al. 1998], dealing with the urban metabolism of the City of Vienna (capital of Austria, 1.5 million inhabitants). Cities are the main driving force for a high material turnover. With a high population density (>3000 inhabitants/km^2) cities typically induce high energy and material flows, with huge and relatively dense material stocks. The key question for all „industrialised“ cities is not so much one of resource scarcity but rather how to dispose of its by-products. Knowledge about the metabolism of cities should be of great interest to decision makers since this information allows them to prepare for, and react to, present and future issues regarding materials flows and stocks of a city. Cities which adopt efficient substance management strategies are likely to be the most productive centres for generating human welfare in the future.

The selection of Vienna as a Case Study allows important information on the materials flows and stocks for a significantly representative portion of the entire anthroposphere to be determined. A city like Vienna generates a number of partly unknown diffuse emissions both inside and outside the city boundary. However, the entire city itself is an „environmental hot spot“ and on a global scale it represents a point source of materials flows.

Regarding the increase of urbanisation connected with an increasing material turnover, the main task for decision makers is to know more about the metabolism of urban region. This understanding is necessary for both the well-being of the inhabitants and the environment within the city, as well as for understanding the impact of the city in the „Hinterland“. The investigation of the interactions between a city and its „Hinterland“ regarding resource and environmental issues presents information about the (inter)dependence of these two (spatially defined) regions.

Welfare in a sustainable society requires a balanced interaction between economic, ecological and social dimensions. This report focuses primarily on the ecological aspects. Since the 1992 UN Conference in Rio de Janeiro, considerable discussion and research about environmental concerns has revolved around sustainable development. Currently the emphasis is on how to translate this concept into the policy making process on all levels. From the Agenda 21 process on the global scale, to the European Commission Programme for Environment and Climate through to national activities such as the Austrian National Environmental Plan (NUP), regional activities have been identified as the priority to implement sustainable development.

The field of „materials (resource) management“ is a new, and rapidly developing field, with many different terms in usage. To avoid confusion, it is extremely important to clarify terminology.

At the commencement of the project, the term „material“ was used loosely. However, as the project developed it became apparent that amongst the working groups there was some inconsistencies in terminology. The Dutch Group for example, uses the term material to refer broadly to goods, products, and chemical elements whilst other groups use the term „material“ more specifically to refer to substances i.e. only elements and chemical compounds. The following page provides the definitions for the terms as used in this study.

SOME KEY DEFINTIONS

(further definitions are provided in the glossary at the end of this report):

Materials are defined as goods and/or substances.

Substances are chemical elements (e.g. Lead, Carbon) or a chemical compound (e.g. Lead Chloride, Carbon Dioxide)

Goods consists of one or many substances (e.g. petrol, wood, construction materials, water, air, waste water or off-gas). A good can have a negative or positive economic value. Furthermore free goods are also included (e.g. air).

MFA Material Flow Analysis. During the course of the project, the importance of highlighting stocks became apparent. The term „Material Flow and Stock Analysis“ (MFSA) was therefore created which replaces the term MFA in this report.

MFSA - Material Flow and Stock Analysis is based on a holistic approach which examines the materials flowing into a given system (private household, company, region, city etc.), the stocks and flows within this system, and the resulting outputs from the system.

MAc -Materials Accounting, is the process of periodically registering data necessary for Material Flow and Stock Analysis. Such a register allows comparisons to be made with other accounts such as financial accounts.

Policy decisions - in this report this term refers to more than just those decisions made within the political-administrative system. Rather the term here includes all „policy“ decisions made on the public, private and even the household level. However, the focus in this report is on the administrative level of Vienna.

Material (Resource) Management - encompasses all the decisions associated with the input, the use, the treatment and disposal of goods and substances within a defined system. Thus, material management involves accounting, evaluating and controlling substance flows and stocks in order to efficiently utilise natural and human resources.

2 Scope and Objectives

The main objective of this study was to examine the metabolism of the City of Vienna by means of **Material Flow and Stock Analysis** (MFSA) and to explore the use of MFSA in the decision making process in view of environmental protection and resource conservation.

In this study, the flows and stocks of goods and of the substances Carbon (C), Nitrogen (N), Lead[1] (Pb), Iron (Fe), Aluminium (Al), and Zinc (Zn) are considered through Vienna. The long term environmental impacts and optimum resource utilisation of these flows and stocks are discussed. Three different interconnected investigations were carried out to gain a holistic understanding of the urban metabolism of Vienna:

I. Anthropogenic Metabolism

Objective: To identify the key anthropogenic material flows and stocks within the City of Vienna. The results from this investigation are essential for the design of efficient material management strategies within the anthroposphere.

II. Linking the Anthropogenic and Natural Metabolism

Objective: To understand the interaction between the anthroposphere and the environment. In particular, to assess the current anthropogenic material flows into the environment and to investigate the effect of decisions made within the anthroposphere on the environment.

III. Linking the City with the „Hinterland“

Objective: to assess the dependence of the City of Vienna on its „Hinterland“ for supply and disposal of materials.

In line with the goals of the MAcTEmPo project, the Viennese Case Study addresses the use of MFSA as a tool:

- for early recognition of future problems of environmental loadings and resource depletion
- to set priorities for and to define measures to protect the environment and to use resources more efficiently, especially in urban areas
- to analyse and improve the effect of measures taken to protect the environment and to use resources more efficiently
- for the next generation of environmental measures, which will focus on efficient regional materials management in view of sustainable development, that is the change from the so called filter strategies at the back-end to front-end measures such as the design of goods and services.

---

[1] It should be noted that although Lead is not included in the project contract, it was included since data was available.

3 Methodology

In this chapter the methodology used in this study is introduced. A general description of the City of Vienna is given followed by a general outline of MFSA methodology. The main part of this chapter are the descriptions of the systems used to describe the metabolism of the City of Vienna.

3.1 Case Study Region - The City of Vienna

Over 20 % of Austria's total population resides within Vienna's city boundaries (1.5 million inhabitants), making it the biggest city in the country. Vienna also employs 26 % of Austria's working population. The area of Vienna's administrative boundary covers only 0,5 % of Austria's total area.

Table 3-1: Parameters of the City of Vienna (1991)

PARAMETER	VIENNA
Population	1,540,000
population density	3,710 capita/km^2
inhabitants per household	2.12
total net-floor-area	56,301,000 m^2
average inhabitant per net-floor-area	0,03 capita/m^2
Employment	
employees (1993)	742,200
shops (1993)	71,000
employee/shop (1993)	10
Land use (1988)	
agriculture	76 km^2 (18 %)
forestry	80 km^2 (19 %)
park land	46km^2 (11 %)
water	20 km^2 (5 %)
built area	183 km^2 (44 %)
other unbuilt area	10 km^2 (3 %)
Total area	415 km^2
Elevation	151 - 543m
Climate	
average temperature	10.0 °C
min-max.-temperature	-15.9 to 33.9 °C
average rainfall	638 mm/y
average wind speed	3 m/sec
Hydrosphere	
ground water reservoir	220x10^6 m^3
Danube average water flow	1,630 m^3/sec

Sources: [ÖSTAT 1989, MA66 1994, Maier et al. 1996]

Vienna is subdivided into 23 districts, which carry out specific but not all local administrative functions. The „city“ government of Vienna is also a provincial government, such that each official in Vienna plays a dual role (i.e. the city council is also the Provincial Assembly). As a consequence, Vienna has the jurisdictional power and decision-making authority of an Austrian province, which far exceed those of typical Austrian municipal governments [König 1997].

This fact is significant in understanding the environmental policy framework for Vienna, particularly since it pertains to the division of responsibilities in such matters as natural resource management and environmental protection, among other policy areas. In keeping with the Austrian Constitution, some matters rest entirely under Federal responsibility (e.g. public health), while others are the responsibility of Austria’s nine Provinces (e.g. nature protection and construction codes). In other instances, the Federal Government is responsible to legislate in certain matters, and the Provinces must carry out the administration and/or implementation (e.g. forestry and hazardous waste) [OECD 1995].

Further discussion on the environmental policy framework see Appendix B (chapter 12.2).

3.2 MFSA Approach

The approach Material Flow and Stock Analysis (MFSA) was used to describe the metabolism of Vienna. The methodological steps were similar to those used in existing studies, such as Baccini & Brunner (1991), Brunner et al. (1990) and Baccini & Bader (1996).

In Baccini & Brunner (1991) this approach is introduced as a method to describe the flow of substances between different processes within a defined system by including stocks. There are two principle ways to describe the complex metabolism of a system. The first way is to describe single activities, for example to identify chains of processes that are necessary to satisfy human needs for nourishment. In the second approach a system under investigation is divided into its main processes. For example, Baccini & Brunner (1991) select the „Swiss Economy“ as a system and divided it into the processes Anthroposphere, Atmosphere, Hydrosphere and Pedo-/Lithosphere.

MFSA is based on a holistic approach which examines the materials flowing into a given system (private household, company, region, city etc.), the stocks and flows within this system, and the resulting outputs from the system to other systems. Furthermore, MFSA focuses on loadings rather than concentrations. MFSA can be used quantitatively by looking at „goods“ (concrete, biomass, cars, milk etc.). MFSA can also be used on a qualitative level to examine the potential environmental harm or resource potential of the flows and stocks of substances (SFSA). The methodological steps of MFSA are given in Appendix A, chapter 12.1.

In previous MFSA studies geogenic references have been used as a reference point for sustainability. This approach was also used by the Vienna team to indicate the „gap“ between the current urban metabolism conditions of Vienna and geogenic conditions (prior to settlement). Further discussion on this methodology see chapter 6.5.

The new challenge in this project was to apply the MFSA approach to a large urban region and to investigate „Hinterland“ relationships.

Modelling

To derive mathematical models for MFSA, the two Vienna groups (IOKSI and IWAG, Vienna University of Technology) of the MAcTEmPo project co-operated together. IWAG provided IOKSI with information and data on MFSA studies on all levels (e.g. enterprises, natural processes, regions). The Vienna case study was, in part, used by the IOKSI Group to help develop their model. Nevertheless, the IOKSI model has not yet been used to calculate and optimise the Vienna material balance. The model is described in the IOKSI Case Study Report [Deistler et al. 1998].

3.3 Selection of Substances Investigated

Six substances were selected for investigation: Carbon and Nitrogen are essential elements for the biosphere, the elements Lead, Iron, Aluminium and Zinc comprise the most important metals of the anthroposphere. All elements selected are important for the anthroposphere as well as for the environment.

Carbon

At present, the metabolism of the anthroposphere depends highly on the transformation of chemical energy into heat by the oxidation of Carbon (transportation, domestic and process heating, nutrition). An important part of the structure of the anthroposphere is made of Carbon (wood, plastics), and most of the anthropogenic information is still contained and transported in Carbon (cellulose in paper). If a sustainable economy can be based on biomass as the chief resource, Carbon will remain the most important substance in the future.

Nitrogen

Like Carbon, Nitrogen is an essential element for the biosphere. In densely populated areas with a high per area turnover of Nitrogen, the input of Nitrogen into the water regime may become a limiting factor for the quality of the receiving waters. Rural areas largely support the activity „to nourish“ for urban regions. Thus the Nitrogen throughput is larger in rural areas since there is a net export of Nitrogen goods. The management of Nitrogen with respect to both the city and it’s „Hinterland“ is an important challenge. In combustion processes, Nitrogen is partly transformed into oxides, which take part in atmospheric processes resulting in products hazardous to humans and the biosphere. For the cautious management of Nitrogen, complete information about the flows and stocks of this element is indispensable, including anthropogenic and natural inputs, stocks and outputs in the urban system as well as the „Hinterland“.

Iron and Aluminium

Iron and Aluminium are included in this investigation because they are the primary metals used in the anthroposphere. Flows and stocks have to be known for resource and waste management purposes. If the stock of these metals is managed properly, the present day „ore mining“ may be replaced in the future by „urban mining“.

Zinc

Zinc is of particular interest since it is increasingly being used in a range of different products resulting in diffuse emissions into the environment (e.g. surface coatings). Flows and stocks of Zinc in the urban environment are largely unknown. Stocks may be a potential threat in the future if they are released to the environment without control. If well controlled, this stock represents a valuable future resource. There are difficulties in identifying, measuring and assessing goods which contain Zinc since statistics generally do not contain trace element concentrations in goods. For metals in general, the problem will be to find data and information about the concentrations in the stock and reservoirs. The loading of Zinc in the environment might increase due to diffuse emissions. The capacity for the dissipation of Zinc in water, air and soil is limited due to the toxicity of this heavy metal.

Lead

The heavy metal Lead is used in the anthroposphere in both a highly concentrated form in goods like batteries and in a residual form in goods such as plastics and paint. Lead is a potentially toxic element to many ecosystems. There is still a high amount of Lead currently used in the anthroposphere, and thus strategies are required for future management.

3.4 Description of Systems Investigated

In general, systems can be defined in relation to a specific problem, a specific goal, or specific questions. For this reason systems are never exactly the same and have to be defined for each case. The most critical and demanding step in defining a system for MFSA is in trying to depict reality in an simplified manner. A key issue in MFSA is that all the processes within the system are balanced. One must recognise that by not including a process in a system may mean that a potential problem may be hidden. However, as long as the conclusions are based on a well defined and understandable system, MFSA provides a objective tool for decision making.

As introduced in chapter 2, three different interconnected investigations were carried out to gain a holistic understanding of the urban metabolism:

I. Anthropogenic Metabolism - the anthropogenic materials flows and stocks are described within the administrative boundaries of Vienna.

II. Linking the Anthropogenic and Natural Metabolism - the environmental processes within the administrative boundaries were also taken into account and linked to the anthropogenic processes

III. Linking the Metabolism of the City with the „Hinterland“ - flows are followed out of the administrative boundary to the origin at the one end and/or to the final sinks at the other end. Today it is usual to call on such an approach e.g. „From Cradle to Grave“, „Rucksack“, „Ecological Footprint“ or „Hinterland“ approach. In this report the term „Hinterland“ is used.

The methodological steps involved in each of the three investigations are identical. However, there are some subtle differences within the individual MFSA steps. For example, consider the step „defining the system boundary“. In system I and II the administrative boundary of Vienna is selected. However, in system III the boundary is defined by that area (relevant to a particular material) which is influenced by the metabolism of the City of Vienna. The choice of the processes and system boundaries are explained in detail below (chapter 3.4.1, 3.4.2, 3.4.3).

The three systems were defined more or less as part of a scientific investigation into urban metabolism. The main goal in this case is to find strategies for sustainable urban metabolism (resource management strategies) and to understand a complex systems such as a city. This essentially means that the systems were not defined to solve a specific problem, rather to investigate the overall metabolism and also to improve methodology. Based on the findings of such investigations more detailed studies can then be conducted to address specific environmental problems or resource potentials.

3.4.1 Anthropogenic Metabolism of the City of Vienna

As in the project „Metabolism of the City of Vienna“ [Daxbeck et al. 1996], the case study of the anthroposphere of the City of Vienna is divided into processes (see Figure 3-1). To describe the materials metabolism of the anthroposphere of the City of Vienna, the first step involves investigating the flows and stocks of all goods. Accounting for goods is instrumental in identifying the most important carriers of substances within a given system and their most significant pathways. This was done separately on four partial balances (for energy sources, for construction materials, for water and for producer and consumer goods) given in Daxbeck et al. (1996). Based on the accounting of goods the substances were calculated.

In order to investigate the potential of MFSA as a policy tool, it is more appropriate to define the system in terms of processes rather than under various activities. This is since responsibilities are typically defined in terms of processes (e.g. water and wastewater management) rather than activities (e.g. to nourish). However, in order to interpret the results, various flows were linked to the associated activities (as identified in Baccini & Brunner (1991)). A further reason to divide the city into processes is due to the availability of materials data. The availability of data for certain processes within the city is relatively good. For example, for the waste incineration plant, the landfill, the waste water treatment plant, the river Danube, the soil of Vienna etc.

Selection of processes

The following processes have been defined to describe the anthropogenic metabolism of Vienna:

- distribution of goods
- industry, trade and service (ITS)
- private household (PHH) and

- waste and waste water management (including the sub-processes: water collection (sewer), private and public waste collection, waste water treatment, incineration plant, treatment of separate collected waste and disposal).

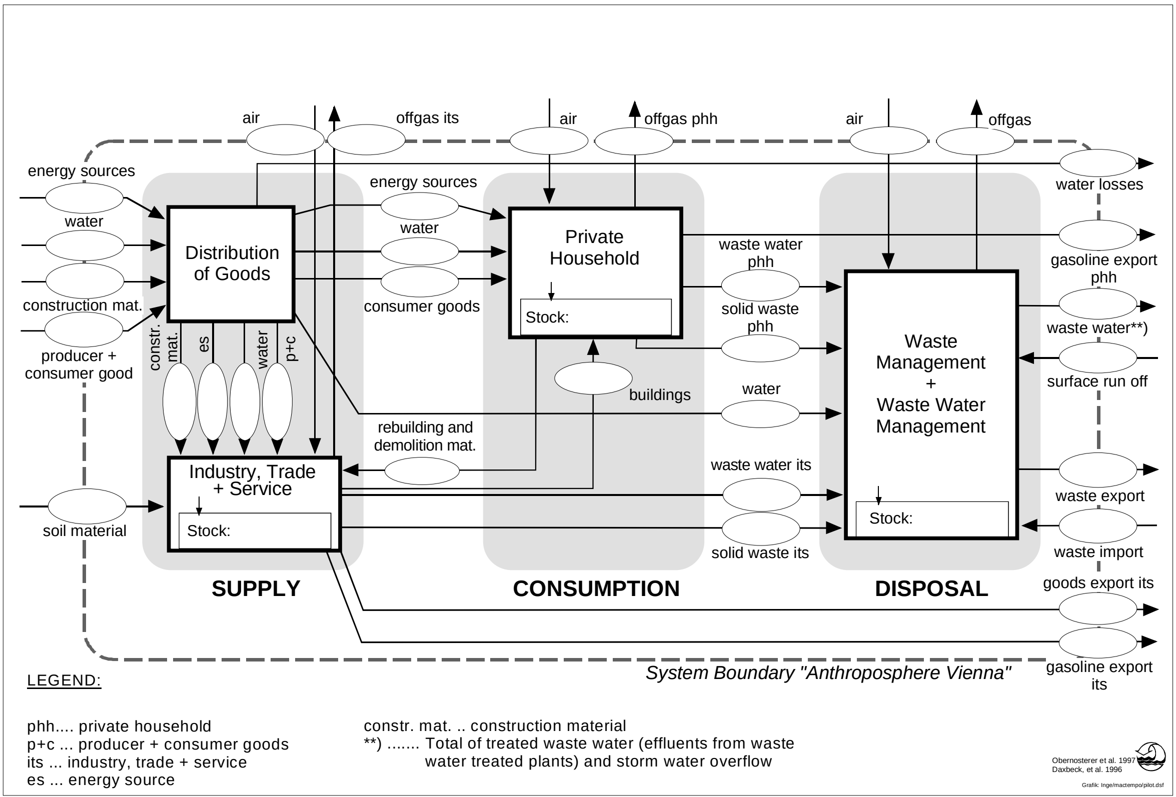


Figure 3-1: Description of the System of the Anthroposphere of the City of Vienna [Daxbeck et al. 1996]

Selection of goods

Goods are essentially carriers of substances and therefore form the basis of understanding the metabolism of a system on a substance level. The aggregated groups of goods include: water, air, energy sources, producer and consumer goods, construction materials, waste and waste water.

Selection of system boundaries

In order to describe the materials flows and stocks of a system, the system boundaries must be defined, both spatially and temporally.

Temporal border - The timeframe of this case study is the year 1991.

Spatial border - The administrative borders of the City of Vienna were selected as the spatial boundaries for this system.

The main arguments to support the choices of this study's system boundaries are:

First, this system is compatible with the policy decision making framework of the City of Vienna. Second, the availability of data within this selected boundary is relatively good. From a practical point of view, the accessibility and location of the data is extremely important since the project team must contact key institutions in order to gather relevant and reliable information. A geographically-tight boundary, such as the administrative boundary of the City of Vienna, results in more concentrated data source points (e.g. public services, industrial activities, waste treatment facilities), and saves resources (time and money) on the information gathering stage. Furthermore, one year is practical as a time frame because of the availability of annualised data. The Austrian federal office of statistics (ÖSTAT) collects census data in the required grade of detail every 10 years, and 1991 was such a census year. The majority of data used in this study relates to 1991 and where necessary, some data was taken from other years and were treated as 1991 data. Time series were collected only where necessary for the calculation of the stocks within the anthroposphere.

3.4.2 Linking the Anthropogenic and Natural Metabolism of the City of Vienna

The objective of this investigation is to determine the interaction between the anthroposphere and the environment. In particular, to assess the current anthropogenic flows into the environment and to investigate the effect of decisions made within the anthroposphere on the environment.

The link between the anthropogenic and natural metabolism of Vienna was conducted by Paumann et al. (1997) based on investigations from Dackbeck et al. (1996) and Maier et al. (1996). The following system definition is an outline of that described in Paumann et al. (1997) (see Figure 3-2).

Selection of processes

The environmental processes are sub-divided into planetary boundary layer, surface water, groundwater and cultivated area (in particular agricultural, forestry, urban soil up to 50 cm depth and vegetation). These processes have been aggregated into atmosphere, hydrosphere and pedosphere and vegetation and were linked to the Anthroposphere (see Figure 3-2).

Selection of system boundaries

The temporal and the spatial borders of the system *'anthroposphere and environment'* have been defined as described in 3.4.1. That means that the temporal border is the year 1991 and the spatial borders are the administrative borders of the City of Vienna. The system boundaries were chosen for similar reasons to those outlined above in the section 3.3.1. Furthermore, the spatial borders of environmental processes atmosphere, hydrosphere and pedosphere (including vegetation) are defined as follows.

The process planetary boundary layer has been assumed - according to [Beer et al. 1990] - to be 500 m thick, because a large amount of atmospheric processes take place in this region. The spatial border of the process pedosphere and vegetation is assumed to be to a 50 cm depth of soil. This is based on the fact that 50 cm is approximately the average depth of soil-layer in Vienna [Maier et al. 1996]. The subsoil has not been balanced. The process hydrosphere includes surface waters and groundwater. The main groundwater bodies of Vienna are associated to a large extent with the surface water body of the river Danube. The unsaturated zone of soil (interflow[2]), which in some publications is added to groundwater has not been included in the process hydrosphere but is included in the process pedosphere and vegetation. Smaller surface waters which are to a certain extent connected to the main river, namely Donaukanal, Neue Donau, Alte Donau, Wienfluß and Liesingbach have been added additionally to the process hydrosphere.

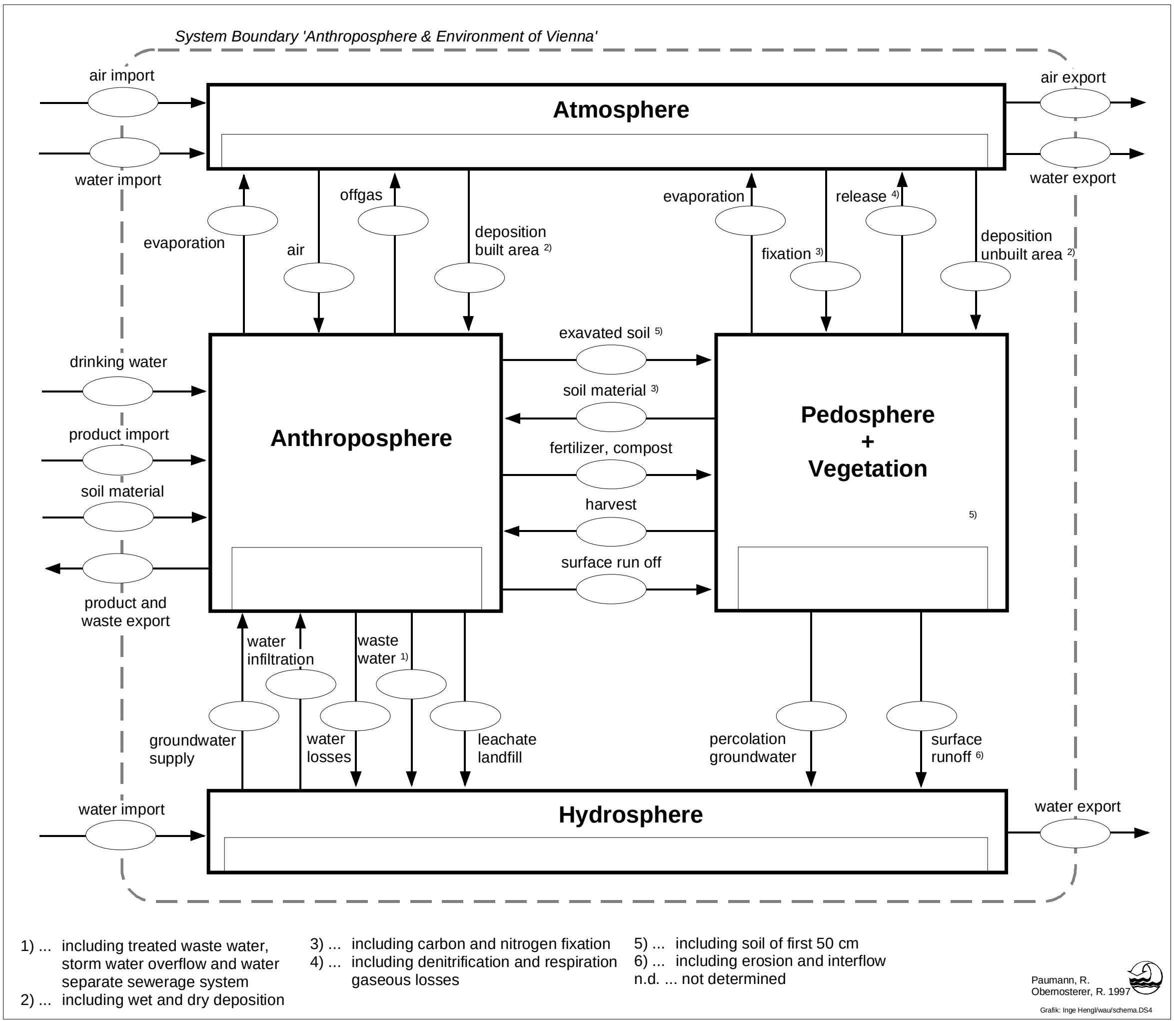


Figure 3-2: Description of the System of the Link between Environment and Anthroposphere of the City of Vienna [Paumann et al. 1997]

2 water that flows from the surface through soil and ends up in surface water

3.4.3 Linking the Metabolism of the City of Vienna with it's „Hinterland“

The objective of this investigation is to assess the dependence of the City of Vienna on its „Hinterland“ for supply as well for disposal of goods and substances. Decision makers have to be sensitised to their responsibility for measures which effect supply from and disposal in the „Hinterland“ (and vice versa). Up until this point, the system boundary has been defined by the administrative boundary of the City of Vienna, and therefore its „Hinterland“ has not been included in the investigations. That is, materials flows induced by production and transport of goods imported into Vienna as well as flows induced by transport, use and disposal of goods exported out of Vienna are excluded. Environmental impacts and resource depletion largely occur irrespective of administrative boundaries.

A city however has many interactions with its surrounding area and with other regions and nations around the globe. One has only to think about the food supply from various agricultural regions around the world, or the supply of minerals from different mining sites. The by-products of a city's metabolism leave urban regions by the way of rivers, air or human transport systems. The effects of these by-products are felt in neighbouring regions and all over the globe. For example, consider Carbon dioxide and the Greenhouse Effect. A city striving for a sustainable future must consider its „transboundary“ impacts. In order to do this, the key processes from the „Hinterland“ which are induced by the metabolism of the city, should also be taken into consideration („Hinterland“ processes can no longer be considered „transboundary“ since they are included in the system).

There are a number of different ways to incorporate the „Hinterland“ into MFSA. One suggestion is to start with the key-processes or flows from the results of the anthropogenic metabolism of Vienna. Rather than investing time and resources on tracing the origin and sink for each key flow, in this project the focus is on investigating and refining the methodology to determine how this approach could function. To do so, three examples where carried out on different issues:

- Carbon - activity orientated system boundary (*activity: to transport*)
- Lead - good orientated system boundary (*good: car batteries*)
- Nitrogen - environmental process orientated system boundary (*process: surface water*)

Methodology to include the cities „Hinterland“:

In general, a MFSA study which includes the „Hinterland“ follows the same methodology as a traditional MFSA. The system description essentially relates to the problems, goals and questions under investigation and therefore each system will not look the same. There are, however, some common elements of a „Hinterland“ study, which are quite different to traditional MFSA studies. In order to compare the impacts within and outside an urban system, only those flows outside the administrative boundaries which relate to the metabolism of the „inside“ city were taken into account. For example, consider the lead emissions from a Lead battery recycling plant which is located in the „Hinterland“ of Vienna. If Vienna contributes 1 portion of batteries to this plant and the rest of the Input is 4 portions then Vienna is theoretically responsible for 1/5 of the Lead emissions which are emitted from the recycling plant (in a similar way Vienna could also „use“ 1/5 of the allowed environmental standard set for the „Hinterland“).

The definition of the system boundaries in each investigation does not follow a geographical boundary. Instead the system boundary is defined by including the key-processes, or by the substance or goods under investigation.

Example: „Hinterland“ Carbon flows related to the activity to transport

- *system boundary activity orientated*

In this example, the „Hinterland“ is integrated into the urban Carbon system by including those external processes which are related to transport fuels used by Viennese. The activity to “transport“ (people and goods) is given special consideration in this example because it plays an important role in energy consumption and also in the turnover of certain substances (e.g. Carbon, Nitrogen, Lead). The example considers the flows of „transport fuels“ which are induced by the Viennese outside the city: the traffic of Vienna’s inhabitants and the transport of goods by the Vienna lorry fleet between Vienna and its „Hinterland“ were incorporated in an internal process (EEIP - external effective internal process). Furthermore, the flows that are generated by non-Viennese people within the city are calculated in the process IEEP (internal effects of external processes). The approach of course only partially represents the Carbon interactions between Vienna and its „Hinterland“.

NOTE: In order to address „external emissions“, the system boundary was extended from the administrative level to a „Carbon emission orientated system boundary“ called - Anthroposphere Vienna & „Hinterland“ of transport fuels.

Example: Lead flows relating to the production and recycling of car batteries

- *system boundary: good orientated*

The annual Lead flow from industry and private household to Vienna’s waste management system amounts to about 4,500 t. Waste management within Vienna treats only about 15% of this load. About 85% of the Lead is exported to the „Hinterland“. Waste management as well as Lead recycling can result in Lead emissions. Obviously, the Lead-problem for the city itself could be partly „solved“ by transferring the Lead over the city’s jurisdictional boundaries to the „Hinterland“. In view of the goals of sustainability, these „transboundary“ issues should be included in the system.

This example is based on the flows and stocks which result from the use of car batteries in the anthroposphere of Vienna. All flows which relate to car batteries in Vienna where traced outside the administrative boundaries and all processes relevant to these flows where taken into account i.e. included within the system boundary. The system boundary in this case is therefore expanded from the administrative boundary of Vienna to a product orientated boundary for Vienna.

NOTE: This example was further used to discuss the potential of MFSA studies to compare different scenarios of policy strategies. In the results (5.3.2), the different strategies linear use, current use and cyclical usage of car batteries are compared and discussed.

Example: Nitrogen flows into the surface water

- *system boundary environmental process orientated*

In this investigation, the Nitrogen flows in the City of Vienna were examined in view of decreasing the nutrient loading entering the Danube River and the Black Sea thereafter. In this example the Nitrogen flows contributing to hydrospheric pollution in the „Hinterland“ which are induced by Viennese activities were taken into account.

In this investigation, no entire system was defined but rather a calculation of the „Hinterland“ flows was conducted based on two previous MFSA studies, namely:

- the results from a recent study on the nutrient balances for Danube countries [Somlyódy et al. 1997]
- the results of a recent study linking the anthropogenic and natural flows of the City of Vienna [Paumann et al. 1997]

Based on the above mentioned reports, the most significant inputs into the surface waters in the „Hinterland“ were calculated (i.e. the study looked at only those significant flows induced by Viennese demands). The flows under investigation include:

- base flow in groundwater (from percolation from both agriculture and „other“ land activities)
- erosion and runoff from agricultural land
- erosion and runoff from forested and from „other“ land activities

NOTE:

- these flows represent primarily contributions from agricultural activities and atmospheric deposition.
- the effluent flows from the wastewater treatment plants in the „Hinterland“ were not included in this investigation.

The induced „Hinterland“ flows were compared with the equivalent flows within Vienna in order to highlight the reliance of a city on its „Hinterland“ for disposal of substances.

4 Collection of Data and Information for MFSA of the City of Vienna

This chapter gives an overview of the sources of materials data and outlines how existing data can be used for MFSA. In the first section a general description is given. In the second section an overview for the data bases for the Vienna case studies is presented. Furthermore, a discussion of the treatment of uncertainty is included in this chapter.

4.1 General Information to MFSA Data Sources

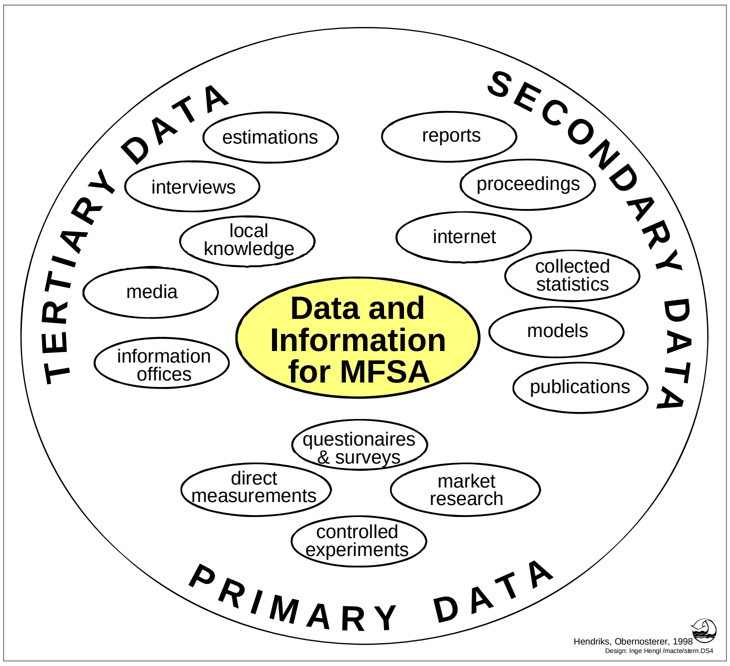


Figure 4-1: Overview of the Sources of Materials Data

To date, no operational data base for MFSA exists. No specific measuring programs were carried out for this case study. Thus, existing data was used as the base for this investigation. Broadly there are three different types of data sources which can be used for MFSA purposes.

- Primary data - generally raw data (e.g. direct experiment results or results from questionnaires, surveys etc.)
- Secondary data- raw data that has been processed, collated and interpreted (e.g. statistics, publications, proceedings and reports, Internet, models)
- Tertiary data - „informal“ or non-traditional data sources (estimations, interviews, non-published data, local or „hands on“ knowledge, individually performed estimates, the media etc.)

4.1.1 Source of Regional and National Data

Data provided in regional and national statistics has two general characteristics: time and space. Another characteristic of statistics is that they are often collected and stored in various different units and require standardisation for use in MFSA e.g. data in ECU requires conversion to tonnes.

In this case study data was used from:

- Austrian Federal Office of Statistics (ÖSTAT)
- Regional statistics (city and province of Vienna)
- Public service data statistics (different departments of the City of Vienna)
- National statistics of other countries (e.g. Switzerland, Germany)
- Other regional statistics (e.g. St. Gallen, Upper Austria)
- Data from our associated project partners of MAcTEmPo
- Data from Literature
- Information gathered from personal contact with experts

For MFSA, the important fact is that unfortunately standard statistics often supply either limited or no information about the chemical composition (substance content) of goods which are turned over in a selected region or state. Instead, they traditionally focus on units such as monetary values or (sometimes) mass flow of a product. In addition to considering flows during a selected time period, MFSA also incorporates stocks and their changes. This means that for MFSA, time series of goods and substances should exist, or data about stored goods and substances should be available. However, in many cases such data was not available for this case study and where necessary estimations were made.

4.1.2 Estimation of Flows and Stocks

From a methodological point of view, the system is defined based on the problem under investigation. The next step involves collecting the necessary data. In some cases this leads to problems, since the information and the data are insufficient for a completely balanced system. In such circumstances, the system must be adapted to suit the amount of available information or alternatively additional measurements can be undertaken. In many cases, these missing flows and stocks are estimated. Cross checking such estimations with additional information from other sources is then of primary importance. Unknown flows can also be calculated by counterbalancing the system. Furthermore, data were used from other systems and were transformed to data sets for the City of Vienna.

E.g. estimations of flows and stocks for the anthroposphere include:

- Estimation of relationship between monetary amounts (normally available in statistics) and mass amounts (used in material balances) of imported, exported and internally (inside Vienna) distributed producer and consumer goods.
- Estimation of chemical composition of the imported and exported as well as internally (inside Vienna) distributed producer and consumer goods.
- Estimation of material flows and their composition of the input, the stock and the output of the buildings and infrastructure in Vienna.
- Estimation of the stock of material and their composition in waste dumps and final storage.
- Assignment of the total measured flows to the waste and waste water treatment plant, either from PHH or ITS.

4.2 Source of Data for the Case Studies

The good flows and stocks of the anthropogenic system of the City of Vienna were calculated in project „Anthropogenic Metabolism of the City of Vienna" [Daxbeck et al. 1996]. In this project the accounting of goods and the substances Carbon (C), Nitrogen (N) and Lead (Pb) is given. Parallel to these projects the natural metabolism of Carbon (C), Nitrogen (N) and Lead (Pb) of Vienna was calculated in the project „The natural metabolism of the City of Vienna" in Maier et al. (1996). The connection of the natural and the anthropogenic metabolism for these three substances is described in Paumann et al. (1997). The experience and results of these three projects provides the basis for the Mac Tempo project particularly in investigating how policy decision makers can use MFSA.

Additional data and information collection was however necessary for describing the metabolism of Vienna for the MAcTEmPo project. This particularly applied to the substances Zinc (Zn), Iron (Fe) and Aluminium (Al), for the „Hinterland" approach and for some specific issues like the investigations on construction materials (data bases given in the Appendix). Additional data was also collected as part of the two studies:

1. investigations into the relationship between material stocks and urban density within Vienna [Möslinger 1998]
2. examination of the induced Lead flows in the „Hinterland" by the use of car-batteries in Vienna [Smutny 1998].

4.3 Treatment of Uncertainty

There is a level of uncertainty associated with all forms of data. To use MFSA as a tool in the decision making process, the uncertainties of the presented results must be known.

In order to conduct a MFSA on the regional level, numerous data sources are required. Often this means that different levels of data uncertainty must be combined and taken into account. As a consequence, the system is usually not „balanced". That is, the input minus output does not equal stock variations.

If different values are available for a flow or a stock, the minimum-maximum values are taken into account (data range). This data range could be misleading, if one supposes that the true value is within this range. It is sometimes the case that this range exists as a result of two different literature values, each with their own level of uncertainty. In addition, sometimes data on material flows or stocks or on substance concentration of goods is limited or unknown. When no values are available, estimations may need to be made.

The actual data quality for regional MFSA leads to a system which shows the order of magnitude of the flows and stocks. Experience demonstrates that typically the information is sufficient enough to indicate the key-processes and key-flows within a defined system. The obvious shortcomings of the data required that it is essential to check the plausibility of the system, e.g. comparison of flows with the calculated stock. Another methodological step to check data is to make use of scenarios. In this case, the results and conclusions can be cross-checked using different estimations.

When using MFSA as a tool for decision making the question arises: How much uncertainty is acceptable? In general, when the conclusions of the flow and stock analysis reveals that the comparative magnitude of the flows if far greater than its associated level of uncertainty, then the significance of the uncertainty is reduced.

For example, considering a process in which the flows require reduction. In this process, there are two input flows, one of which is much greater than the other one. The uncertainty associated with both flows however is the same. In this case, the decision to reduce the greater flow is unaffected by the uncertainty. But if the uncertainty of the larger flow is greater than the uncertainty of the smaller flow and if there is a possibility that in the worst case both flows are of the same order, then the uncertainty influences the decisions, since it is unclear which flow one should reduce. In this case, further investigations might be necessary.

The data used in the Vienna Case Study was collected in view of the project goals i.e. to get an overview of the city's metabolism and to investigate the use of MFSA as a tool for environmental policy decision making. The collected data was significant to reach the goals of the project and for this reason large resources were not invested into finding missing data. However, the results reflect the order of magnitude of the flows and stocks of the metabolism of the City of Vienna and this provides a suitable basis for making conclusions for this report.

The level of uncertainty for data relating on the Vienna study to water and energy sources is relatively low. The uncertainties are higher for data collected for consumer goods and for construction materials and are the highest for the industry and trade sector. The quality of data on the substance level increases as follows: Fe, Al, Zn < Pb < C,N.

5 MFSA Results

In the following section the results are given and structured for the three investigations

- Anthropogenic Metabolism of Vienna
- Linking Anthropogenic and Environmental Metabolism
- Linking the Metabolism of Vienna with the induced flows in the „Hinterland“

In addition this section includes a comparison of Viennese results with the other MAc-TEmPo projects.

5.1 Anthropogenic Metabolism of the City of Vienna

The figures of the results for this system, which is defined in chapter 3.4.1 are given in Appendix F, chapter 12.6. In the following sections overall pictures of the results on an aggregated level are presented. In some cases the following text refers sometimes to the detailed figures given in the Appendix.

5.1.1 Good Flows and Stocks in the Anthroposphere of the City of Vienna

The flows of water and air through the city are important „conveyor-belts“ for substances. This input is e.g. essential to provide the city with oxygen and drinking water. On the other hand, the water and air conveyor belts are essential in removing the off-products generated in Vienna. E.g. offgas leaves the city via the air, and treated waste water leaves via the Danube River (see section 5.2).

Approximately 300 million tons of goods enter the City of Vienna each year. This results in an anthropogenic flow of goods of nearly 200 t per capita, per year. Approximately 75 % of this input is water, nearly 18 % consists of air, and the import of construction materials amounts to between 2 and 5 %. Producer and consumer goods, and soil material moved within Vienna contribute about 1 %.

Nearly 40 % of the total imports of goods flow to private households (PHH), and between 35 and 40 % to the industry, trade and service sector (ITS). The portion of rain and intake water (ground water that seeps into the sewer but shouldn’t) makes up just over 20 % of total imports. Almost, the entire amount of the approximately 300 million tons of waste water, offgas and solid waste leaves Vienna. Approximately 0.2 % of these off-products are deposited in Vienna’s landfills. The biggest part (76 %) runs out of the city as treated waste water. The output via air contributes about 20 % and nearly 2 % is exported as solid waste.

The ITS process is not counterbalanced. This shortcoming is partly due to the structure of the official statistics which were used. Based on industrial and trade statistics, a raised input of 1.8 million tons into industry and trade meant an output of 2.4 million tons. Cities, as service centres, are generally expected to have a small turnover of goods from industry and trade. However, the calculation of good flows showed that industry and trade sector in Vienna has a high turnover compared with the other solid flows of the city.

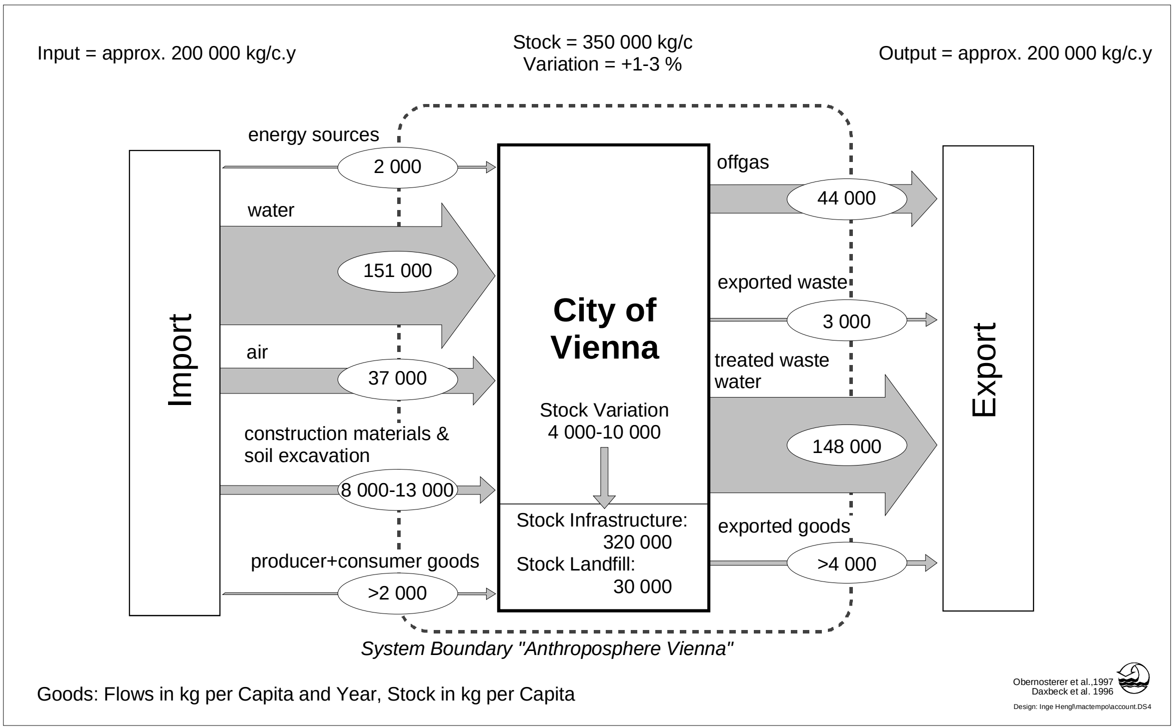


Figure 5-1: Flows [kg/c.y] and Stocks [kg/c] of Goods in the Anthroposphere of the City of Vienna in 1991

The stock of anthropogenic goods in the City of Vienna totals nearly 500 million tons. This amounts to 350 tons per capita. The stock of goods in the anthroposphere grows by approximately 1 - 3 % in the year 1991. The largest part (nearly 90 %) of this stock is construction material accumulating in the buildings and infrastructure of the city. Both stocks in the process ITS and in the process PHH are approximately equivalent. However the inputs of goods into ITS are higher than the inputs into PHH. There could be several reasons for this: e.g. the accumulation rates in ITS are higher or the taken assumptions are incorrect. The share of landfill of the entire anthropogenic stock amounts to nearly 10 % and grows by about 1 % in the investigated year.

5.1.2 Carbon Flows and Stocks in the Anthroposphere of the City of Vienna

Between 4.1 and 4.9 million tons of Carbon (3 t/c.y) in various goods flowed to the anthroposphere of Vienna in 1991. The Carbon balance of the City of Vienna is dominated by the use of fossil fuels, but also by organic and inorganic bound Carbon in construction materials. In particular, this input was dominated by energy source-bound Carbon flows (approximately 600 kg/c.y transport fuels and 1,100 kg/c.y heating fuels) that amount to between 53 % and 63 % of total Carbon inputs (depending on the range of construction materials). The portion of construction material-bound Carbon flows is between 17 % and 30 %, producer and consumer goods-bound Carbon contributes between 16 % and 20 % to total Carbon input, depending on construction material turnover. The sizes of water-bound Carbon input (6 kg/c.y) are relatively small in relation to the total balance.

Within the anthroposphere of Vienna, slightly more than 60 % of the entire Carbon input (2.5 - 3.2 million t/y) is turned over by the industry, trade and service sector and slightly less than 40 % by private households (1.7 million t/y). Waste management plays a quantitatively insignificant role in the Carbon balance of Vienna. In particular, the Carbon turnover in ITS is around 1.5 times larger than that in PHH, and around 5 times larger than that in waste management.

The total ITS Carbon flows is divided, depending on the assumption of construction materials flow, as approximately 47 % to 64 % from energy sources, 20 % to 40 % from the buildings and infrastructure, 14 % to 18 % from consumed goods and less that 1 % from water. The total private household Carbon flow is divided in similar proportions: energy sources 65 %, consumed goods 22%, buildings and infrastructure 12 % and water < 1 %.

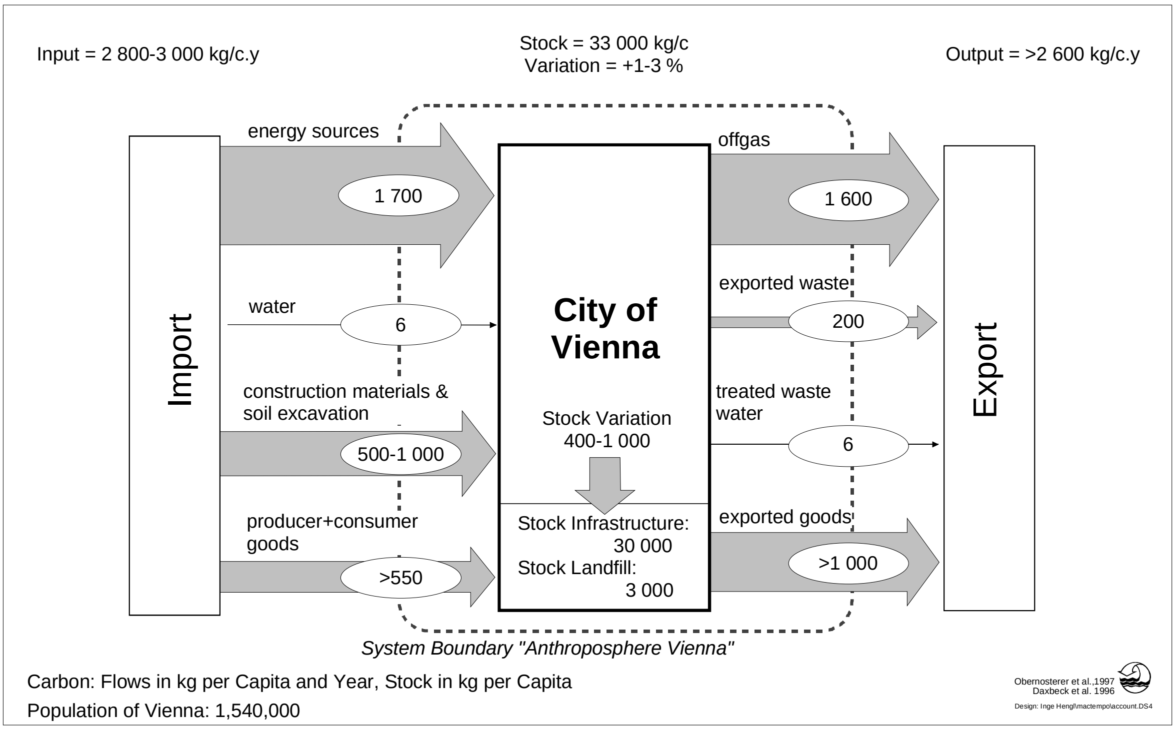


Figure 5-2: Flows[kg/c.y] and Stocks [kg/c] of Carbon in the Anthroposphere of the City of Vienna in 1991

Roughly 330 kg of Carbon per capita and year from ITS and from PHH goes to waste treatment and disposal. About 90 % of this amount is in solid waste (300 kg/c.y) and around 10 % is in waste water (30 kg/c.y).

The biggest Carbon output is that emitted directly into the atmosphere by private households, and ITS sectors. The second major flow of the system goes into the stocks of buildings and infrastructure. Therefore, with regard to Carbon, waste management can only fulfil its filter function to the environment.

The entire output flow of Carbon from the City of Vienna amounts to approximately 2,600 kg/c.y. About 60 % of this Carbon (2.4 million. t/y, 1,600 kg/c.y) leaves Vienna as waste air (from these 1,600 kg/c.y 55 % leaves via industry and trade, 39 % via private households and 6% via waste water and solid waste management into the atmosphere; Note: the portion released by human breath in the process private household is 210,000 t/y). Fuels spent outside the system boundary of Vienna from ITS (140 kg/c.y) and PHH (230 kg/c.y) represent about 14% of the total Carbon export, under the assumed reference scenario of Vienna traffic (see also „Hinterland“ chapter 5.3.1). There is still some uncertainty about the amount of Carbon connected to ITS in the form of roughly 470 kg/c.y of producer and consumer goods, amounting to approximately 18% of the total Carbon export. The portion of Carbon exported through wastes (200 kg/c.y) represents about 8 % of the total.

The Carbon stock of Vienna (33,000 kg/c) is essentially defined by its buildings and infra-structure (30,000 kg/c). This stock grew by around 2 % in the investigated year. The total Carbon stock has built up to around 50 million tons. One tenth of this amount is located in landfills, where organic-bound Carbon is not fixed over the long term. The major portion of the Carbon stock however is integrated into the buildings and infrastructure and 2/3 of it is present in organic form (e.g. wood, synthetic materials, plastics). The anthropogenic Carbon stock of the City of Vienna increases about 2 % each year. The absolute stock growth in ITS is 2 to 6 times larger than that of private households, as well as that of waste management. The fastest growing stock Carbon in the anthroposphere is in the „landfill“. Considering the life span of the buildings and infrastructure of several decades, the flow in waste management must clearly increase over the long term.

Given the high organic share in the flow from the buildings and infrastructure, construction waste is not suited to be directly landfilled since the organic Carbon content in landfills leads to biological activities which generate methane and other greenhouse gases. The currently-growing stock could represent a significant potential resource in the future, and should be more effectively recovered and used, to substitute for fossil energy sources, and to minimise potential future problems (e.g. landfill). In order to replace fossil energy sources, CO_2 -neutral wood imported for buildings and infrastructure construction and renovation must still be replaced through reforestation. The current share of organic Carbon accumulation due to buildings and infrastructure is about 5 % of energy source-bound Carbon inputs from Vienna. Anticipated additional accumulation of Carbon from buildings and infrastructure could reach up to 10 % of the Carbon portion of the energy source inputs in the future. This demonstrates the importance of the prudent management of residual construction waste for the future C-balance.

5.1.3 Nitrogen Flows and Stocks in the Anthroposphere of the City of Vienna

The amount of total Nitrogen imported into the City of Vienna was between 44,000 and 61,000 tons in 1991, that is about 30 - 40 kg /c.y. About 50 % of this amount is imported in producer and consumer goods, 30 % in construction materials and 20 % in energy sources (only taken reduced and oxidised Nitrogen into account).

The Nitrogen export of the City of Vienna amounts to 40 kg/c.y. The largest Nitrogen export is through goods from industry and trade (60-65 %). A load of about 4 kg /c.y is emitted into the atmosphere. This corresponds to roughly 10 % of the total Nitrogen that is exported from Vienna. Roughly 5 kg N/c.y leaves Vienna via waste water; some 95 % of this amount comes from the discharge flow of the sewage treatment plant. The share of Nitrogen in waste water comes roughly in equal parts from private households as from industry and trade enterprises.

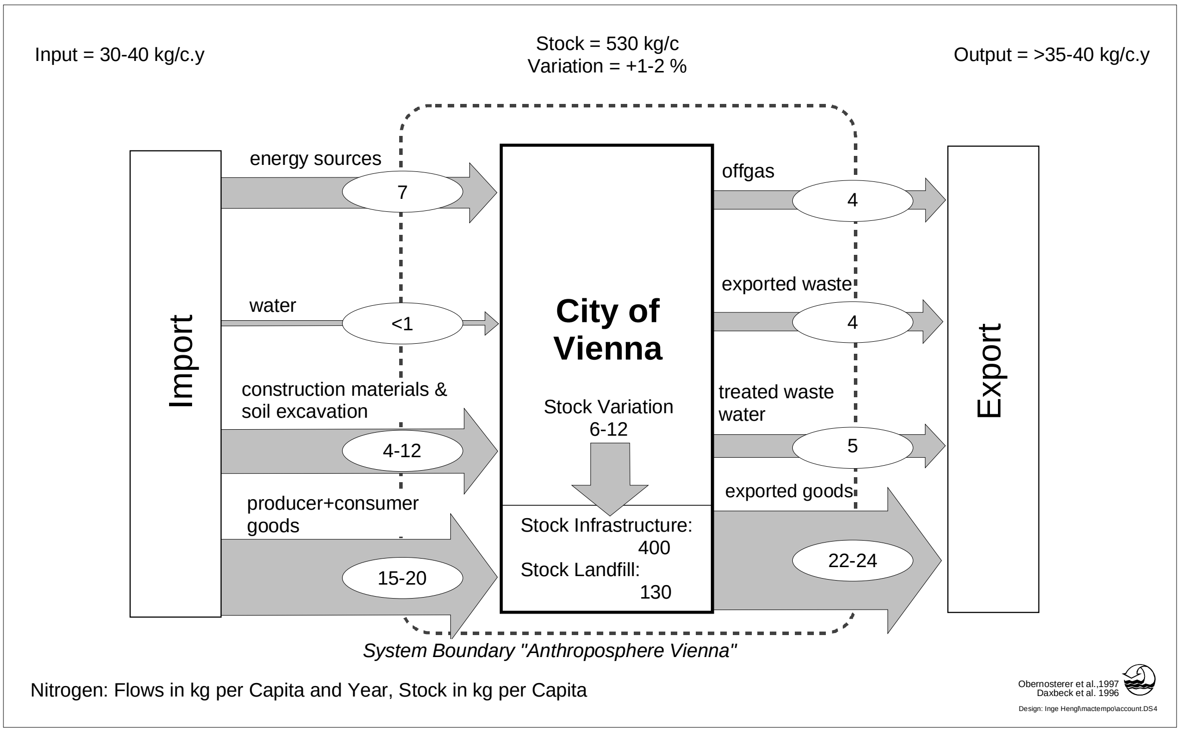


Figure 5-3: Flows [kg/c.y] and Stocks[kg/c] of Nitrogen in the Anthroposphere of the City of Vienna in 1991

The current Nitrogen stock of Vienna amounts to 530 kg N/c.y. The different stocks of Nitrogen are: 70 % in construction materials, 20 % in landfill, and the remainder in various (stored) consumer goods (e.g. furniture and automobiles). About a third of Nitrogen goes to the landfill through construction waste, the other two-thirds through the landfilling of solid waste from PHH and ITS. In total, the stock grows by 1 % - 3 % in the investigated year. Quantitatively, the largest and fastest growth is found in ITS with 4,100 to 13,000 t Nitrogen. The stock of Nitrogen in the landfill grew in the balance year (1991) by about 3,000 t Nitrogen. The growth in PHH was slightly less, growing by 1,700 to 5,700 t Nitrogen. Within 25 to 70 years, the Nitrogen stock in the city will double.

The major part of this Nitrogen stock is located within the building sector. In the last few years, synthetic materials (e.g.. polyurethanes, nylons) have been increasingly used in construction. Consequently, a larger Nitrogen load in construction waste can be expected in the future. It remains to be clarified, whether the increase in N-containing synthetics in construction waste will develop into a relevant waste management problem (quality and quantity of emissions from thermal waste treatment plants, possible changes in landfill qualities of construction waste and how these synthetics behave in the landfill).

5.1.4 Results of Metal Flows and Stocks in the Anthroposphere of the City of Vienna

For all investigated metals (Lead, Iron, Aluminium and Zinc) the flows into the city are larger than the export flows. Today, the important stocks are located within the cities infrastructure and buildings (90 %). Only 10 % of the stocks are stored in the city's landfills. This calculation is based on the data from known landfills within Vienna's administrative boundaries. Other studies highlight that the Zinc stocks in landfills could be more significant. For example, in „Metaland“ 20 % of the entire Zinc stock is located in landfills [Baccini & Bader 1996], for Austria 15 % of the entire Zinc stock is located in landfills [Daxbeck et al. 1998], in Upper Austria, a construction balance for Al, Zn and Pb gives a range between 10 - 30 % in landfills [Glenck et al. 1997] and in the USA about 35 % of the Copper to date is located in landfills [Zeltner et al. 1998].

Given the high level of uncertainty concerning the metal balances, it is not yet possible to quantify the total amount of diffuse emissions. Diffuse metal emissions are those emissions which result from the losses over the use and disposal of metal containing goods. The impact of emissions is widely dispersed, and cannot be easily controlled due to numerous non-point sources. Typical examples of diffuse emissions include those leaching from leaded water pipes or corrosion of Zinc coated roofs and others.

5.1.5 Lead Flows and Stocks in the Anthroposphere of the City of Vienna

Since early antiquity, the per capita use of Lead has increased more than a hundred-thousand fold. In Austria today, Lead use is at about 4 kg/c.y. In 1991, the Lead import into Vienna was about 24,000 tons, that is 16 kg/c.y mainly to industry and trade activities. In the same year, between 12 and 15 kg/c.y were exported from Vienna primarily in the form of produced goods and waste.

The input of Lead from different groupings of goods are different by 4 orders of magnitude. The smallest Lead import to Vienna, via drinking water, amounts to less than 1 g/c.y (because of the small amount of metal input flows via drinking water, this flow is not shown in the figure). From energy sources about 66 g/c.y were imported; from construction materials and soil materials roughly 2.8 kg/c.y and from producer and consumer goods about 13 kg/c.y. This means that 80 % of Lead imports reached Vienna in the form of producer and consumer goods and 17 % through construction materials.

The Lead flow within Vienna consists primarily of construction materials and car batteries. Of the total Lead imported into the City of Vienna, nearly 90 % (21,000 t) were turned over through ITS and about 10 % through PHH. Of the 21,000 tons of Lead which flow through ITS, 80 % were used in Lead containing and manufacturing enterprises. Lead-content goods from ITS leave the city of Vienna in manufactured products (ITS export goods). In private households, 2,400 t Lead flow in the forms of consumer goods and primarily leave households as solid waste (solid waste PHH).

On the basis of identified Lead flows, this means that the Lead stock in the City of Vienna grew that year, adding some 2.2 kg/c to the accumulated Lead stock. The stock itself is already about 230 kg/c, mainly due to the buildings and infrastructure stock.

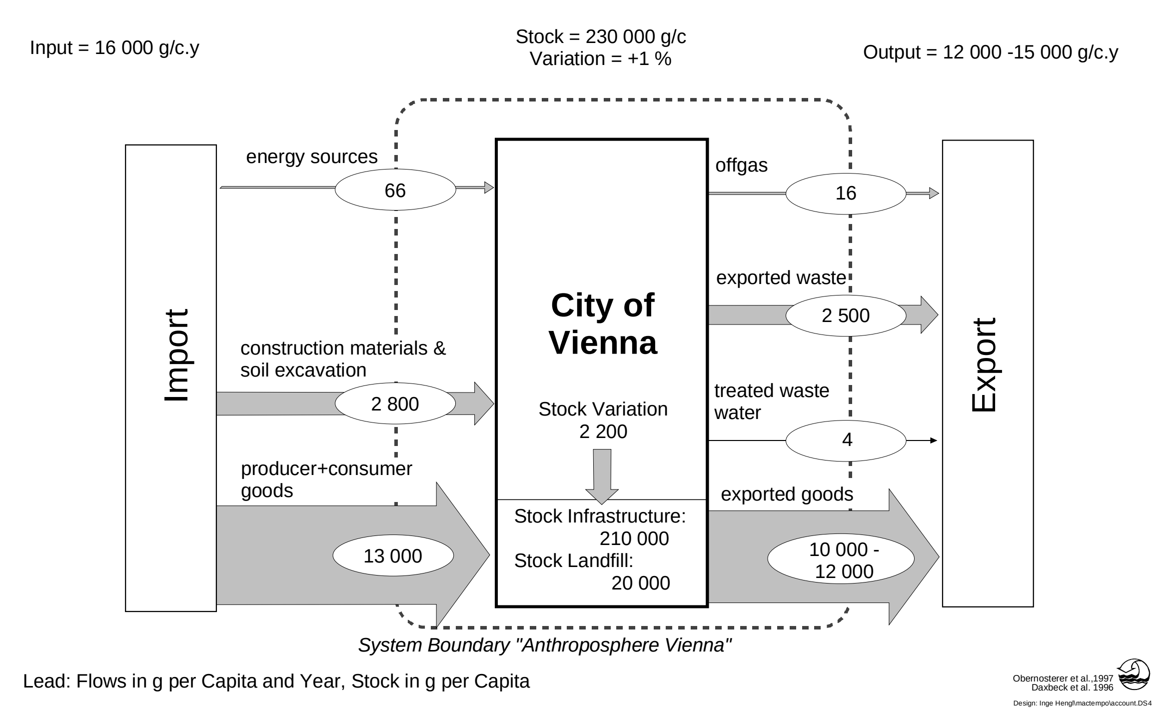


Figure 5-4: Flows [g/c.y] and Stocks [g/y] of Lead in the Anthroposphere of the City of Vienna in 1991

In waste and waste water management, the input flows of Lead in solid waste from PHH and from ITS are about the same size (approx. 1.5 kg/c.y). Approximately 20 kg/c of Lead are stored in the landfills within Vienna's administrative boundary. In 1991 this stock increased by about 0.5 kg/c.y or 2.5 %. The City of Vienna lost 3,800 t of Lead in exported waste in 1991; therefore roughly 20 % of Lead in the output of waste and waste water management remains in the city.

In the balance year 1991, leaded petrol was still available in Vienna (since 1993 the sale of leaded petrol is forbidden in Austria). The Lead emissions into the air of Vienna, through the use of fuel and combustible substances, totalled 25 tons in 1991. No leaded petrol has been used in Vienna since 1993, yet 10 tons of Lead emissions into the air from combustion of fuels and combustibles can be expected, due to the geogenic lead content in fuels and combustibles (coal). In comparison, the annual Lead-load from the municipal waste incineration plant was 0.08 t/a in 1992 [UBA 1995]. As a result of reduced usage of Lead fuel, the Lead load from rain water draining from road, roof and yard surfaces into the sewer system has also decreased.

5.1.6 Aluminium Flows and Stocks in the Anthroposphere of the City of Vienna

In total, 220-540 kg Aluminium /c.y flow into the City of Vienna. The main amount is used for construction activities in industry and trade and in private households. Approximately 3 % of the total input into Vienna are included in producer and consumer goods. Less then 1 % is imported through energy sources into Vienna (above all in the form of coal). 1 - 7 % of the entire Aluminium input flow are in elementary form (eg.

Aluminium window frames), and the remaining amount is present in a non-elementary form (e.g. Aluminium Silicate).

Around 130 kg Aluminium /c leave the system boundary of the City of Vienna each year. The dominant portion of this amount is exported outside the city limits in form of solid waste. The Aluminium output flows via waste air and via waste water are quantitatively negligible.

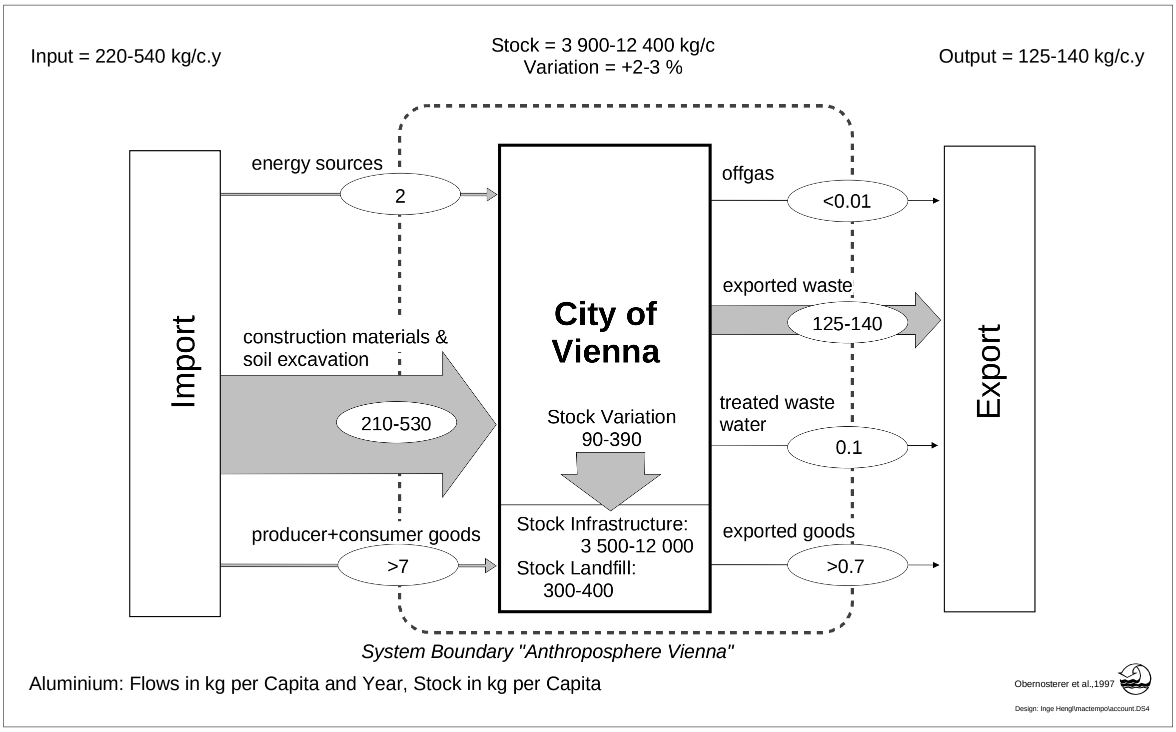


Figure 5-5: Flows[kg/c.y] and Stocks[kg/c] of Aluminium in the Anthroposphere of the City of Vienna in 1991

The growth of the Aluminium stock in Vienna is about 90 - 390 kg/c.y. The Aluminium stock from PHH grows at 5 - 35 kg/c.y, from ITS at around 12 - 285 kg/c.y and in Waste Management at 70 kg/c.y. The increase resulting from construction activities dominates compared with the increase from consumer goods. Energy sources and water flows account for only a negligible amount of the Aluminium stock's growth.

The total accumulated amount of Aluminium within the system boundary of Vienna (the stock) is estimated to be between 4,000 - 12,000 kg/c. Of this total, around 1,600-5,300 kg/c is attributed to PHH, 2,000 - 6,700 kg/c to ITS and 300 - 400 kg/c to Waste Management. The ratio between the stock from the buildings and infrastructure and from consumer goods is estimated to be 100 : 1.

5.1.7 Zinc Flows and Stocks in the Anthroposphere of the City of Vienna

The Zinc metabolism of Vienna is dominated by construction activities. Between 50 - 80 % of the annual import into the city are through construction materials and excavated soil, amounting to a Zinc flow between 1 - 4 kg Zn/c.y. The second important group of Zinc containing goods are producer and consumer goods, with a flow bigger then1 kg

Zn/c.y 10 - 50 % of the entire Zinc input flows are in elementary form (eg. Zinc pipes) and the remaining amount is in non-elementary form.

The Zinc exports from Vienna are also dominated by the building sector. About 80 % of the annual Zinc-export leave the city as construction wastes. 20 % of Zinc is found in exported goods and treated waste water.

The Zinc stock in Vienna grows about 3 kg Zinc per capita and year. The Zinc stocks are to be found within buildings in the private household (calculated up to 45 kg Zn/c) and the supplying sector (calculated up to 55 kg Zn/c).

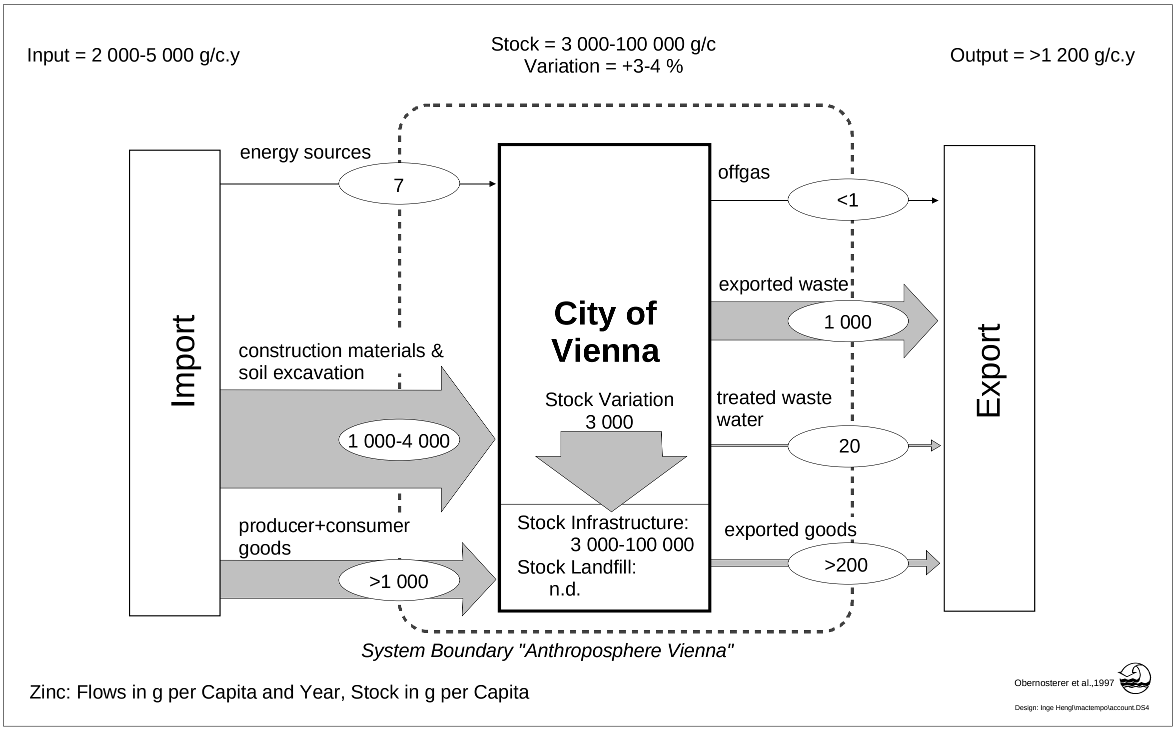


Figure 5-6: Flows [g/c.y] and Stocks[g/c] of Zinc in the Anthroposphere of the City of Vienna in 1991

Private households consume most of the Zinc-input through consumer goods and dispose of Zinc via solid wastes (60 %) and waste water (<2 %). About 40 % of Zinc is stored longer than one year.

Waste and waste water management treats wastes with a Zinc-flow of about 1.6 to 2.6 kg Zn/c.y. About 1 to 2 kg Zn/c.y are to be found in industry, trade and service sector (including excavated soil) and about 0.6 kg Zn/c.y within solid wastes from private households. In waste water only 1 % of the Zinc output can be found.

5.1.8 Iron Flows and Stocks in the Anthroposphere of the City of Vienna

Around 190 - 290 kg Iron/c.y flowed into the anthroposphere of Vienna in 1991. Within the anthroposphere, 70 - 80 kg/c of the entire Iron input are turned over by industry and trade and 20 - 30 kg/c are turned over by private households. The input is dominated by construction materials (50 - 150 kg Iron/c.y mainly in steel products, gravel, rocks and concrete) and soil material (50 kg Iron/c.y as matrix component). The remaining 90 kg Iron/c.y were contained in consumer goods turned over by ITS and PHH (mainly in automobiles, furniture and packaging). 40 - 60 % of the entire Iron input flow are in elementary form, (e.g. construction steel) and the remaining amount is in non-elementary form.

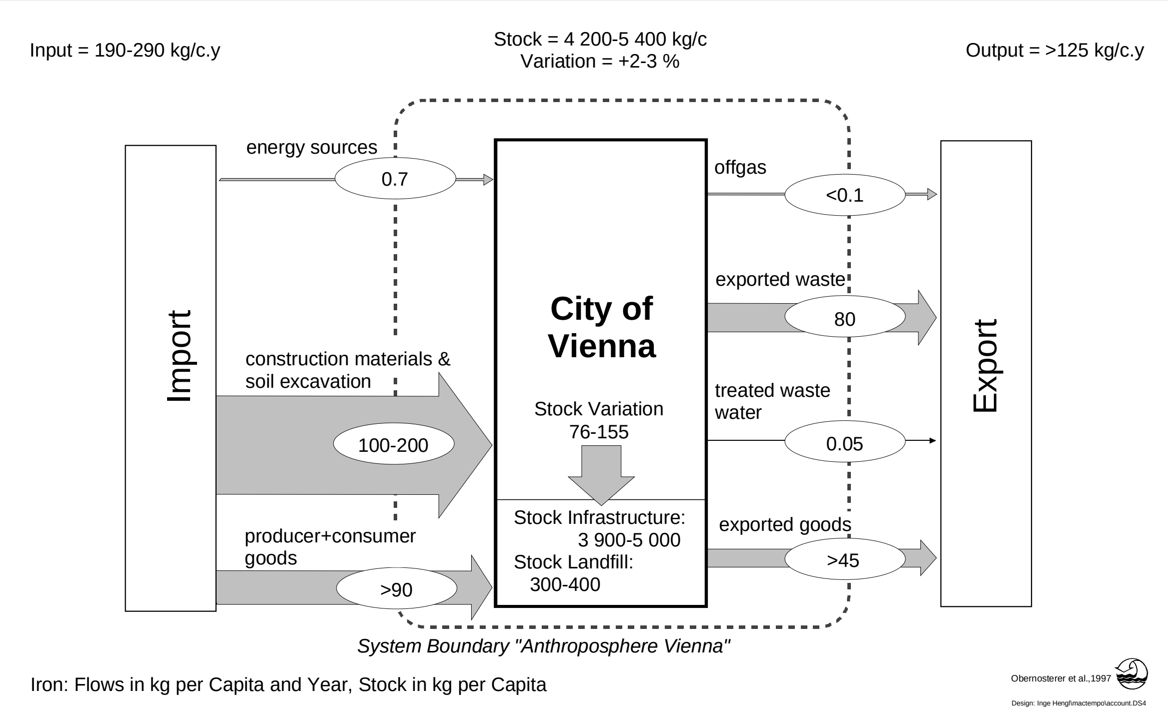


Figure 5-7: Flows [kg/c.y] and Stocks[kg/c] of Iron in the Anthroposphere of the City of Vienna in 1991

The Iron stocks within the processes ITS and PHH are quite similar, each totalling approximately 2,000 kg Iron/c, with 85 % in building materials and 15 % in consumer goods. These stocks are one order of magnitude greater than the waste management stocks in landfills, however the stock landfill is growing at a faster rate.

The total output from the buildings and infrastructure in ITS and PHH represents about 70 kg Iron/c.y. About 75 % of the Iron in solid waste are exported (as construction and demolition waste) and 25 % are landfilled within the city system (1/3 as construction and demolition waste, 2/3 as municipal waste). There is limited data available on the Iron flows in goods produced and exported by the ITS sector of Vienna.

5.2 Results of Linking the Anthropogenic and Natural Metabolism

The following chapters (0 to 5.2.4) contain the MFSA results for the system ‘anthroposphere and environment’. After a summary of the magnitude of good flows and stocks in the system the major characteristics of the single substances are highlighted.

5.2.1 Good Flows and Stocks of Linking the Anthropogenic and Natural Metabolism

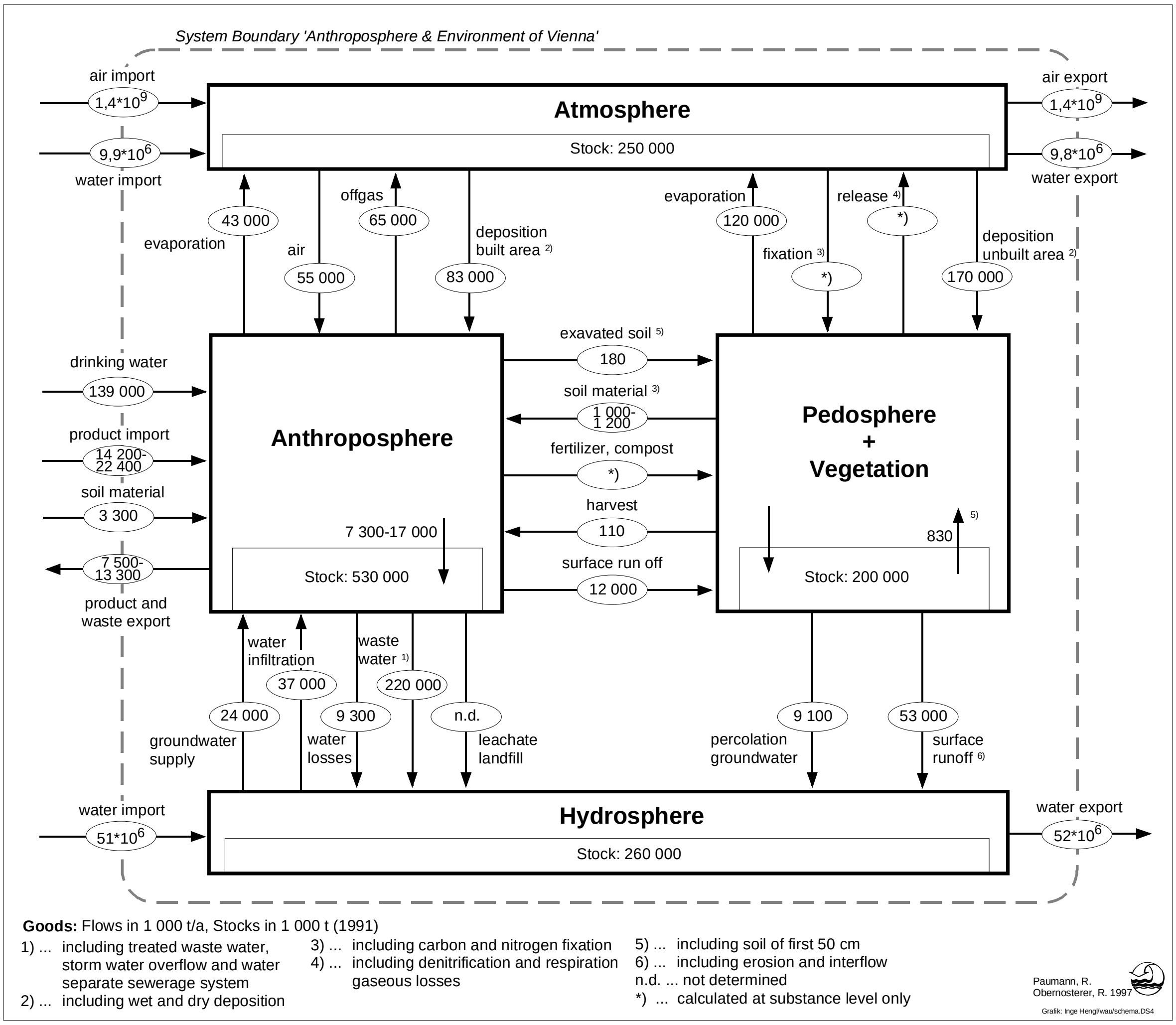


Figure 5-8: Flows [1,000 t/y] and Stocks [1,000 t] of Goods in the Environment and the Anthroposphere of the City of Vienna in 1991

The import of goods in the anthroposphere is of several orders of magnitude less then the input of air and water into the natural processes of the City of Vienna. The water import is dominated by surface water (mainly due to the Danube River), followed by imports from precipitation and saturated air within the planetary boundary layer [3]. Regarding the usage of water, 83 % of the city's water supply (including water supply of private households, industrial and agricultural use, e.g. water used for irrigation) is imported from the „Hinterland". Due to the use of groundwater in Vienna, the groundwater-level is suspected to decrease in some areas of the city [MA 45 1991]. The input to surface water from the anthroposphere is dominated by treated sewage water, including storm water overflow and water from separate sewerage system: surface run off from adjacent soil (including 'real' surface run off and 'interflow') represents 20 % of the total load to surface water.

[3] *'planetary boundary layer'* has been assumed - according to [Beer et al. 1990] - to be 500 m thick.

About 2.5 % of production and consumer goods which are required within the city stem from agricultural and forestry yields within the city. The biggest flow between anthroposphere and environment is soil material which is shifted to landfills due to construction and de-construction activities. This highlights the increase of sealed surfaces and the need to conserve „green space“ as has been previously recognised as a major challenge for the City of Vienna [MA 22 1995a].

It can be noted that biomass (i.e. forestry) increases by about 0,7 % p.y. This phenomenon has been regarded as trend all over Austria [UBA 1996]. This could imply that based on a resource perspective only, wood could be more intensely used in the future. This possibility is further discussed in chapter 6.3.

5.2.2 Carbon Flows and Stocks of Linking the Anthropogenic and Natural Metabolism

The metabolism of Carbon is dominated by discharges into the planetary boundary layer. The import of Carbon containing goods into the anthroposphere, mainly in form of energy sources, is about 2.2 % of discharging CO_2 via the atmosphere.

Focusing on air emissions: CO_2- and CO-concentrations in the air currently do not exceed established limits, which are based primarily on human health factors [UBA 1996]. However, in relation to the current Greenhouse Effect debate it should be noted that only 0.4 % of CO_2-emissions are absorbed by the biomass (due to the increase of biomass in Vienna’s forests) within the administrative boundary of the city. The estimations indicate, that based on current circumstances, an area of approximately 50 times the size of Vienna would be necessary for a long term fixation of Viennese CO_2-emissions. In order to achieve the goal of sustainability and resource-efficiency, the magnitude of Carbon flows emitted into the environment must be reduced in the City of Vienna. This goal can best be reached firstly, if less energy is used and secondly if fossil fuels are replaced by renewable energy sources. The different measures which can be taken to reduce CO_2 production are given for instance in the annual report of the Austrian CO_2 Commission [Akademie fur Umwelt und Energie 1995] or in the Vienna regional energy-management-programme KLIP [MA 22 1997].

The quantity of Carbon in treated waste water (including storm water overflow and water from separate sewerage system) is in the magnitude of 20,600 t/y. The concentration of dissolved organic Carbon (DOC) in the Danube is in the range of 2.5 to 5.5 mg/l and in the same magnitude as the existing environmental standard for this parameter of 5.5 mg/l [BMLF 1995]. The average DOC-concentration of the groundwater is 1.7 mg/l [BMLF 1995].

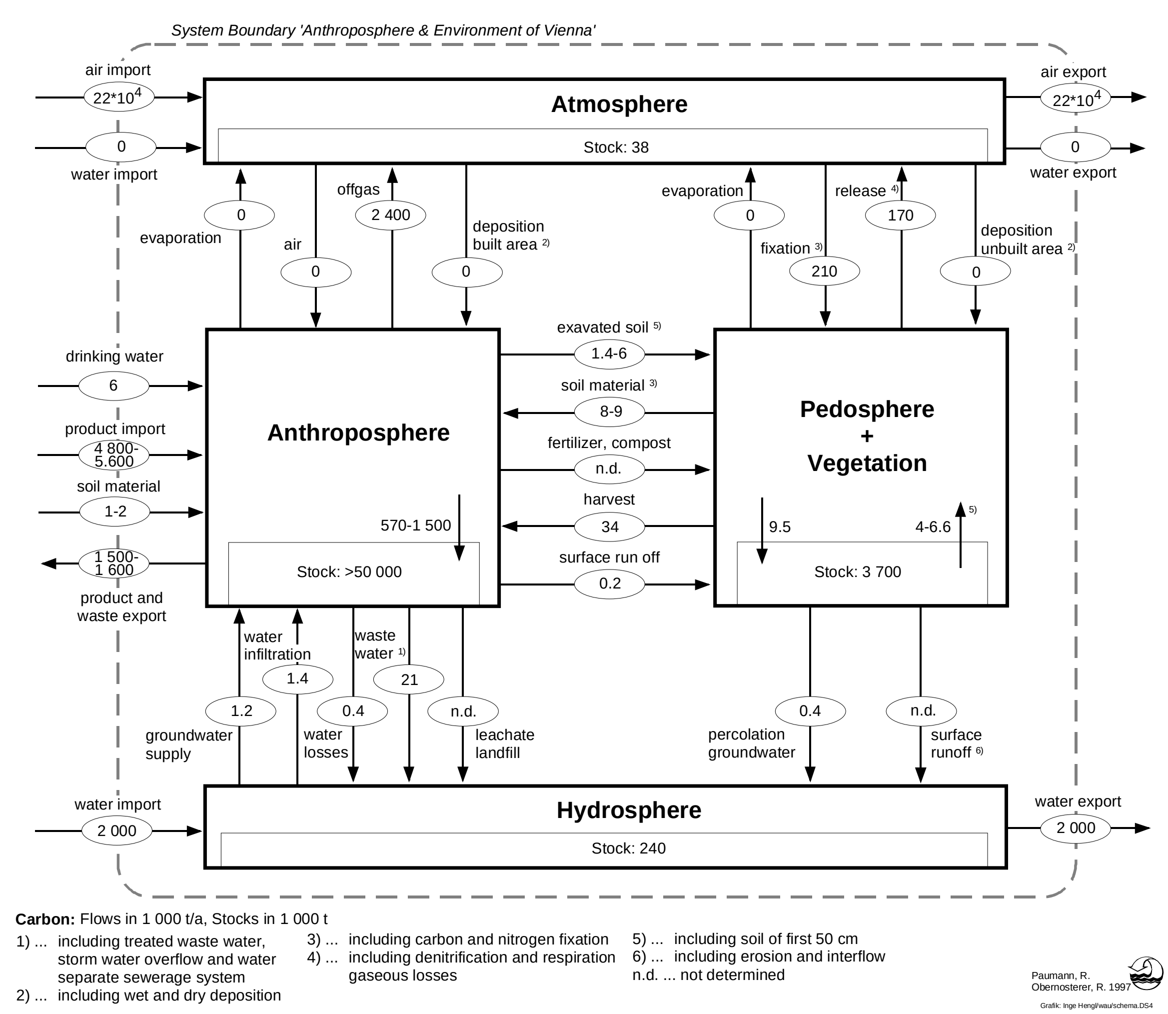


Figure 5-9: Flows[1,000 t/y] and Stocks [1,000 t] of Carbon in the Environment and the Anthroposphere of the City of Vienna in 1991

5.2.3 Nitrogen Flows and Stocks of Linking the Anthropogenic and Natural Metabolism

As for Carbon, the major conveyor belt for Nitrogen is air. The import of Nitrogen containing goods to the anthroposphere, which is dominated by production and consumer goods is only around a small fraction of the Nitrogen throughput of the atmosphere.

Nitrogen Emissions to air (mostly NO_x, NO, primarily from traffic emissions) are in the same order of magnitude as emissions to surface water. The so called maximum-daily-average-value of 100 µg NO_2/m^3 has been exceeded in Vienna several times during the year mostly in summer [UBA 1996]. The wet and dry deposition of Nitrogen to Vienna's forests and to soil, which occurs in various forms (e.g. NO_2-N, NH_4-N, etc.) [Puxbaum & Rosenberg 1989] is about 4 times higher than the deposition in „non-urban“ areas [Paumann 1997]. As a result of this and also as a result of high Nitrogen input to soil via fertiliser; surface run-off, percolation to surface water and to ground water (primarily as NO_3), and gaseous emissions (e.g. as N_2O-N) are all higher than in natural ecosystems.

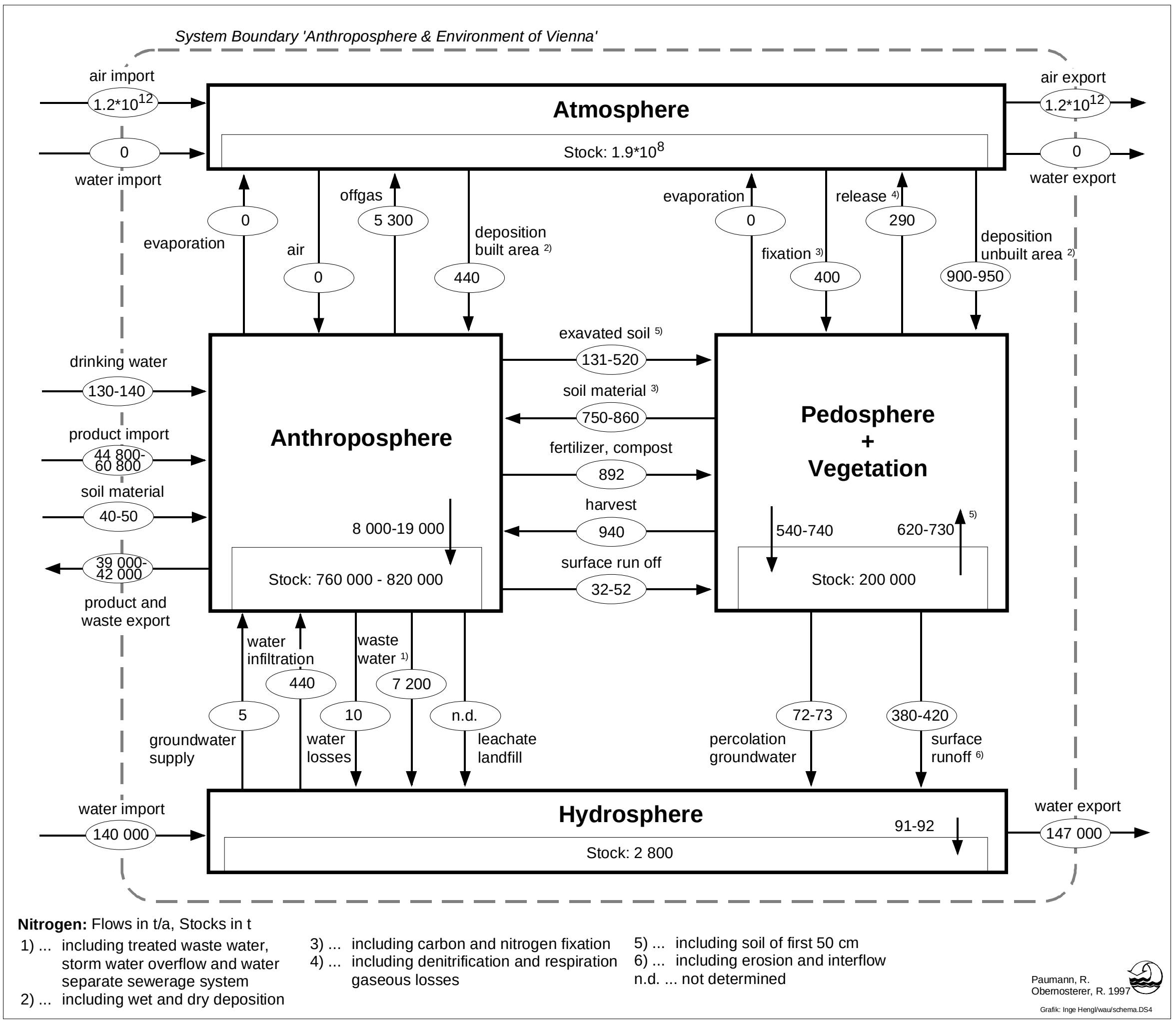


Figure 5-10: Flows [t/y] and Stocks[t] of Nitrogen in the Environment and the Anthroposphere of the City of Vienna in 1991

The Nitrogen output from the anthroposphere to the hydrosphere is dominated by treated waste water (including storm water overflow and water from separate sewerage systems). Measured concentrations of Nitrogen are about 3.2 mg N/l and do not exceed the existing environmental standard of 6.5 mg N/l (sum of NH_4-N, NO_3-N and NO_2-N) in sampling points in the Danube located within and downstream of the city [BMLF 1995].

The situation in Vienna's groundwater is somewhat contrary. There are significantly high Nitrogen loads percolating through the soil and the retention rates of the receiving groundwater bodies are low. The environmental standard for Nitrate (NO_3) is exceeded in numerous sampling points (see chapter 6.1) and is increasing at a rate of approximately 3 %/y. An issue which remains open (which could not be solved during discussion with local experts) is whether denitrifation processes take place in Vienna's groundwater bodies, and if so to what extent.

5.2.4 Metals Flows and Stocks of Linking the Anthropogenic and Natural Metabolism

The interaction of the metals in the City of Vienna with the environment are similar for all investigated metals. The following section outlines general results. Furthermore, the link between the Lead metabolism of the anthroposphere and the Lead metabolism of the environment is discussed more in detail. The results of the substances Aluminium, Zinc and Iron are provided in the Appendix 12.7.

General Results

Measured concentrations of Lead, Aluminium, Zinc and Iron in the atmosphere, surface water and groundwater are mostly within established environmental standards (where they existing). For instance the environmental standard for Lead in air (2 µg/m^3) and water (50 µg/l) is around a factor 10 higher than measured values in air (157 ng/m^3 [MA 22 1991]), in surface water (1.7 µg/l [Fleckseder 1986]) and groundwater (<1 - 6 µg/l [BMLF 1995]). In contrast to that, Lead concentrations in soil in some areas are exceeding the environmental standard of 100 mg/kg [MA 22 1991]. However, the detected continuous increase of substance concentration in environmental media indicates that environmental assessment should consider not only concentration limits but total loadings and final sinks, especially in relation to long-term environmental effects.

There is little information available for the Aluminium and Iron in urban environmental compartments as compared with Carbon, Nitrogen and heavy metals. No monitoring data is available for the concentrations of Iron and Aluminium in the soil.

Lead Metabolism - linking the anthroposphere and environment

In contrast to Carbon and Nitrogen, anthropogenic Lead flows and stocks exceed the natural flows by several magnitudes. The Lead throughput in the surface water and in the atmosphere amounts to approximately 0.3 % of the anthropogenic input of Lead. The Lead stock in the anthroposphere is about 30 times higher than the Lead stock in soil and in the vegetation of Vienna. The Lead stock in the atmosphere and in the hydrosphere together amounts to only a small fraction of the total anthropogenic stock.

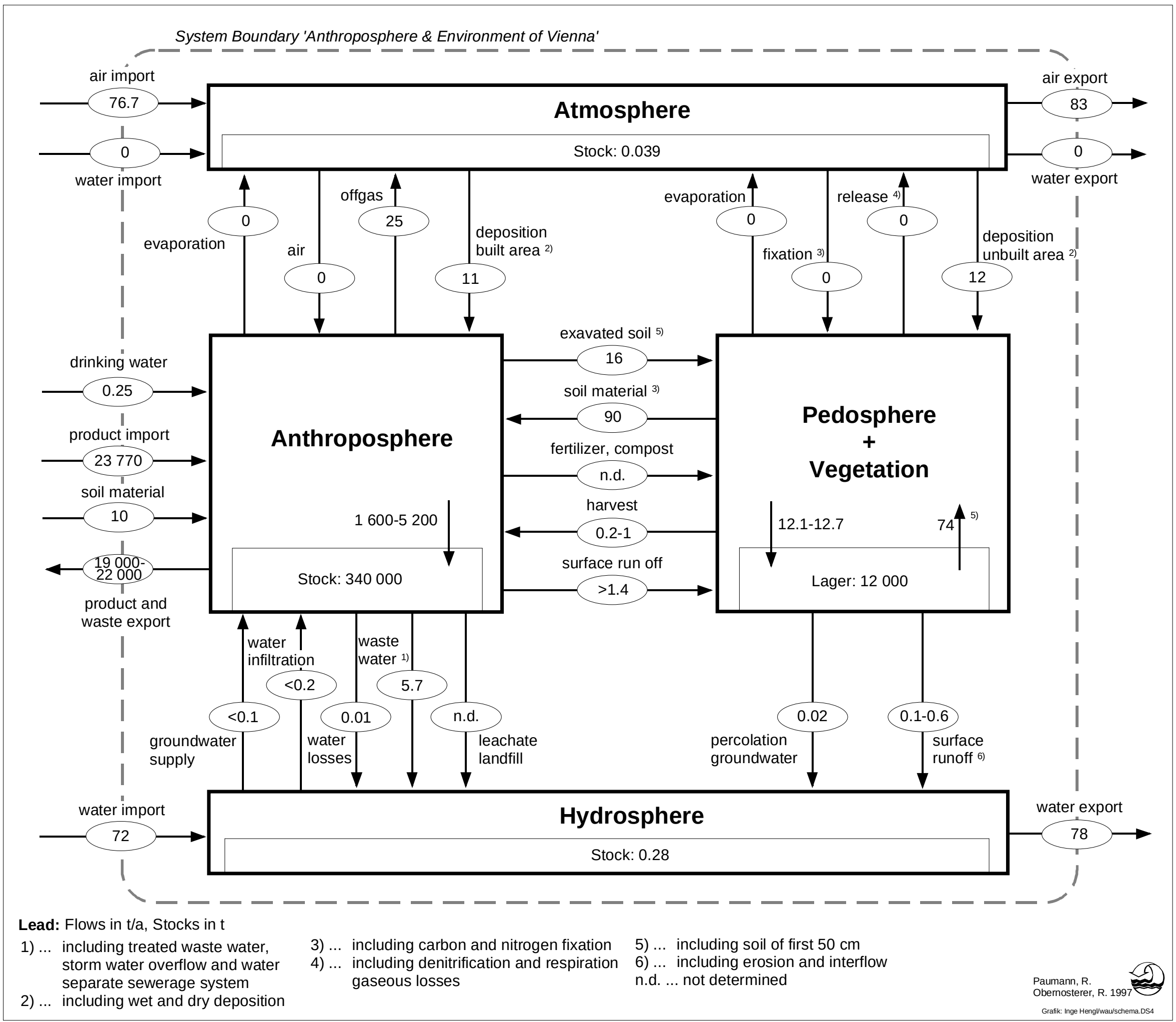


Figure 5-11: Flows [t/y] and Stocks [t] of Lead in the Environment and the Anthroposphere of the City of Vienna in 1991

5.3 Results of Linking the Metabolism of the City of Vienna with its „Hinterland“

5.3.1 Hinterland Carbon Flows related to the Activity „to Transport“

The Carbon „Hinterland“ study attempted to clarify the relationship between the City of Vienna and its surrounding region by focusing on the use of transport fuels transferred from inside and outside the City of Vienna.

The calculated output flow of Carbon from the City of Vienna amounts to almost 4,000,000 tons (2,600 kg/c.y) (see Figure 5-2). Approximately 2,600,000 t (1,700 kg/c.y) of this portion relates to energy sources which today are primarily fossil fuels. The fossil fuels are used in Vienna for heating and transport activities. Referring to Figure 5-12 the flows that are generated by non-Viennese within the city are related to IEEP (Internally Effective External Process), and those flows which are induced by Viennese outside the city are generated by EEIP (External Effective Internal Process). This means that the portion of fuels used outside the administrative boundary of Vienna for transport activities[4] by Viennese is also included in the calculation.

The results indicates that transport fuels used outside the system boundary of Vienna from ITS (210,000 t/a) and PHH (350,000 t/a) represent approximately 20 % of the total Carbon output from energy sources (2.6 mil. t/y). Taking only transport activities under consideration, more than 60 % of the total Carbon emissions are emitted into the atmosphere in the „Hinterland“ due to the Viennese. Since this amount is relatively large, it is important to verify these assumptions with more detailed calculations. Although it is clear that land use and transportation planning must consider surrounding regions. The „Hinterland“ must be taken into account, for example, when effective measures to reduce CO_2 emissions by new public transportation systems are to determined. Such an approach would be most effective when done in co-operation with surrounding communities.

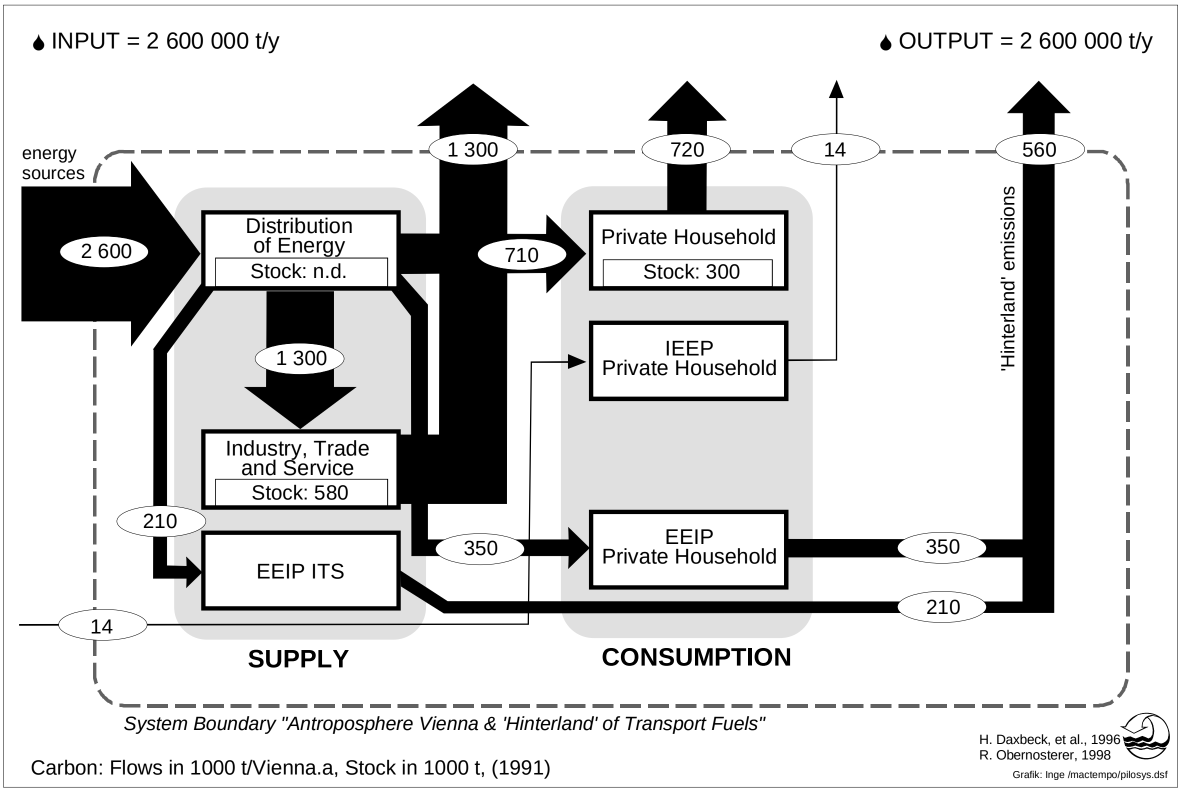


Figure 5-12: Flows [1,000 t/y] and Stocks [1,000 t] of Carbon in Energy Sources in the Anthroposphere and the „Hinterland“ of the City of Vienna in 1991 (EEIP - external effective internal process, IEEP - internally effective external process)

[4] excluding those Carbon flows which are induced by air-traffic, secondary living places, industrial sector etc.

5.3.2 Lead Flows within the Cities Boundaries and the „Hinterland“ by the Use of Car Batteries of Vienna’s Inhabitants

The use of car batteries within Vienna leads to significant Lead emissions in the „Hinterland“. This is because the processes of Lead mining, primary Lead processing, battery production and recycling industry takes place outside the City of Vienna. During the use of car batteries within the City of Vienna only minimal Lead emissions occur in relation to the whole system under consideration. This section describes the results of a study [Smutny 1998] into Lead flows which are induced by the demand of the Viennese by the use of car-batteries.

Table 5-1: Emissions into the environment by the use of car batteries in Vienna [Smutny 1998].

emissions t/y	within Vienna’s administrative boundaries*	in the „Hinterland“ of Vienna
atmosphere	≈0	0.3 - 3.6
hydrosphere	0 - 0.03	0.01 - 2

*if all car batteries were disposed off in Vienna

The data indicates, that today’s use of car batteries within Vienna results in significant Lead emissions in the „Hinterland“. During battery recycling and production of Vienna’s car batteries 0.3 - 3.6 t/y were released into the atmosphere and 0.01 - 2 t/y were emitted into the hydrosphere in the „Hinterland“. The variation is due to the different levels of technology used in the mining and processing of Lead.

Comparing different management scenarios for car batteries in Vienna, (based on [Smutny 1998], some results are given in Appendix H, chapter 12.8.3) the following results can be highlighted. The compared management scenarios are linear (no recycling), cyclic (100 % recycling rate) and current use of car batteries in Vienna.

- After comparing the best and worst technology case scenarios it can be seen that the technology strongly influences Lead emissions in the mining, producing and recycling industry.
- Comparing best or worst case technology scenarios separately, cyclic use of car batteries releases fewer emissions to the environment than the linear usage. E.g. in the best case scenarios the cyclic use results in 40 % less Lead emissions into the atmosphere and 70 % less Lead emissions into the hydrosphere, than the best case linear throughput of car batteries through Vienna.
- Using the best available technologies for the linear use, smaller Lead emissions will be released into the atmosphere and hydrosphere than in the worst case technology scenario of the cyclic use. However, when looking at the amounts going to landfill in this comparison, cyclic use over linear use is preferred.
- The current use of car batteries in Vienna leads to atmospheric emissions which are higher than both the best case linear as well as the best case cyclic use scenario. This indicates, that there is a potential to decrease the Vienna induced „Hinterland“ Lead emissions into the atmosphere.

5.3.3 Viennese induced Nitrogen Flows into the Danube River within Vienna and the „Hinterland“

After comparing Vienna’s Nitrogen flows with those induced in the „Hinterland“ one can see the interdependence which exists between these two „regions“ (calculation given in Appendix H, chapter 12.8.2).

- The input flow of Vienna into the Danube in the „Hinterland“ is approximately 15 kt N/y (10 kg/c.y) and from the city itself 7 kt N/y (5 kg/c.y).
- the main activities involved in Nitrogen flows are „to nourish“ and „to transport“.

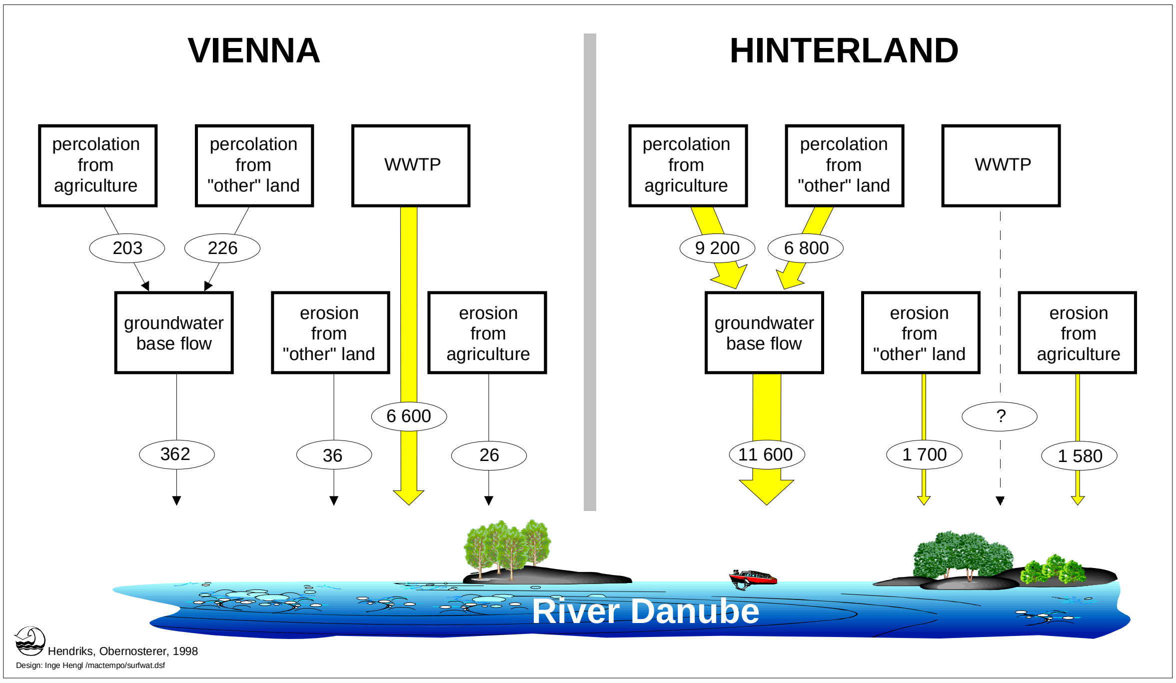


Figure 5-13: Viennese induced Nitrogen Flows into the Danube River within Vienna and the „Hinterland“ [in t/y](WWTP: Waste Water Treatment Plant).

5.4 Comparing Viennese Results with other MAcTEmPo Teams

A comparison between the Viennese Results and the results from the other MAcTEmPo project teams (see Brunner et al. 1998) is useful both from a methodological and „results“ point of view. By comparing the different case studies (in particular the Vienna case study with Baccini et al. (1998) and Lohm et al. (1998)) some results can be confirmed, and any shortcomings or failures can be detected.

- The Carbon input from energy sources in the Swiss Lowlands is approximately 2.0 t/c.y and in Vienna approximately 1.7 t/c.y. In the Swiss Lowlands, Carbon is released within the system, whilst for Vienna approximately 0.4 t/c.y are released in the „Hinterland“.
- The flows and stocks of gravel and sand consumption in Vienna and in Swiss Lowland are remarkably similar (see Table 5-2).

Table 5-2: Comparison of flows and stocks of gravel and sand of Vienna with Swiss Lowland.

Flows and Stocks	**Vienna** [Daxbeck et al. 1996]	**Swiss Lowlands** [Baccini et al. 1998]
construction material input (t/c.y)	5-10	8
construction material stock (t/c)	350	340
demolition waste (t/c.y)	1.6	3

- The flow of surface water through the KSM-system (region in the Swiss Lowlands) is approximately 100,000 t/c.y, mainly due to the River Aare; whilst in Vienna it is approximately 33,000 t/c.y mainly due to the River Danube. This highlights the different dilution potential of the two regions per capita.
- The Stock of Zinc in Stockholm was calculated to be 40 kg/c whilst in Vienna the Zinc stocks are up to 100 kg/c. However, other MFSA Zinc studies [Daxbeck et al. 1997; Baccini & Bader 1996] indicate that Zinc stocks are in the order of 300 kg/c. At this point in time it is unclear if the differences are related to methodological issues or if there are indeed large differences in Zinc stocks between different regions.
- A comparison between Vienna and Stockholm reveals that the Lead stocks in both cities are quite similar (65 kg/c in Stockholm, 100 - 200 kg /c in Vienna). There are however, some differences in the amount of Lead cable stocks which could be related to different settlement densities [see Obernosterer et al. 1998b and Möslinger 1998]. These differences could also be attributed to the fact that in Stockholm there has been no input of Lead cables since 1970.

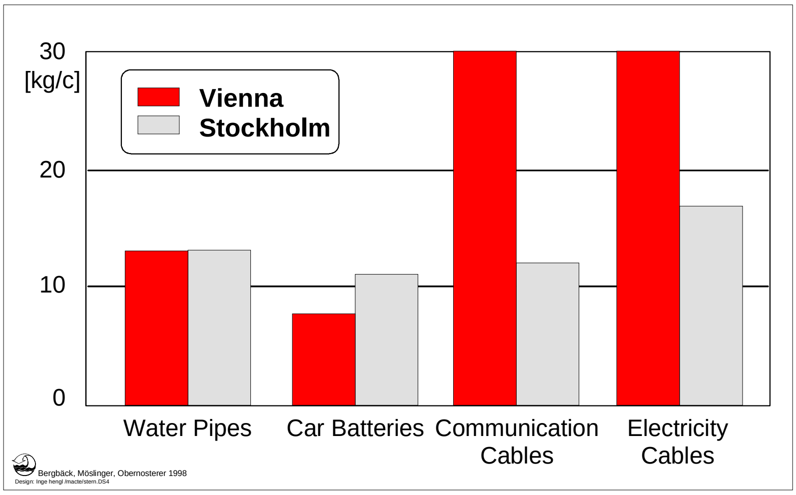


Figure 5-14: Comparison of Lead Stocks in Vienna and Stockholm for four different applications (kg Lead / c) [Lohm et al. 1998, Möslinger 1998].

6 Linkage of MFSA to Environmental and Resource Policy Decisions

Studies on Material Flow and Stock Analysis (MFSA) have generally focused on the methodological and data issues of understanding material flows within a region or within other boundaries. Some steps have been made to introduce MFSA into the policy world by highlighting gaps or failures in existing policies. MFSA has also been used to make recommendations for future policy directions. Further steps must now be taken to integrate the social, technical and economic sciences in order to determine the most efficient material management scenarios. The MAcTEmPo project is one such bridging step, identifying the possible links between the technical MFSA world and its implementation into the policy world.

What follows is a description of the key policy uses of MFSA from a material management point of view. Several examples are used to highlight the applicability of MFSA in the policy world. The examples do not necessarily represent recommendations in themselves. The first ideas of how MFSA could be implemented into the „real world" are introduced at the end of this chapter.

6.1 MFSA for Early Recognition

MFSA allows for a precautionary approach since it can anticipate future environmental problems and does not rely on signals of „environmental" stress. MFSA focuses on forecasting material flows and stocks and can be used to detect whether stocks are increasing or decreasing. MFSA, therefore, provides a strong basis for early recognition since it can identify future environmental problems or resource potentials. The following examples highlight how MFSA results can be used for early recognition purposes. The first example shows how MFSA can be used to forecast the increasing of substances in environmental stocks. The second example discusses the importance of managing buildings and infrastructure stock for future generations.

Early recognition of environmental problems

MFSA can identify future environmental problems by highlighting changes in the stock of substances in different environmental mediums (calculation see chapter 12.8.4). For example:

- Today the average Lead content in Vienna's top soil is approximately 60 ppm (measurements between 20 to 700 ppm). If the current Lead inputs remain constant, then the recommended allowable average level of 100 ppm Lead [Eikmann & Kloke 1993] in the topsoil (10cm) will be exceeded in the next 250 years.
- Currently, the average Nitrogen (NO_3) content in Vienna's upper groundwater layer is approximately 54 mg NO_3/l which exceeds the Austrian standard of 50 mg NO_3/l. If the current Nitrogen input into the groundwater remains constant, then the NO_3 concentration in 10 years will be approximately 70 mgNO_3/l and in 100 years 220 mg NO_3/l.

Early recognition of stocks

About 90 % of city's metal stock is located in Vienna's buildings and infrastructure, whilst only 10 % is in the landfills. Current environmental policy controls concentrate heavily on landfill stock emissions.

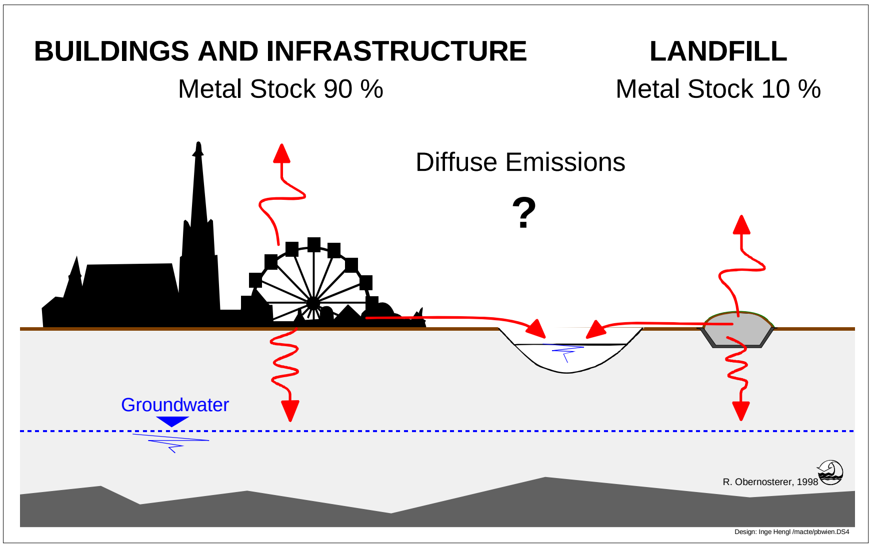


Figure 6-1: Metal stocks and their potential diffuse emission pathways in Vienna.

Further studies are required to identify which specific stocks contribute to environmental problems and/or those which represent potential resources. Some examples of evaluating stocks includes:

- the anthropogenic organic Carbon stock represents a potential environmental problem when disposed of in a landfill (e.g. where biochemical reactions release greenhouse gases such as CH_4 and CO_2) or a potential future energy source when incinerated before landfilling.
- the metal stock within the city represent a potential source of diffuse emissions. On the other hand these stocks represents a potential future resource, as discussed in the next section. The sources of diffuse emissions within urban regions are explored in greater detail in the Swedish MAcTEmPo Case Study [Lohm et al. 1998].

MFSA can be used for early recognition since it can identify stocks and their changes in both the anthroposphere and in the environment. This information can be used to discuss the potential of a stock as a future environmental risk or as resource.

6.2 MFSA for Efficient Resource Management

The identification of key flows and stocks using MFSA can serve as a base for efficient resource management strategies. Two examples are presented: the first presents the idea of stock-management strategies, and the second example discusses the efficient use of materials for urban expansion.

Possible management strategies for Lead stocks

The buildings and infrastructure stock of materials will require management in the future. Consider the possible resource management strategies of the stock of Lead water pipes in Vienna's buildings (amounting to a total of approximately 20,000 tons):

- *Re-use of stock*; City Mining of this Lead stock could provide enough Lead coated telecommunication cables for Vienna for approximately 30 years (assuming the demand for Lead cables remains constant) or enough Lead to produce approximately 1,600,000 traditional car batteries.
- *Disposal of stock;* For non-reusable materials, possibilities to achieve final storage quality must be found. If a Lead stock has a re-use potential, but no market for recycling today, a controlled disposal strategy in view of future use should be adopted.

Urban planing and resource management

In the MAcTEmPo project, the Lead stock in Vienna's buildings and infrastructure was identified as having a large potential for future city mining strategies. An investigation was conducted to further explore this issue focusing particularly on the quantity of Lead stocks in Vienna's pipes and cables [Möslinger 1998]. The results of this study indicate that there is a strong correlation between Lead stocks in the city and settlement density as shown in Figure 6-2. In very high density areas of Vienna (which is comprised of older regions) the stock is lower than that in the newer, less densely populated regions (primarily single family settlements). In the newer regions, Lead is primarily located in energy and tele-communication cables, whilst in the older regions there is also additional Lead in water pipes.

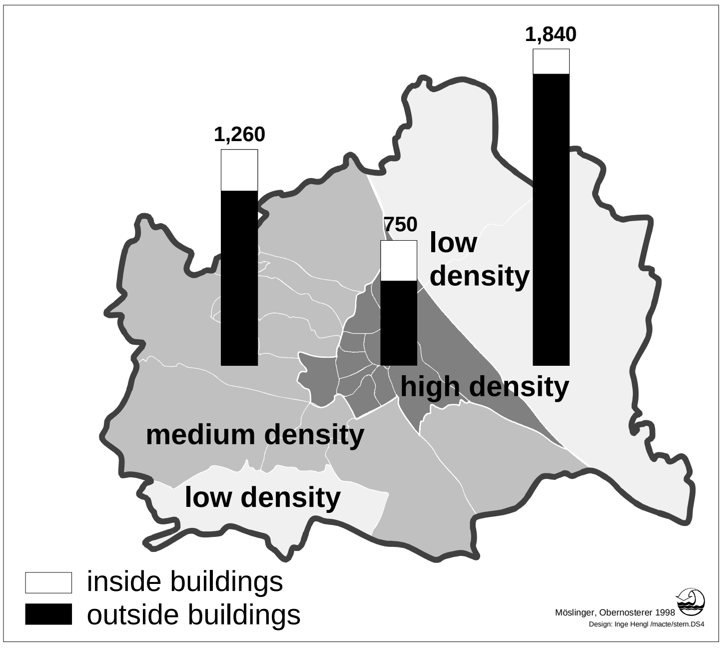


Figure 6-2: Infrastructure Density and Lead Stocks in Vienna in kg Lead per 1,000m² floorspace [Möslinger 1998]

Urban planing, therefore can have a significant impact on resource management particularly in controlling input flows. Planing high density regions will lead to a significantly lower per capita good and substance input than planing less densely populated regions (see also Obernosterer et al. 1998b).

MFSA can be used for planing efficient material management strategies. It provides a basis for designing and optimising material flows and stocks. Furthermore, the resource potential of the current buildings and infrastructure stock for future use can be detected.

6.3 MFSA for Priority Setting in Environmental Policy

MFSA is a useful tool for priority setting since it allows management strategies to concentrate on key issues and examine the effects of various material management strategies on the entire system. In the following two examples, the use of MFSA for priority setting is discussed in relation to the management of Nitrogen and as a platform for discussing strategies for reducing Carbon emissions.

Nitrogen metabolism- identifying key-flows to set priorities

If the increasing eutrophication of the Danube Delta and the Black Sea is to be prevented, measures must be taken to reduce the Nitrogen loads. Since the city is not an independent system, the current largest Nitrogen flows induced by the city activities, flow outside Vienna's administrative boundary into the Danube river. In detail, the current input flow into the Danube in the „Hinterland“ of Vienna is approximately 10 kg/c.y and in the city itself 5 kg/c.y.

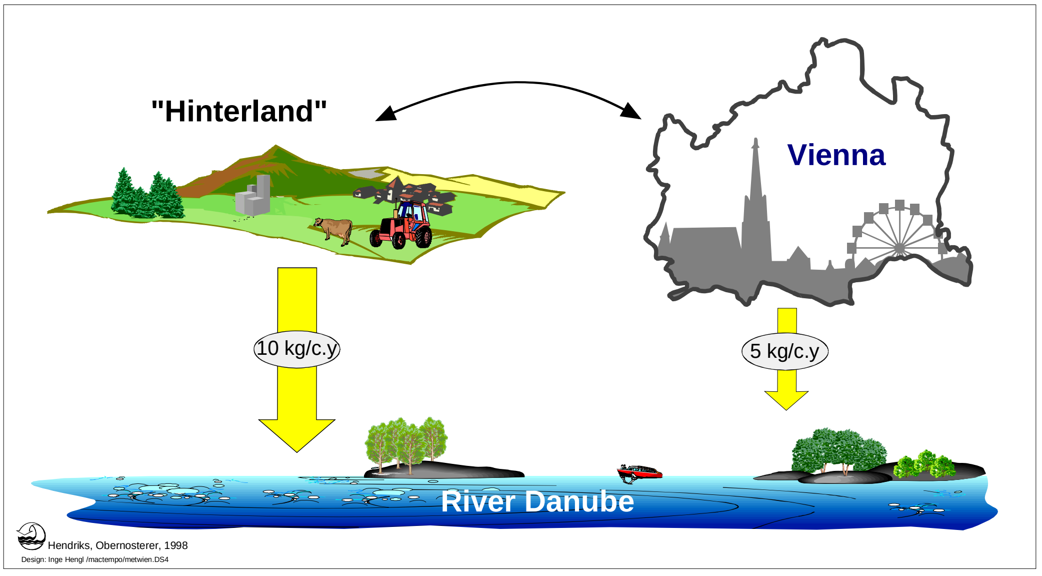


Figure 6-3: Nitrogen flows in kg/c.y induced by the Metabolism of the City of Vienna into the Danube River within the City and the „Hinterland“

In this case it is obvious that setting priorities to further reduce Nitrogen flows must also take into consideration the „Hinterland“. The results also highlight that the major Nitrogen flows are related to not so much a point source problem but rather a result of diffuse sources (agriculture land etc.). From a policy perspective such flows are less controllable, requiring more broad scale approaches rather than end of pipe solutions. In principal the most appropriate policy measures could be made within the city, outside the city or a combination of both. This may also involve changes in social behaviour and patterns of production; with social and economic dimensions. For example, a change in agricultural practices (improved nutrient management) or changes in dietary habits away from heavily meat based protein diets which currently produce large Nitrogen input and outputs.

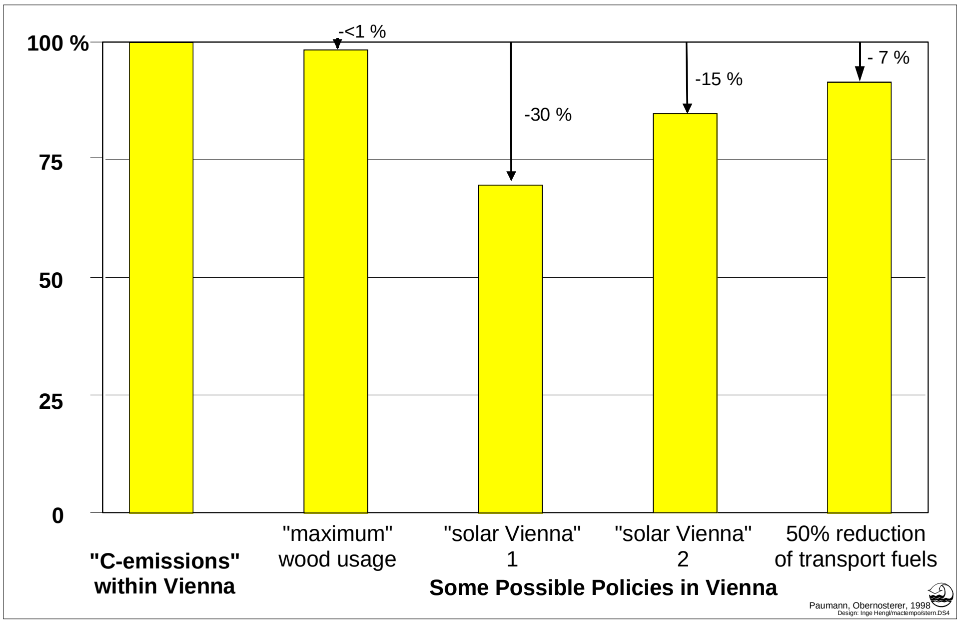
The human Nitrogen demand is difficult to change since it is primarily related to the activity „to nourish“. Eventually it can be lowered by around 40 %, to approximately 6 g Nitrogen per capita and day (or 2.2 kg N per capita per year), through protein-conscious nutrition of the population. Changes in eating habits can only be influenced individually by public information, awareness or indirect solution.

A further possibility toward reduction of the current Nitrogen load is the removal of Nitrogen in the sewage treatment plant; a classic end-of-pipe technology solution within the City of Vienna. At present, a denitrification step is being constructed at the central Vienna sewage treatment plant. At a planned Nitrogen elimination capacity of 80 %, the Nitrogen contribution into the receiving water body would be reduced to about 2 kg N/c.y. This end-of-pipe solutions is well suited to decrease the Nitrogen impact to the river Danube from the point source „Administrative City of Vienna“. However, as mentioned above this policy does not change the main Nitrogen impact into the river Danube of the City of Vienna in the „Hinterland“.

The important „Hinterland“ flows stems from agriculture processes. Significant flows to the surface waters also result from runoff or percolation from forested or non-agricultural lands. This is linked to atmospheric deposition of Nitrogen. Studies in Germany [Flaig & Mohr 1996] on the sources of atmospheric Nitrogen deposition (above the geogenic flows) indicate that it is sourced from primarily two anthropogenic activities - 50% from agricultural activities and 50% from combustion activities. There is a complex interaction between the atmosphere, pedosphere and hydrosphere. This interaction requires policy measures which adopt an integrative approach, focusing not only on single mediums solutions or on point sources but on the interactions between different environmental mediums and the link to the anthroposphere.

Carbon metabolism - running scenarios of various management strategies in order to set priorities

In view of the „Greenhouse Effect“ a key question is, how can the Carbon flows into the atmosphere be reduced? There are a number of possible management strategies available to address this issue. MFSA provides a base to identify the potential success of each strategy in relation to substance reduction in the entire system. Based on the outcomes of different scenarios the most effective mix of materials management approaches can be found.



Current situation (1991): Carbon emissions from activities within Vienna's administrative boundary into the atmosphere = 100%.
Maximum Wood usage: optimisation of the use of available wood resources within Vienna's administrative boundary.
Solar Vienna 1: use of photo-voltaic cells (60-150 kWh/m2 /a) on an area equal to 100% of Vienna's roofs.
Solar Vienna 2: use of photo-voltaic cells on an area of 50% of Vienna's roofs.
50% reduction of transport fuels: ~ halve the use of transport fuels within the city's administrative boundary.

Figure 6-4: The effect of some of the range of policy measures which could be taken to address Carbon emissions within Vienna

Within the four different scenarios presented in Figure 6-4, it is obvious that in view of reducing greenhouse gases, greater priority should be given to encouraging solar energy strategies than to maximising the use of Vienna's wood resources. This example is used to highlight the potential of MFSA as a tool for identifying priorities and does not present all the possible management strategies for reducing Carbon flows in Vienna (such as the possibility of mixing various strategies).

In order to set priorities for environmental policy, a thorough understanding of the anthroposphere (the key flows, processes, and stocks) and it's links with the environment is essential. MFSA provides this holistic view of the system and therefore allows one to set priorities on the possible policy measures, ensuring efficient management strategies. Furthermore, MFSA requires a link to economic tools in order for policy makers to set priorities in material management.

6.4 MFSA to Analyse/Improve the Effectiveness of Policy Measures

Current environmental measures tend to focus on single issues with little consideration of the total system. In many cases this approach can be highly in-efficient since it may only be addressing a small portion of the total flows and stocks. The following two examples illustrate how MFSA can be used to evaluate the response of the total system (flows and stocks) in relation to various policy measures.

Effectiveness of existing CFC management policy

This CFC-example does not focus on just the City of Vienna but rather on the whole of Austria. This study highlights the possibility of using MFSA for evaluating policy measurements. Austria, like many other industrialised countries, regulates the use of chlorinated and fluorinated hydrocarbons in consumer products and in other goods in order to protect the stratospheric ozone layer. A MFSA on CFCs was conducted for Austria [Obernosterer & Brunner 1997] to evaluate the effectiveness of current reduction policies. The current front end regulations, which prevent the use of CFCs, have resulted in a decrease of CFC emissions in the short term. However, the medium to long term emissions from CFC stocks are not efficiently controlled since the current regulations on stocks concentrate on CFCs in refrigerators only. The MFSA results reveal that there is a significantly large stock of CFCs in construction materials (see Figure 6-5). The future emissions from these stocks will be much more significant than from refrigerator stocks. MFSA indicates that to improve current CFC strategies, future management of CFCs must take into account all stocks, including their changes and emissions. The management of CFC is further discussed in the Dutch (CML) MAcTEmPo case study [Voet et al. 1998] and further exchange of ideas and data between IWAG and CML is planed following the MAcTEmPo project.

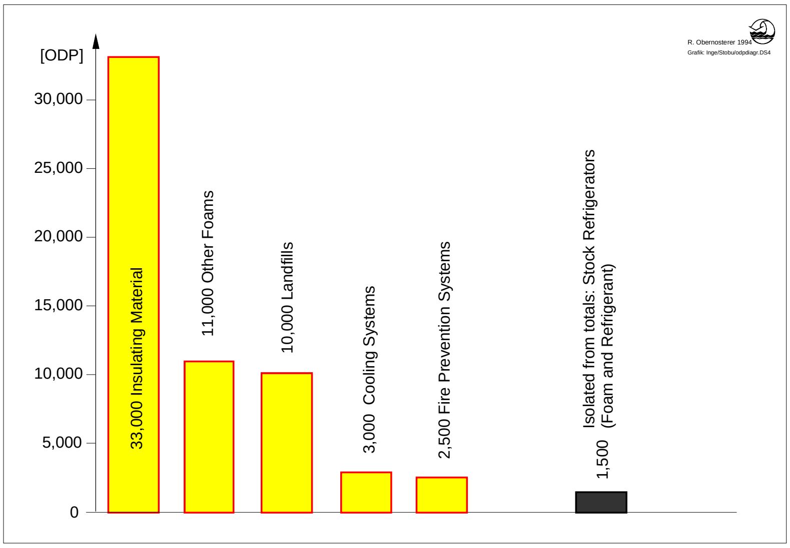


Figure 6-5: Comparison of CFC-stocks for Austria (in ODP units , accumulated until 1993) [Obernosterer & Brunner 1997]

Assessment of the Austrian construction waste recycling legislation

According to the Austrian construction waste regulation, construction and demolition waste must be separated in view of re-use. The MFSA results for the City of Vienna (calculation and further details are given in chapter 12.8.1) provide a basis for discussion of the effect of recycling policy on the current bulk flows in the construction sector. Using today’s demolition techniques such a policy could, when fully implemented, reduce the amount of construction waste flows (not including excavated soil) going to landfill by 45%[5]. The recycling potential of construction waste could only reduce the current use of virgin materials of gravel and sand by 7%. Therefore a cyclic use versus a linear use of gravel and sand has a minor influence on gravel and sand resource depletion (see Figure 6-6). In order to further reduce the use of virgin materials, alternative construction and planning approaches should be adopted such as focusing on higher density settlements. In contrast to Vienna, a project on the City of Zürich highlights that the recycling potential of construction waste could theoretically reduce the current use of virgin materials of gravel and sand use for buildings by 50% (see EAWAG Case Study in Brunner et. al 1998). Such a difference highlights the importance of developing regionally adapted policy strategies.

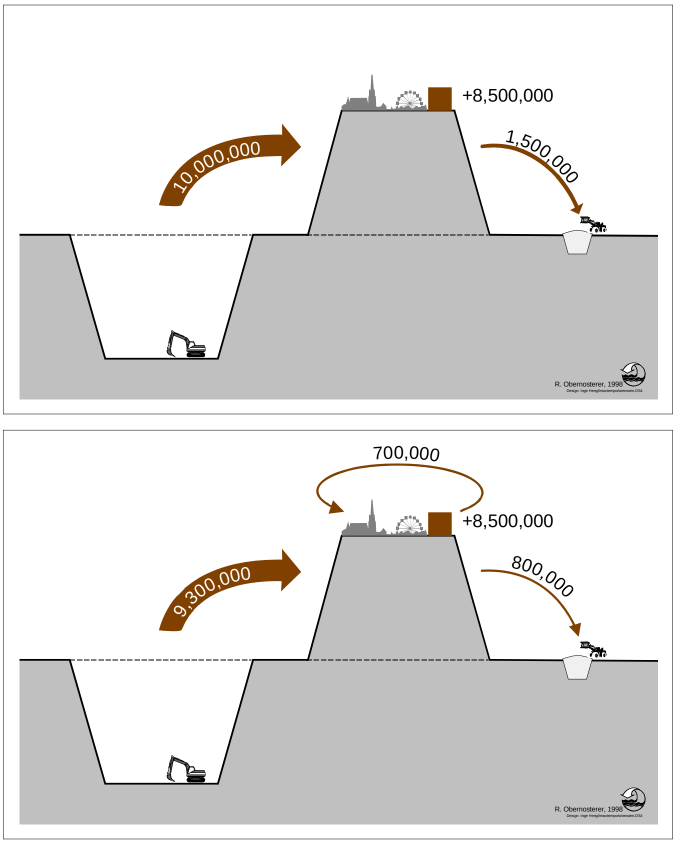


Figure 6-6: Comparison of linear and cyclic use of gravel and sand for construction activities in Vienna in t/year ([6]).

MFSA can provide a basis for assessing the impact of a particular policy on the total system. It can be used to assess the effectiveness of existing and future policy measures and as a basis for designing improvements.

[5] When excavated soil wastes are included into this calculation, the construction waste flows to landfill can be decreased by only 10%.

[6] including a size comparison of the mine hole, the city stock and the landfill stock of gravel and sand.

6.5 Evaluation Criteria for MFSA

The ultimate objective of materials management is to 1) analyse, 2) evaluate and 3) control material flows and stocks in view of certain goals such as sustainable development. The case study of the City of Vienna deals mainly with step 1. Based on the results of the analysis of the metabolism of Vienna some potential uses for environmental and resource policy is discussed. The evaluation of material flows and stocks with additional methodologies, such as Environmental Impact Assessment or Risk Assessment was not included as part of this project. However, the potential to link MFSA with other approaches seem to be very high and should be investigated in future.

The strategy for evaluation in this report was to compare anthropogenic flows and stocks with current „natural“ environmental conditions (e.g. as done in chapter 5.2). Another approach used was to compare the anthropogenic flows and „geogenic“ conditions (i.e. prior to settlement conditions). Such a comparison could indicate the „gap“ between today’s metabolism in relation to a geogenic metabolism of Vienna.

In order to reach this geogenic reference level, it is necessary to understand the metabolism of Vienna prior to anthropogenic impact. A potential environmental problem might be highlighted when a city’s substance flows varies significantly from its geogenic reference levels.

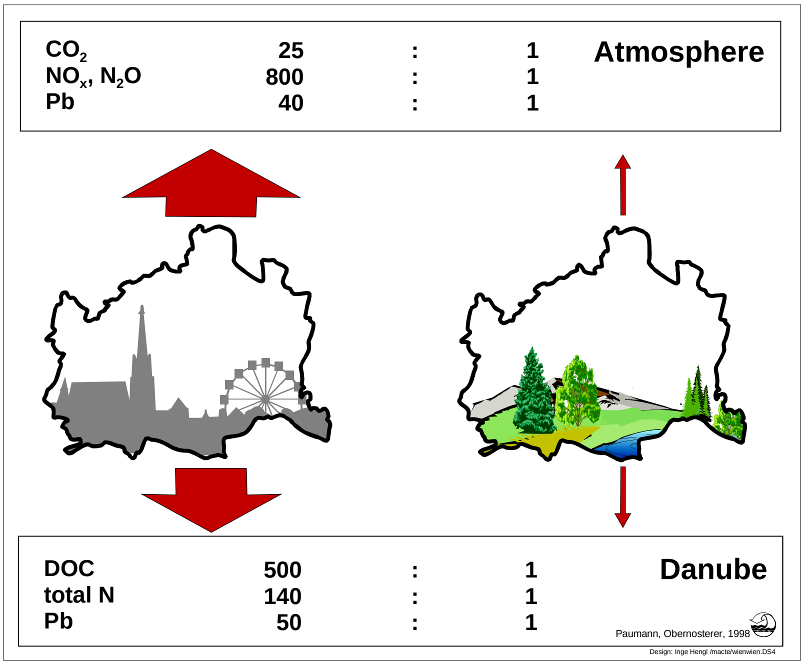


Figure 6-7: Ratio of current and „geogenic“ emissions into the atmosphere and into the Danube river by the City of Vienna for various substances [Paumann et al. 1997].

In general, the comparison of the anthropogenic and geogenic conditions in Vienna [Paumann et al. 1997] shows that:

- today’s anthropogenic emissions to air and water are 25 - 800 times higher than comparable past emissions from an „geogenic“ Vienna.

- today's anthropogenic flows into the „geogenic" Danube and Atmosphere would increase the geogenic loadings in these media by 2 - 480 %.

Are current limits enough to protect the environment, given the large order of magnitude of difference between geogenic and anthropogenic levels?

In order to ensure that the existing and future targets for achieving sustainability are actually heading in the „right" direction, goals should be formed around the basis of geogenic reference levels.

6.6 MFSA as a Monitoring Tool for Vienna

At present environmental monitoring largely involves measuring the current state of the environment, e.g. by taking soil, water and air samples. Environmental policy based on this approach tends to react to the actual state of the environment, highlighting problems only after they have occurred. MFSA allows an precautionary approach (see section 6.1) and therefore is complementary to traditional environmental monitoring approaches.

The discussion on how to use MFSA as a monitoring tool is relatively new, and requires further investigation. In principle the metabolism of the City of Vienna can be monitored by examining the inputs (e.g. trade information), the changes within the city (e.g. growth of residents area), the outputs (e.g. waste water treatment plants) and measurements on the state of the environment. One main problem of the monitoring especially in relation to outputs is measuring diffuse emissions. This problem should be a key research topic in the future (e.g. investigation of corrosion rates). To initiate discussions on the use of MFSA as a monitoring tool, a few possibilities are highlighted as follows:

- The nutrition based Nitrogen flows can be monitored and measured at the point of sale of food or/and at the waste water treatment plant. The amount of Nitrogen in sewage sludge and treated waste water can be related to the distribution of Nitrogen related products (e.g. food products).
- Metal concentrations in MSW incineration plant residues can be routinely measured to monitor cost-effectively the increase of the metal stock in Vienna's landfills and the metal content of Vienna's municipal solid wastes [Brunner & Schachermayer 1995, Morf & Brunner 1998]. The proposed method, which can be extended to nonmetals also, serves as a base to use waste incineration plants as a routine tool for quality control in waste management.
- Car batteries can easily be monitored. Since all car-batteries are recycled within Austria in one enterprise, this is an excellent monitoring point for car-batteries. Regional information on car battery usage could be collected from primarily mechanic firms.
- In order for MFSA to be broadly used to monitor the effect of policy measures, a Material Accounting system (MAc) is required which involves periodically registering material data. (e.g. as introduced in Daxbeck et al. (1998)).

6.7 Implementing MFSA into the „Real World“

It is necessary to explore how MFSA can be utilised in the „real world“ and what form/type/level of information is most useful for policy makers. There must be a two way communication between scientists and policy makers. The real potential of MFSA will be achieved when resource managers (MFSA-experts) work in conjunction with the social sciences and policy makers to determine the most efficient materials management scenarios.

The real potential of such an implementation process can be extended not only due to the technical advantages, but also because MFSA is a powerful education and communication tool. It is a useful approach to convey ideas both to the public and to decision makers. MFSA is a tool that allows for multi-disciplinary approaches, a direction in which many organisations, including the EU, are moving towards.

For these reasons, it is planed to implement the findings of this study in the environmental decision making process in Vienna. For example, possibilities through the „Local Agenda 21“ process for Vienna. Furthermore, the possibilities of implementing MFSA into the decision making process also highlights the potential link to the current discussion of an Environmental Management and Audit System on the regional level (regional-EMAS).

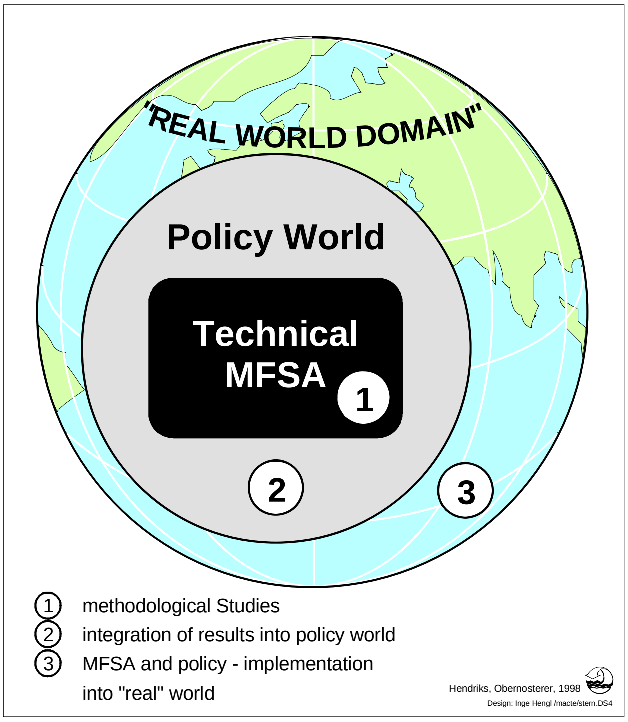


Figure 6-8: Implementation of MFSA into the „Policy World“ and into the „Real World“

In principal, the following steps are suggested for the implementation of MFSA in the policy world:

1. analyse the current metabolism of the region by using MFSA

2. analyse of the policy framework and connecting responsibilities with material flows and stocks.
3. assess and evaluate the current state (policy, social and economic criteria).
4. implement a resource and environmental management system in the region.
5. take measures using policy instruments to improve the current situation in view of sustainable development.
6. control and monitor the success of the taken measures. This step also includes a possible feedback to the previous steps (↑).
7. presentation of the results and appropriate dispersion of the information.

7 Conclusions and Recommendations

To date, studies on MFSA have primarily focused on the methodological description of material flows and stocks within a given system boundary. The MAcTEmPo project has been a bridging step linking the „technical“ MFSA world with it’s potential policy uses. Such uses include: early recognition; setting priorities; analysing/improving policy measures; and assisting efficient resource management.

The main conclusions and recommendations stemming from this study have been separated into urban metabolism, data requirements, capacity building and policy strategies.

Urban Metabolism

- The City of Vienna is essentially a “flow through” reactor for the most of important mass goods (water, air and energy sources). The city is therefore dependent on it’s „Hinterland“ for supply (e.g. fresh water and air), as well as for disposal of its residuals (water and air are the most important disposal conveyor belts for the City of Vienna).
- The material import into the city by far exceeds the export, thus the stock of the anthroposphere of the City of Vienna is growing. This stock of materials in Vienna is mainly in the city’s buildings and infrastructure itself and not in the landfills. Currently, the composition of the stock within the city is similar to that in the landfills. In the future, this stock will be either a potential resource or pollutant which will need to be recycled or disposed of in some way. Comprehensive information and knowledge is needed on the type and composition of these stocks, the dynamics of their changes, and about how to control and manage them. Compared with the stock increase the "classically" discussed outputs such as waste waters or off-gases represent only minor substance flows.
- In the case of the City of Vienna, the comparison of the metabolism of the private households with that of industry and trade shows, that Vienna is not only a service region but also a production centre. Roughly the same quantity of materials flowing through the private household is treated and re-exported from industry and trade.
- The link between the anthroposphere and the environment highlights that anthropogenic activities are significantly altering environmental conditions.
- The relationship between an urban region and its „Hinterland“ reveals that in some cases, the induced flows in the „Hinterland“ into the environment can be more significant than those in the city itself.
- The recycling potential of construction waste could reduce the current use of virgin materials of gravel and sand by only 7 %. However, compared to a linear disposal strategy this potential can reduce the sand and gravel flows going to landfill by 45%. On the substance level, for Lead a comparison of a linear versus a cyclic use of car batteries in Vienna highlights the important influence that the level of technology can have on the degree of environmental impact.

- Materials are defined as goods or substances. From a methodological point of view it is important to use these terms correctly. Furthermore, MFSA requires a focus on loadings and material stocks. In order to improve the comparability of current reports, the terms and the steps of MFSA should be standardised e.g. ISO. While such a standardisation for MFSA on a technical/methodological level is recommended, it is too early to develop MFSA material accounting, evaluation and also MFSA policy implementation standards.

Data Requirements

- It is evident that the results from material accounting studies are as good as the quality of the raw data. Basically, there is far more data available on the level of goods in Vienna than there is on the level of substances.
- To date, no operational data base for MFSA exists and therefore collecting data for MFSA studies is resource intensive. However, there are a number of different data sources which can be used to obtain the necessary information. The main data sources are statistical and technical reports as well as other publications. In addition, interviews with specialists and skilled workers play an important role in extracting data for MFSA studies. It should be noted that there are a number of efforts to create MFSA data bases, particularly on the level of goods.
- In order for MFSA to be broadly used in an efficient manner, a Material Accounting system (MAc) is required which involves periodically registering material data. Such an accounting system (MAc) could be operationalised by altering current data collection systems (e.g. statistical departments, government agencies, enterprises etc.). In particular, data sets should include: information on both goods and substances (input and output) and information where these materials are produced and used. Furthermore, these data sets should be collected in common units e.g. for the anthroposphere in mass flows per capita and per unit time (kg/c.y).
- Data collection should concentrate on those areas where a potential environmental problem or a potential policy implication is envisaged. In those cases where the „potential problem“ is unknown, a MFSA could be conducted as a „data screening test“, to assess whether indeed more data is necessary. These „rough“ studies could be used to highlight priorities for data collection and be used for providing initial forecasts for decision makers.

Capacity Building:

- MFSA is a powerful education and communication tool. It can be used to visualise future environmental and resource management scenarios to decision makers and to the public. It is an appropriate decision making tool whose use should be expanded on all levels: European, national, local, and the enterprise level.
- Several opportunities have been identified in order to disseminate the results of the MAcTEmPo Case Study Vienna. In particular, a presentation was given in conjunction with a member from the Swiss MAcTEmPo team and also a representative from the City of Vienna at a seminar organised by the Internal Environmental Agency for Local Governments (ICLEI). It is planned to implement the results of the MAcTEmPo study

into a possible Local Agenda 21 process for the City of Vienna. In addition, it is anticipated that the results of this project will be published in relevant journals and used for education material in current and future curricula. In order to expand the number of MFSA experts, it is planned to establish a MFSA Focal Centre in Austria which will run a number of MFSA education and training programs.

- During the MAcTEmPo project two key future research topics were identified. The first relates to diffuse emissions from urban metal stocks which will be investigated in a PhD-thesis at IWAG. The second identified research topic involves integrating the science of MFSA with the policy world. IWAG has been awarded funding to conduct a project titled: Material Flow Analysis as a Tool for Resource Policy Making. This project aims to examine the links between the results of MFSA and policy decision making processes on a case study basis.

Policy Strategies

- Using MFSA for policy making involves shifting from the back-end so called „filter strategies“ to more pro-active front-end measures which look holistically at the design of goods, services and regions.
- MFSA is a complementary tool to traditional environmental and resource management strategies. Today’s environmental monitoring systems measure the current state on the environment and tend to focus on single issues with little consideration of the total system. MFSA should be used as a environmental decision making tool since it can present a holistic picture of the system linking current information and data bases. Furthermore, MFSA focuses on short and long-term loadings and highlights current and potential stocks.
- In order to reduce resource depletion and environmental harm, materials (including goods and substances) must be used within the anthroposphere in an optimum manner. MFSA provides a guiding tool for efficient resource management within the anthroposphere. Decision makers responsible for a given system, here the City of Vienna, can use the results from these studies to examine the potential effectiveness of their policies both within the anthroposphere and in terms of the environment.
- A comparison between the Vienna Case study with other investigations reveals that in some cases traditional national or EU-wide environmental standards should be combined with regionally adapted environmental protection and resource management strategies. This recommendation is primarily based on the fact that the dilution potential of environmental sinks and conveyor belts, as well as the availability of resources is regionally variable.
- To assess the sustainability of urban metabolism geogenic references can be used. Such a comparison could indicate the „gap“ between today’s metabolism in relation to geogenic (prior to settlement) reference conditions. Sustainable (efficient) resource management should be defined in the sense that anthropogenic material flows into the environment strive towards achieving geogenic references. The results of MFSA studies provide a useful platform for discussing different management strategies in view of this goal.

- It is necessary to explore how MFSA can be utilised in the „real world“ and what form/type/level of information is most useful for policy makers. A number of controlled experiments on the enterprise, urban and regional scale should therefore be conducted. This strategy is essential since new methods and additional data does not necessarily lead to improved policy making. With the experience of a number of controlled experiments the capacity of efficient implementation of MFSA in the policy world will rapidly increase.
- The real potential of MFSA will be achieved when resource managers (MFSA-experts) work in conjunction with the social sciences and policy makers to determine the most efficient materials management scenarios. Then, the effects of social, technical and economic tools (education, taxes, legislation, materials accounting systems, cost benefit analysis etc.) on materials flows can be discussed in view of achieving sustainable materials management.

Overall Policy Recommendations

- Future environmental policies should be expanded from measuring the human impact on environmental media to designing efficient resource management strategies with the main emphasis on the anthroposphere.
- The strategy to control the anthropogenic metabolism based on Material Flow and Stock Analysis (MFSA) is complementary to traditional environmental and resource management strategies.
- Decision makers responsible for a given system should use MFSA as a base to examine the potential effectiveness of their policies both within the anthroposphere and the environment.
- The current investigations into the use of MFSA have been primarily academically focused. However, experiences show that the tool has a significant potential for use in policy making. MFSA requires further capacity building. In order to broaden the experience and use of MFSA, a number of controlled experiments on the enterprise, city and regional scale should be conducted. In addition, MFSA education programs should be implemented.

8 SUMMARY

8.1 Objectives and Introduction

The main objective of this study was to examine the metabolism of the City of Vienna by means of **Material Flow and Stock Analysis** (MFSA) and to explore the use of MFSA in the decision making process in view of environmental protection and resource conservation.

Since the 1992 UN Conference in Rio de Janeiro, considerable discussion and research regarding environmental concerns has revolved around sustainable development. Currently, the emphasis is on how to translate this concept into the policy making process on all levels. The tool Material Flow and Stock Analysis (MFSA), which is introduced in this study can be implemented on the administrative and on the private policy level to support the decision making process as we move towards sustainability. MFSA has a high potential to be implemented as a guiding tool on the regional level. For example, as part of a Regional Environmental Management and Audit System (regional-EMAS) or as a part of the Local Agenda 21 Process.

MFSA is a complementary tool to traditional environmental and resource management approaches. It provides the necessary links between anthropogenic activities and their impacts on the environment. In a policy sense, MFSA has been used for early recognition, to set priorities, to analyse and improve the effectiveness of measures and to design efficient material[7] management strategies in view of sustainability[8].

This project, which was financed within the 4th European Commission Programme for Environment and Climate, involves five partners from The Netherlands, Sweden, Switzerland and two groups from Austria. This particular section of the project focuses on the metabolism of an urban area, the City of Vienna.

Urban regions typically induce high energy and material flows, due to high population densities and their huge and relatively dense material stocks. Knowledge about the metabolism of cities allows decision makers to react to and prepare for present and future issues regarding materials flows and stocks of a city.

---

[7] Materials are defined as goods and/or substances.

Substances are chemical elements (e.g. Lead, Carbon) or compounds (e.g. Lead Chloride, CO_2)

Goods are economic entities with either a positive or negative value. Goods consist (in general) of many substances (e.g. petrol, wood, construction materials, drinking water, waste water or sewage sludge). Also included in MFSA are „free“ goods like air.

[8] Sustainable (efficient) resource management should be defined in the sense that anthropogenic material flows into the environment strive towards achieving geogenic references.

8.2 Methodology

The approach Material Flow and Stock Analysis (MFSA) was used to describe the metabolism of Vienna. The methodological steps were similar to those used in existing studies, such as Baccini & Brunner (1991), Brunner et al. (1990) and Baccini & Bader (1996).

The new challenge in this project was to apply the MFSA approach to a large urban region and to investigate „Hinterland“ relationships. During the course of the project, the importance of highlighting stocks became apparent. The term „Material Flow and Stock Analysis“ (MFSA) was therefore created which replaces the term MFA in this report.

MFSA is based on a holistic approach which examines the materials flowing into a given system (private household, company, region, city etc.), the stocks and flows within this system, and the resulting outputs from the system to other systems. Furthermore, MFSA focuses on loadings rather than concentrations.

System Definition

In this project, the City of Vienna was subdivided into a number of key processes. The flows and stocks of goods within the system were initially investigated in order to identify the most important substance carriers. In order to understand the system on a substance level, six indicator substances were selected for investigation: Carbon and Nitrogen (essential nutrients for the biosphere), and Aluminium, Iron, Zinc and Lead (some of the most important metals in the anthroposphere). Three different interconnected investigations were carried out to gain a holistic understanding of the urban metabolism of the City of Vienna:

I. Anthropogenic Metabolism

II. Linking the Anthropogenic and Natural Metabolism

III. Linking the City with the „Hinterland“

The temporal system boundary for all three systems was a period of one year and the selected year was 1991. This time frame was primarily selected due to data availability, practicability and compatibility. The spatial system boundary for Investigation I and II was the administrative boundary of the City of Vienna. This boundary was selected for two reasons. Firstly, this system is compatible with the policy decision making framework of the City of Vienna. Secondly, the availability of data within this selected boundary is relatively good. The spatial boundary in Investigation III does not follow a common geographical boundary. Instead it was defined by incorporating those key-processes and materials into the system which represent the issue under investigation. Within all three systems, the materials flows between the key processes were investigated. The methodological steps involved in each system were identical.

For this project, no specific measurements were carried out. Existing data from many varied sources were used to create the MAcTEmPo case study of Vienna (see reference).

8.3 Results

Flows and Stocks of Goods within the City of Vienna

- The flow of goods through Vienna amounts to 200,000 kg/c.y (kilogram per capita and year). Approximately 90 % of this amount consists of the „goods“ water and air which are used within the anthroposphere. At present, Vienna is essentially a “flow through” reactor for the most of important mass goods (water, air, and energy sources). The city is therefore, highly dependent on its „Hinterland“ for supply, as well as for disposal of its residuals.
- The import of solid goods into the city exceeds the exports, and hence there is a stock build up of 350,000 kg/c. If the input and the output of the stock remains constant then it is expected that the stock will double in the next 30 to 100 years.
- The flow through of goods through the private households is in the same order of magnitude as the flow of goods through the industrial and trade sector. This indicates that Vienna is not only a service region, but also has a significant production sector.

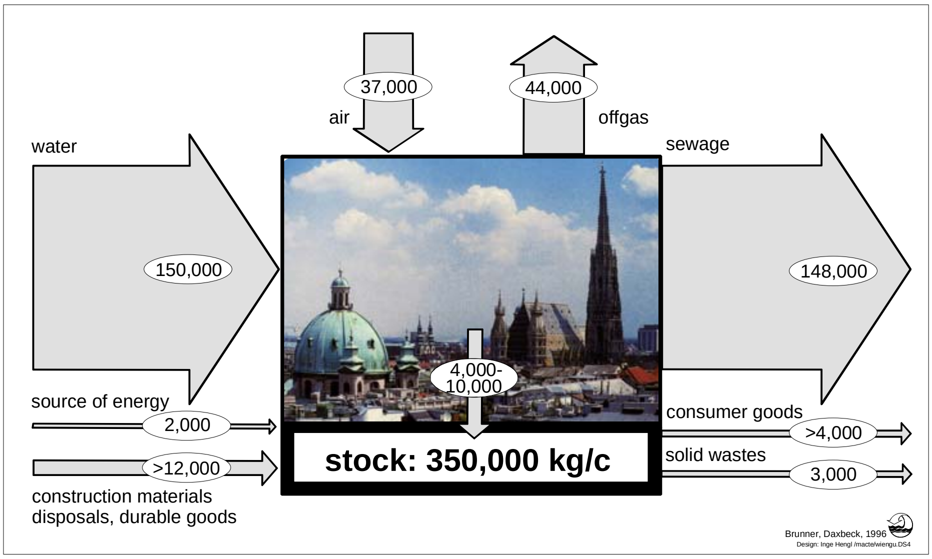


Figure 8-1: Flows and Stocks of Goods in the Anthroposphere of Vienna in 1991 (flows in [kg/c.y]; stock in [kg/c]); Population of Vienna - approx. 1.5 million

Flows and Stocks of Substances within the City of Vienna

- The Carbon flows within Vienna (3 t/c.y) are primarily related to the consumption of fossil fuels. Thus, the key activities to control the Carbon flows within the City are „to reside“ and „to transport“. Nitrogen flows (30 - 40 kg/c.y) are due to the activities „to nourish“ and again „to transport“ and „to reside“.
- Today, the important stocks within the City of Vienna are the buildings and infrastructure stocks and not the landfills. These urban stocks are increasing by 1 - 3 % per year. In general, between 70 and 90 % of the stocks investigated are found within the city’s buildings and infrastructure. The Carbon stock in Vienna’s buildings and infrastructure (33 t/c) increases by 1 - 2 % per year and for Nitrogen stock it increases by 1.5 - 3 %

per year. For the investigated metals, Lead, Iron, Aluminium and Zinc, the flows into the stocks are larger than the output flows. In the future, these stocks will be potential resources and/or pollutants and will need to be recycled or disposed of in some way.

Linking Anthropogenic and Natural Metabolism

- Viennese conveyor belts (River Danube and air throughput) have a high dilution potential and therefore established „concentrations limits“ are generally met. However, the link between the anthroposphere and the environment shows that the anthropogenic activities are altering environmental conditions. For example:
  - ⇒ the link to <u>geogenic</u> conditions (past environmental conditions prior to human settlement) shows that today’s anthropogenic loadings into the air and water for the substances Carbon (CO_2, DOC), Nitrogen (NO_x, N_2O, total N) and Lead (Pb) are 25-800 times higher than comparable past loadings from a „geogenic“ Vienna.
  - ⇒ the link with the <u>current</u> environmental conditions shows, that there is an increase of substance concentration in environmental media, e.g. the concentration of Pb and N in environmental media increases by approximately 0.1 and 0.3 % per year respectively.
  - ⇒ the current concentration of Nitrogen in the river Danube in Vienna does not indicate the increase of Nitrogen in the Danube Delta and in the Black Sea. The increases however, can be highlighted, by following substance loadings to their final sinks.
- The above examples indicate that environmental assessment should consider not only concentration limits but total loadings and final sinks, especially in relation to long-term environmental effects.

Linking the City with the „Hinterland“

- It is possible to examine the relationship between an urban region and its „Hinterland“ using MFSA.
- In some cases, the induced flows in the „Hinterland“ are more significant than those in the city system itself The first investigations into the relationship between a city and it’s „Hinterland“ using MFSA (relaying on many assumptions) reveals that:
  - ⇒ the Nitrogen flows into the River Danube, induced in the „Hinterland“ are 2 times larger than those flows directly coming from the city itself (primarily due to the activity „to nourish“).
  - ⇒ about 60% of the Carbon flows related to transport fuels are emitted by the Viennese as „shadow emissions“ through transport and leisure activities outside the city.
  - ⇒ significant Lead emissions are released in the „Hinterland“ due to the processing and recycling of car batteries demanded by the Viennese.

8.4 Using MFSA for Environmental and Resource Policy Making

What follows is a description of the key policy uses of MFSA. Several examples are used to highlight the applicability of MFSA in the policy world.

8.4.1 Early Recognition - from Reaction to Precaution

MFSA allows for a precautionary approach since it can anticipate future environmental problems and does not rely on signals of „environmental“ stress. MFSA can be used for early recognition since it can identify actual and future stocks and their changes in both the anthroposphere and in the environment. This information can be used to discuss the potential of a stock as a future environmental risk or as resource. The following examples highlight how MFSA results can be used for early recognition purposes.

MFSA can identify future environmental problems by highlighting changes in the stock of substances in different environmental mediums. Currently, the average Nitrogen (NO_3) content in Vienna’s upper groundwater layer is approximately 54 $mgNO_3/l$ which exceeds the Austrian standard of 50 $mgNO_3/l$. If the current Nitrogen input into the groundwater remains constant, then the NO_3 concentration in 10 years will be approximately 70 $mgNO_3/l$ and in 100 years 220 $mgNO_3/l$.

As mentioned above in the results, about 90% of city’s metal stock is located in Vienna’s buildings and infrastructure, whilst only 10% is in the landfills. Current environmental policy controls, however concentrate heavily on landfill stock emissions. Further studies are required to identify which specific stocks contribute to environmental problems and/or those which represent potential resources.

8.4.2 Efficient Resource Management - from Mining Nature to Mining Cities

The identification of key flows and stocks using MFSA can serve as a base for efficient resource management strategies. It provides a basis for designing and optimising material flows and stocks. Furthermore, the resource potential of the current buildings and infrastructure stock for future use can be detected. For example, consider a possible stock-management strategy for the stock of Lead water pipes in Vienna’s buildings (approximately 20,000 tons). This Lead stock has the potential to provide enough Lead coated telecommunication cables for Vienna for approximately 30 years (assuming the demand for Lead cables remains constant) or enough Lead to produce approximately 1,600,000 traditional car batteries.

8.4.3 Priority Setting - from ad-hoc Measures to Efficient Policy

In order to set priorities for environmental policy, a thorough understanding of the anthroposphere (the key flows, processes, and stocks) and its links with the environment is essential. MFSA provides this holistic view of the system and therefore allows one to set priorities on the possible policy measures, ensuring efficient management strategies. Furthermore, MFSA requires a link to economic tools in order for policy makers to set priorities in material management.

Consider various management strategies for managing the metabolism of Carbon: In view of the „greenhouse effect“ a key question is, how can the Carbon flows into the atmosphere be reduced? There are a number of possible management strategies available to address this issue. MFSA provides a base to identify the potential success of each strategy in relation to the entire system. Based on the outcomes of different scenarios, the most effective mix of materials management approaches can be found.

An investigation including the „Hinterland“ reveals that the city is not an independent system. In view of Nitrogen the input flow into the Danube from the „Hinterland“ is approximately 10 kg/c.y and from the city 5 kg/c.y. In order to reduce Nitrogen flows, priority settings must also take into consideration the „Hinterland“ and not only the city system itself.

8.4.4 Effective Policy Measures - Finding Efficient Strategies

Decision makers responsible for a given system, for example the City of Vienna can use the results from MFSA studies to examine the potential effectiveness of their policies both within the anthroposphere and in relation to the environment. Current environmental measures tend to focus on single issues with little consideration of the total system. In many cases, this approach can be highly in-efficient since it may only be addressing a small portion of the total flows and stocks. MFSA can provide a basis for assessing the impact of a particular policy on the total system. It can be used to assess the effectiveness of existing and future policy measures and as a basis for designing improvements.

According to the Austrian construction waste regulation, construction and demolition waste must be separated in view of re-use. The MFSA results for the City of Vienna provide a basis for examining the effect of a recycling policy on the current bulk flows in the construction sector. Using today’s demolition techniques such a policy could, when fully implemented, reduce the amount of construction waste flows (not including excavated soil) going to landfill by 45%[9]. However, the recycling potential of construction waste could only reduce the current use of virgin materials of gravel and sand by 7%. In order to further reduce the use of virgin materials, alternative construction and planning approaches should be adopted such as focussing on higher density settlements. In comparison to Vienna, a project on the City of Zürich highlights that the recycling potential of construction waste could theoretically reduce the current use of virgin materials of gravel and sand use for buildings by 50% (see EAWAG Case Study in Brunner et al. 1998). Such a difference highlights the importance of developing regionally adapted policy strategies.

[9] When excavated soil wastes are included into this calculation, the construction waste flows to landfill can be decreased by only 10%.

8.5 Recommendations

To date, studies on MFSA have primarily focused on the methodological description of material flows and stocks within a given boundary. The MAcTEmPo project has been a bridging step linking the „technical“ MFSA with it’s potential policy uses. In this case study, the policy applicability of the MFSA was investigated in view of the metabolism City of Vienna. The following comments and recommendations can be made:

- Traditional environmental management strategies focus heavily on specific environmental compartments, and measure the concentration of substances in various media. Material Flow and Stock Analysis should be implemented as a complementary tool to traditional environmental and resource management approaches, since it gives an understanding of the anthroposphere and it can provide an overview of the total system by linking the anthroposphere with the environment based on current information and data bases. Furthermore, MFSA focuses on short and long-term loadings and highlights current and potential stocks. Comprehensive information and knowledge is needed on the type and composition of the stocks, the dynamics of their changes, and how they can be controlled and managed.
- Using MFSA for policy making involves shifting from the back-end so called „filter strategies“ to more pro-active front-end measures which look holistically at the design of goods, services and regions.
- In order to reduce resource depletion and environmental harm, materials (including goods and substances) must be used within the anthroposphere in an optimum manner. MFSA provides a guiding tool for efficient resource management within the anthroposphere. Decision makers responsible for a given system, here the City of Vienna, can use the results from these studies to examine the potential effectiveness of their policies both within the anthroposphere and in terms of the environment.
- A comparison between the Vienna Case study with other investigations reveals that in some cases traditional national or EU-wide environmental standards should be combined with regionally adapted environmental protection and resource management strategies. This recommendation is primarily based on the fact that the dilution potential of environmental sinks and conveyor belts, as well as the availability of resources is regionally variable.
- To assess the sustainability of urban metabolism geogenic references can be used. Such a comparison could indicate the „gap“ between today’s metabolism in relation to geogenic (prior to settlement) reference conditions. Sustainable (efficient) resource management should be defined in the sense that anthropogenic material flows into the environment strive towards achieving geogenic references. The results of MFSA studies provide a useful platform for discussing different management strategies in view of this goal.
- To date, no operational data base for MFSA exists and therefore collecting data for MFSA studies is resource intensive. In order for MFSA to be broadly used in an efficient manner, a Material Accounting system (MAc) is required which involves periodically registering material data. The collection of data does not necessarily imply improved policy making and therefore data collection should be goal orientated.

- MFSA is a powerful education and communication tool. It can be used to visualise future environmental and resource management scenarios to decision makers and to the public.
- It is necessary to explore how MFSA can be utilised in the „real world“ and what form/type/level of information is most useful for policy makers. A number of controlled experiments on the enterprise, urban and regional scale should therefore be conducted. This strategy is essential since new methods and additional data does not necessarily lead to improved policy making. With the experience of a number of controlled experiments the capacity of efficient implementation of MFSA in the policy world will rapidly increase.
- The real potential of MFSA will be achieved when resource managers (MFSA-experts) work in conjunction with the social sciences and policy makers to determine the most efficient materials management scenarios. Then, the effects of social, technical and economic tools (education, taxes, legislation, materials accounting systems, cost benefit analysis etc.) on materials flows can be discussed in view of achieving sustainable material management.

9 References

Akademie für Umwelt und Energie (1995) *Jahresbericht 1994 der österreichischen CO2-Kommission (ACC).* Reihe Forschung, Band 7, Laxenburg, Wien.

Baccini, P. & Brunner, P.H. (1991) *Metabolism of the Anthroposphere*. Berlin, Heidelberg, New York: Springer Verlag.

Baccini, P., Daxbeck, H., Glenck, E. & Henseler, G. (1993) *Metapolis - Güterumsatz und Stoffwechselprozesse in den Privathaushalten einer Stadt.* Bericht 34 a+b des Nationalen Forschungsprogrammes „Stadt und Verkehr", ETH Zürich, EAWAG, Abt. Abfallwirtschaft und Stoffhaushalt, Dübendorf, Schweiz.

Baccini, P. & Bader, H.P. (1996) *Regionaler Stoffhaushalt: Erfassen, Bewerten, Steuern*. Spektrum Akademischer Verlag Heidelberg, Berlin, Oxford.

Baccini, P.H., Bader, H.-P, Faist, M., Henseler, G., Janett, D., Kytzia, S., Müller, D, Redle, M. & Scheidegger, R. (1998) *SYNOIKOS - A MAcTEmPo Case Study*. Swiss Federal Institute for Environmental Science and Technology, EAWAG, Dept. S+E, Dübendorf, Switzerland. Case Study Report in: Brunner et al. (1998).

Beer, B., Mönch, H. & Brunner, P.H. (1991) *RESUB - Regionale Stoffhaushaltsstudie „Unteres Bünztal", Teilprojekt RESUB Luft.* ETH Zürich, EAWAG, Abt. Abfallwirtschaft und Stoffhaushalt, Dübendorf, Schweiz.

BGBL 557 (1989) *Trinkwasser-Nitratverordnung*. Bundesgesetzblatt für die Republik Österreich BGBl 1989/557.

BGBL 325 (1990) *Abfallwirtschaftsgesetz. Bundesgesetz über die Vermeidung und Behandlung von Abfällen.* Bundesgesetzblatt für die Republik Österreich BGBl 1990/325.

BGBL 514 (1990) *Verordnung über die Rücknahme und Schadstoffbegrenzung von Batterien und Akkumulatoren.* Bundesgesetzblatt für die Republik Österreich BGBl 1990/514.

BGBL 49 (1991) *Verordnung über die Festsetzung gefährlicher Abfälle.* Bundesgesetzblatt für die Republik Österreich BGBl 1991/49.

BGBL 259 (1991) *Verordnung über die Trennung von bei Bautätigkeiten anfallenden Materialien*. Bundesgesetzblatt für die Republik Österreich BGBl 1991/259.

BGBL 164 (1996) *Verordnung über die Ablagerung von Abfällen (Deponieverordnung).* Bundesgesetzblatt für die Republik Österreich BGBl 1996/164.

Blume, H.P. (1990) *Handbuch des Bodenschutzes*. Landsberg, Lech, Ecomed-Verlags- Ges.mbH.

Blümel, B. (1996) *Neue Instrumente in der Umweltpolitik im Bereich der Abfallwirtschaft*. Salzburg: Universität Salzburg, p. 26.

BMfLF (1995) *Wassergüte in Österreich, Jahresbericht 1994*. Bundesministerium für Land- und Forstwirtschaft, Wien.

BMWA & BMU (1995) *Der Öko-Audit-Kompaß für die Wirtschaft: Die EMAS-Verordnung der EU und ihre Umsetzung in Österreich.* Bundesministerium für wirtschaftlicher Angelegenheiten (BMWA) und Bundesministerium für Umwelt, Jugend und Familie (BMUJF), Wien.

Borchardt, K.D. (1994) *The ABC of Community Law.* Office for Official Publications of the European Communities, p21-49, Luxembourg.

Brunner, P.H., Daxbeck, H., Henseler, G., von Steiger, B., Beer, B. & Piepke, G. (1990) *RESUB - Der Regionale Stoffhaushalt im unteren Bünztal - Die Entwicklung einer Methodik zur Erfassung des regionalen Stoffhaushaltes*. ETH Zürich, EAWAG, Abt. Abfallwirtschaft und Stoffhaushalt, Dübendorf, Schweiz.

Brunner, P.H. & Schachermayer, E. (1992) *Die MVA als Analyseinstrument*. Waste Magazin, 3, p. 23.

Brunner, P. H. & Stämpfli, D. M. (1993) *Material Balance of a Construction Waste Sorting Plant (SORTAG).* Waste Management & Research, 11.

Brunner, P.H., Baccini, P., Deistler, M., Lahner, Th., Lohm, U., Obernosterer, R. & Voet, E. van der (1998*) Materials Accounting as a Tool for Decision Making in Environmental Policy (MAcTEmPo), Summary Report*. 4th European Commission Programme for Environment and Climate, Research Area III, Economic and Social Aspects of the Environment, ENV-CT96-0230, Institute for Water Quality and Waste Management, Vienna University of Technology, Vienna.

Brunner, A. & Stoye, H. (1995) *Bodenverhältnisse und Mikroelement - Hintergrundwerte in der Stadtregion Leipzig*. GKSS - Workshop, Report No. GKSS 95/E/69, GKSS-Forschungszentrum Geesthacht GmbH, Geesthacht, Deutschland.

Daxbeck, H., Lampert, C., Morf, L., Obernosterer, R., Rechberger, H., Reiner, I. & Brunner P.H. (1996) *Der anthropogene Stoffhaushalt der Stadt Wien - Projekt PILOT*. Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft, TU-Wien, Wien.

Daxbeck, H., Lampert, C., Morf, L., Obernosterer, R., Rechberger, H., Reiner, I. & Brunner P.H. (1996b) *Der anthropogene Stoffhaushalt der Stadt Wien - Projekt PILOT - Anhang*. Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft, TU-Wien, Wien.

Daxbeck, H., Schönbauer, A., Maderner, W. & Brunner, P.H. (in preparation 1998) *Stoffbuchhaltung Österreich - Zink*. Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft, TU-Wien, Wien.

Deistler, M., Bauer, G., Gleiß, A. & Matyus, Th. (1998) *Identification of Material Flow Systems.* Vienna University of Technology, Institute of Economics, Operations Research and Systems Theory, Vienna. Case Study Report in: Brunner et al. (1998).

Eikmann, Th. & Kloke, A. (1993) *Nutzungs- und schutzbezogene Orientierungswerte für (Schad-) Stoffe in Böden*. In: Rosenkranz (Hrsg.), Bodenschutz - Ergänzendes Handbuch der Maßnahmen und Empfehlungen für Schutz, Pflege und Sanierung von Böden, Landschaft und Grundwasser. Erich Schmidt Verlag, Berlin.

Ellenberg, H. (Hrsg.), Mayer, R. & Schauermann, J. (1986) *Ökosystemforschung - Ergebnisse des Sollingprojektes 1966 - 1986*. Verlag Eugen Ulmer, Stuttgart.

EUROP (1996) *Serving the European Union: A Citizen's Guide to the Institutions of the European Union*. EUROP (Office of Official Publications of the EC), p. 7-11,17,26, Luxembourg.

European Commission (1996a) *How is the European Union Protecting Our Environment?* Office for Official Publications of the European Communities, p. 5, Luxembourg.

European Commission (1996b) *Taking European Environmental Policy into the 21st Century, A summary of the EC Progress Report and Action Plan on the 5th Program of Policy and Action in Relation to the Environment and Sustainable Development.* Office for Official Publications of the European Communities, p 13-14, Luxembourg.

European Parliament (1994) *Directory of the Most Important Community Legislative Measures in Environmental Policy*. Directorate General for Research, Environment, Public Health and Consumer Protection Series, W-131-12, Luxembourg.

Federal Minisitry of the Environment (1995) *NUP National Environmental Plan - Austria*. Austrian Federal Government, Vienna.

Fehringer, R. & Brunner, P.H. (1997) *Kunststoffflüsse und Möglichkeiten der Kunststoffverwertung in Österreich.* Umweltbundesamt Österreich, Wien.

Fiedler, H.J. & Rösler, H.J (1993) *Spurenelemente in der Umwelt*. Gustav Fischer Verlag, Jena.

Flaig, H. & Mohr, H. (1996) *Der überlastete Stickstoff-Kreislauf, Stategien einer Korrektur*. Hrsg: Akademie für Technikfolgenabschätzung in Baden-Wüttermberg/ Stuttgart Deutsche Akademie der Naturforscher Leopoldina, Halle.

Fleckseder, H. (1986) *Phosphor und Stickstoff sowie Blei, Cadmium, Quecksilber und Zink.* In: Biologie der Donau, Gustav Fischer Verlag.

Frischknecht, R., Hofstetter, P., Knoepfel, I., Dones, R. & Zollinger, E (1995) *Ökoinventare für Energiesysteme, Grundlagen für den ökologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Ökobilanzen für die Schweiz.* Teil VI, Kohle, 2. Auflage, ETH-Zürich, Institut für Energietechnik, Zürich.

Glenck, E., Lauber, W., Lahner, Th. & Brunner, P.H. (1996) *Güterbilanz des Bauwesens - Baurestmassen in Oberösterreich (Projekt BRIO).* Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft, TU-Wien, Wien.

Glenck, E., Lahner, Th., Arendt, M. & Brunner, P.H. (1997) *Baurestmassen in Oberösterreich - Stoffbilanzen der Bauwirtschaft (Projekt BRIO-S).* Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft, TU-Wien, Wien.

GUA (1987) *Entsorgung von Baurestmassen und anderen überwiegend mineralischen Abfällen im Bereich der Gemeinde Wien, Erhebung des IST-Zustandes und Vorschläge für ein Gesamtkonzept.* Studie im Auftrag der Gemeinde Wien, GUA - Gesellschaft für umweltfreundliche Abfallbehandlung GmbH, Wien.

GUA (1988) *Wiener Baurestmassen, Erhebung der im Jahre 1988 deponierten Mengen.* Studie im Auftrag der Gemeinde Wien, GUA - Gesellschaft für umweltfreundliche Abfallbehandlung GmbH, Wien.

Henseler, G., Scheidegger, R. & Brunner, P.H. (1992) *Die Bestimmung der Güter- und Stoffflüsse im Wasserhaushalt einer Region, RESUB Wasser*. ETH Zürich, EAWAG, Abt. Abfallwirtschaft und Stoffhaushalt, Dübendorf, Schweiz.

Hochholdinger, C. (1997) *personal discussion.* Bundesministerium für Umwelt, Jugend und Familie, February 17.

Holzer, C. (1997) *personal discussion.* Bundesministerium für Umwelt, Jugend und Familie, February 21.

Janak, G. (1997) *personal discussion.* Umweltschutzabteilung der Stadt Wien, MA-22, January 17.

Kernbeis, R., Stark, W. & Brunner, P.H. (1995) *Der relative Beitrag von Kompost und Klärschlamm zu ausgewählten Stoffbilanzen des Bodens*. Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft, TU-Wien, Wien.

König, U. (1997) *personal discussion.* Wiener Umweltanwaltschaft, February 20.

Krauskopf, U.B. (1985) *Introduction to Geochemistry*. Hrsg. Mc Graw-Hill Book Company, New York.

Krivan, V. & Egger, K.P. (1986) *Multielementanalyse von Schwebstäuben de Stadt Ulm und Vergleich der Luftbelastung mit anderen Regionen*. Fresenius Z.Anal.Chem. 325: 41-49.

Lechner, P. et al. (1991) *Fachgrundlagen zur Beurteilung der Deponiefähigkeit von Bauschutt.* Bundesministerium für Umwelt, Jugend und Familie, Sektion V, Wien.

Lohm, U., Bergbäck, B., Hedbrant, J., Jonsson, A., Svidén, J., Sörme, L. & Östlund, C. (1998) *Metals in Stockholm - A MAcTEmPo Case Study*. Department of Water and Environmental Studies, Linköping University, Sweden. Case Study Report in: Brunner et al. (1998).

MA 22 (1991) *Untersuchung des Bleigehaltes der Luft*. Bericht des Magistrats der Stadt Wien MA 22 - 4284/91, Wien.

MA 22 (1995) *Flächendeckende Schwermetalluntersuchung des Wiener Bodens an 257 Stellen 1994*. Bericht des Magistrats der Stadt Wien, Magistratsabteilung 22, Wien.

MA 22 (1995a) *Wiener Umweltbericht*. Magistratsabteilung 22, Wien.

MA22 (1997) *Das Wiener Klimaschutzprogramm - KliP*. Magistrat der Stadt Wien, MA 22, Wien.

MA 45 (1991) *Wasserwirtschaftliche Untersuchungen zur Grundwasserbilanz der quartären Bach- und Flußalluvionen im rechtsufrigen Wiener Stadtgebiet*. Report not published.

MA66 (1994) *Statistisches Jahrbuch der Stadt Wien 1993*. Magistratsabteilung 66, Kommissionsverlag, Jugend und Volk Verlagsgesellschaft m.b.H., Wien.

Maier, R., Punz, W., Hietz, P., Dörflinger, A. N. & Brandlhofer, M. (1994) *Ökosystem Großstadt Wien. Quantifizierung des Energie-, Kohlenstoff, und Wasserhaushaltes unter besonderer Berücksichtigung der Vegetation*. Studie im Auftrag der MA 22 der Stadt Wien, Institut für Pflanzenphysiologie, Universität Wien, Wien.

Maier, R., Punz, W., Weish, P., Dörflinger, A., Eisinger, K., Fussenegger, K., Geisler, A. & Gergelfi, H. (1996) *Der natürliche Stoffhaushalt als Grundlage einer nachhaltigen Entwicklung Wiens unter besonderer Berücksichtigung des natürlichen Kohlenstoff-, Stickstoff- und Bleihaushaltes*. Institut für Pflanzenphysiologie, Universität Wien, Wien.

Meyer, K. (1991) *Bodenverschmutzung in der Schweiz - Untersuchung und ausgewählte Ergebnisse über die Stoffbelastung von Böden, Stand 1990.* Themenbericht des Nationalen Forschungsprogrammes „Boden“, Liebefeld-Bern.

Merian, E. (1984) *Metalle in der Umwelt - Verteilung - Analytik und biologische Relevanz.* Verlag Chemie, Weinheim.

Möslinger, J. (in preparation 1998) *Stadtstrukturbezogene Analyse des Güter- und Stoffhaushaltes der Stadt Wien - Ein Beitrag zur Erstellung eines Ressourcenkatasters*. Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft, TU-Wien, Wien.

Morf, L., Ritter, E. & Brunner, P.H. (1997) *MAPE III - Online Messung der Stoffbilanz einer MVA als Instrument der Erfolgskontrolle in der Abfallwirtschaft.* Teil A: Güter- und Stoffbilanz der MVA Wels, Final Report, Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft, TU- Wien, Wien.

Morf, L. & Brunner, P.H. (in preparation 1998) *The MSW Incinerator as a Monitoring Tool for Waste Management.* Environ. Sci. & Technol. (accepted 23. March 1998).

Obernosterer, R. & Brunner, P.H. (1997) *Baurestmassen als zukünftige Hauptquelle für FCKW in der Abfallwirtschaft.* Müll und Abfall, 2/97, p. 89-95.

Obernosterer, R., Möslinger, J. & Brunner, P.H. (in preparation 1998b) *Der Einfluß der Raumplanung auf den regionalen Stoff- und Energiehaushalt - Ein Beitrag zur Bestimmung und*

Quantifizierung. Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft, TU-Wien, Wien.

Ober, E. & Puxbaum, H. (1988) *Sondermessplatz Exelberg*. Report UBA-88-026, Umweltbundesamt Österreich, Wien.

OECD (1995) *Environmental Performance Reviews*: *Austria*. OECD, p.19-25, p. 90, Paris.

ÖGNU (1988) *Wasserwirtschaft und Wassergüte - Stand der Wassergütebewertung*. Fachgespräch in Brandschadhof in Wien, ÖGNU, Wien.

ÖSTAT (1989) *Statistisches Handbuch für die Republik Österreich*. Österreichisches Statistisches Zentralamt, Wien.

ÖSTAT (1996) *Sonderauswertung im Zuge des Projektes „Der anthropogene Stoffhaushalt der Stadt Wien"* für die MA 18 der Stadt Wien und für das Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft der TU-Wien. Österreichisches Statistisches Zentralamt, Wien.

Paumann, R., Obernosterer, R. & Brunner, P.H. (1997) *Wechselwirkung zwischen anthropogenem und natürlichem Stoffhaushalt der Stadt Wien am Beispiel von Kohlenstoff, Stickstoff und Blei.* Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft, TU-Wien, Wien.

Perman, R., Yue, M. & McGilvray, J. (1996) *Natural Resource and Environmental Economics.* Longman Publishing, p.223, New York.

Puxbaum, H. & Rosenberg, C. (1989) *Deposition of ozoneand acidic components in two forest ecosystems in Austria.* Proceedings of the joint symposium 'environmental threats to forests and other natural ecosystems' held at the university of Oulu, I. Szabolcs (ed.), Finland.

Reiner, I., Lampert, Ch., Piterkova, M. & Brunner, P.H. (1996) *Stoffbilanzen landwirtschaftlicher Böden von ausgewählten Betriebstypen bei Verwendung von Klärschlamm und Kompost (BKKB2).* Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft, TU-Wien, Wien.

Schachermayer, E., Bauer, G., Ritter, E. & Brunner, P.H. (1995) *Messung der Güter- und Stoffbilanz einer Müllverbrennungsanlage.* Umweltbundesamt Österreich, Monographien Band 56, Wien.

Schachermayer, E., Lahner, Th., Bauer, G. & Brunner, P.H. (1997) *Stoffflußanalyse einer Bauschuttsortieranlage.* Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft, TU-Wien, Wien.

Sedlacek, E. (1991) *Energie in Wien.* Wiener Stadtwerke, Generaldirektion/ Energiereferat, Wien.

Sieber Cassina & Partner (1991) *Stoffflussanalyse der Bauabfallsortieranlage BASORAG.* Hrsg. Amt für Umweltschutz und Energie, Kanton Basel-Landschaft, Basel.

Smutny, R. (in preparation 1998) *Vergleich der Umwelteinwirkungen von linearen versus zyklischen Bleiflüssen anhand der Verwendung von Bleiakkumulatoren in Wien.* Institut für Wassergüte und Abfallwirtschaft, Abteilung Abfallwirtschaft, TU-Wien, Wien.

Somlyódy, L., Brunner, P.H., Fenz, R., Kroiß, H., Lampert, Ch. & Zessner, M. (1997) *Nutrient Balances for Danube Countries*. Project EU/AR/102A/91, Danube Applied Research Programme, PHARE, Vienna University of Technology, Institute for Water Quality and Waste Management, Vienna.

Talos, E. (1996) *Corporatism - The Austrian Model*. In: Lauber, Volkmar (Ed.) Contemporary Austrian Politics. Boulder, CO and Oxford: Westview Press p. 103-123.

Tschulik, A. (1997) *personal discussion*. Bundesministerium für Umwelt, Jugend und Familie, February 18.

UBA (1995) *Abschätzung der Schwermetallemissionen in Österreich*. Umweltbundesamt Österreich, Wien.

UBA (1996) *Umweltsituation in Österreich. Vierter Umweltkontrollbericht - Teil A*. Umweltbundesamt Österreich, Wien.

Voet, E. van der, Kleijn, R. & Mulder, P. (1998) *Chlorine in Western Europe*. Rijksuniversiteit Leiden, Centruum voor Milieukunde, Leiden, The Netherlands. Case Study Report in: Brunner et al. (1998).

Walker, I. & Dohmann, M. (1994) *Grundlagenuntersuchungen zur Beurteilung der Umweltverträglichkeit von Bauschutt und Baustellenabfällen*. Hrsg. Institut für Siedlungswasserwirtschaft, Rheinisch-Westfälische Technische Hochschule Aachen, Aachen.

Weinhandl, M. (1996) *Blei im Trinkwasser*. AK (Konsumentenschutz), p. 1-3, Wien.

Weiss, R. A. (1997) *personal discussion*. Bundesministerium für Umwelt, Jugend und Familie, February 21.

Witzani, H. (1997) *personal discussion*. Umweltbundesamt Österreich, February 20.

Zeltner, C., Bader, H.-P., Scheidegger, R. & Baccini, P. (in preparation 1998) *Methode zur nachhaltigen Bewirtschaftung von Metallen am Beispiel des Kupfers in den USA*, eingereicht in Zeitschrift Metall.

10 Acronyms and Abbreviations

BMLFW	Bundesministerium für Land- und Forstwirtschaft (Federal Ministry of Agriculture and Forestry Affairs)
BMUJF	Bundesministerium für Umwelt, Jugend und Familie (Federal Ministry of Environment, Youth and Family Affairs)
BMWA	Bundesministerium für wirtschaftliche Angelegenheiten (Federal Ministry of Economic Affairs)
BMWV	Bundesministerium für Wissenschaft und Verkehr (Federal Ministry of Science and Transportation)
EEIP	Externally Effective Internal Process
IEEP	Internally Effective External Process
ITS	Industry, Trade and Service Sector
LCA	Life Cycle Analysis
MAc	Materials Accounting
MAcTEmPo	Materials Accounting as a Tool for Environment Policy Decisions
MFA	Material Flow Analysis
MFSA	Material Flow and Stock Analysis
n.d.	not determined
n.a.	no assessments carried out
NGO	Non Governmental Organisation
PHH	Private Household
SFSA	Substance Flow and Stock Analysis
WWM	Waste and Waste Water Management
kg/c.y	kilograms per capita and year

11 Glossary

Activity - *a* set of processes and flows of goods, substances, energy and information serving a certain purpose, such as to nourish, to clean or to transport.

Anthroposphere - a part of the biosphere where human activities take place. It is a complex system of energy, good, substance and information flows and stocks, which is driven by human biological and cultural needs.

Atmosphere - the mixture of gases together with small amounts of finely divided particles of liquids and solids that envelopes the entire earth to an indefinite altitude.

Buildings and infrastructure - mobiles and immobiles of the anthroposphere of the city by excluding landfills.

Externally Effective Internal Process (EEIP) - processes within the system boundaries, that show their (materials) effects in the „Hinterland“.

Flow - a transport of a given mass per unit of time.

Flux - a transport of a given mass per unit of time and area.

Geogenic Metabolism - metabolism prior to human settlement (there is no anthropogenic impact considered into the environment in the calculation of a geogenic reference).

Good - a good consists of one or more substances such as construction materials, cars or energy sources. A good can have a negative or positive economic value. In an economic sense a good can also be energy, information or a service. If a substance has an economic value, it is included in the good balance (e.g. traded Zinc). Furthermore free goods are also included, like air.

Hinterland - this term is used in relation to the defined system boundary to specify any sphere (anthroposphere, atmosphere, biosphere, pedosphere etc.) outside the system boundary which is impacted by activities from within the system boundaries [Perman et al. 1996].

Intake water - ground water that seeps into the sewer.

MAc -Materials Accounting, is the process of periodically registering data necessary for Material Flow and Stock Analysis (MFSA). Such as register allows comparisons to be made with other accounts such as financial accounts.

Material - can be a good or a substance.

Material Balance - involves balancing the material input and output flows within a defined system based on the Law of Mass Conservation, taking into consideration changes in stocks.

Material Management - encompasses all the decisions associated with the input, use, treatment and disposal of goods and substances within a defined system. Thus material management involves accounting, evaluating, controlling material flows and stocks in order to efficiently utilise natural and human made resources.

MFA - Material Flow Analysis. During the course of the project, the importance of highlighting stocks became apparent. The term „Material Flow and Stock Analysis“ (MFSA) was therefore created which replaces the term MFA in this report.

MFSA - Material Flow and Stock Analysis is the process of calculating the inputs and outputs of materials through key processes within a defined system by considering stocks and their changes. Ideally, MFSA involves balancing the total system. However, in reality due to lack of data and incompatible system boundaries etc. it is always difficult to completely balance the system. For this reason, the terms „flows and stocks“ of the material under investigation are used to describe the results of an MFSA which is not balanced.

Natural Metabolism - current metabolism of the environment.

Off-products - waste water, offgas and solid waste from processes within the system.

Policy decisions - in this report this term refers to more than just those decisions made within the political administrative system. Rather the term here includes all „policy“ decisions made on the public, private and even the household level.

Policy instrument - a set of arrangements, introduced by some level of government which could be used to attain some target policy (e.g. taxes, permits, directives, legislation)

Policy tool - is an input into the policy formation/decision making process. The use or application of a policy tool will depend in part on how well its utility, value or effectiveness is communicated to those making decisions (e.g. MFSA, SFSA, LCA).

Process - transformation, transport or a storage of substances, goods, energy or information.

Regional Metabolism - the metabolism of a region. A region is a more or less autonomous network of ecosystem and anthroposphere. Its area can vary from tens to thousands of km^2 , its population density from tens to thousands of inhabitants/km^2.

SFSA - Substance Flow and Stock Analysis is similar to MFSA, but particularly refers to substances rather than the broader term "materials".

Substance - chemical element (eg Lead or Carbon) or a compound (Lead Chloride or Carbon Dioxide).

System boundary - dimensions in order to limit the system in time and space. Boundaries in time means the accounting period. The boundaries in space have to be defined in both the horizontal and in the vertical. The horizontal boundary typically is a catchment area of a river, political boundaries or a plant. The vertical boundary defines the height and depth of the considered system.

12 Appendix

12.1 Appendix A - MFSA - Methodology Steps

Standardisation as well as the application of common terms and definitions are necessary to compare different systems. Five major steps for the MFSA technique are suggested:

1. *Definition of the objectives and questions:* Formulation of the problems, the goals and the questions to be answered by the study.
2. *System description:* The description of the system - system boundaries (time and space), processes, goods, substances and their relationships within the system.
3. *Data acquisition and calculation*: The provisional balance tries to estimate the material flows and stocks with the use of existing and/or easily available data that do not have to be specific for the region. By means of a provisional balance the processes and materials essential for the system are determined. The results of the provisional balance enable the selection of those processes and flows of substances and goods that have to be studied with first priority.
4. *Sensitivity analysis* of the data: The sensitivity analysis allows the identification of the key variables of the system and the estimation of effects due to variations of input variables.
5. *Presentation and documentation*: All results are combined and presented by means of simple graphs and tables. The primary data should remain secure and easily accessible. Modelling different scenarios would be useful to assess the impact of various measures on the regional stocks and flows of selected substances in view of environmental loads or of resource depletion's.

12.2 Appendix B - Background Policy Information

The following section outlines the divisions of jurisdictional and legal powers at all levels (federal, provincial, local and EU), and also clarifies the role of the „Social Partnership" in Austria's policy formation process. This is followed by a section which covers highlights of current environmental policy issues and implementation status at the various levels.

12.2.1 Environmental Policy Framework in Austria

12.2.1.1 Jurisdictions and the Legal Framework (Division of Powers)

Federal Level

In Austria, most jurisdictions are defined by the Constitution. Matters which have not been made explicit in the Constitution may be deemed of national importance, whereby the federal government retains authority. Political power tends to be centralised. For example, the powers to legislate and to tax rest predominantly at the federal level. This is the case in most matters related to environmental quality and natural resource management.

Environmental policy has usually focused on the use of regulatory instruments (e.g. legislation based on emission standards), and is primarily set at the federal level (e.g. the National Environment Plan) [OECD 1995]. In addition to the Federal Ministry of the Environment, Youth and Family Affairs (BMUJF), several other federal ministries influence environmental policy formation, especially regarding matters involving their respective "competencies" (e.g. the powerful Ministry of Economic Affairs (BMWA) for industry, energy and mining; Ministry of Agriculture and Forestry (BMLFW) for water management; and Ministry of Science and Transportation (BMWV) for traffic and transport of goods). This policy formation process includes ongoing harmonisation with relevant EU legislation and deregulation [Holzer 1997, Tschulik 1997].

Traditional spheres of influence revolve around federal domains within a consensus decision-making mechanism. In Austria, this structure is called the "Social Partnership" and is comprised of representatives from government and representatives from the Federal Economic (Business) Chamber (WK), the Federal Chamber of Labour (AK), the Trade Union Federation (ÖGB), and from the Presidential Conference of the Chambers of Agriculture. Legislative drafts pass through the various federal ministries and the Social Partners [OECD 1995]. It is realistic to note that despite the focus on consensus, intra-ministerial rivalries and political posturing are also characteristic of the policy-making process.

Some matters rest entirely under Federal responsibility (e.g. public health). In other instances, the Federal government is responsible to legislate in certain matters, and the Provinces must carry out the administration and/or implementation (e.g. forestry and hazardous waste) [OECD 1995]. The Federal Waste Management and Chemical Acts are examples of federal legislation where responsibility for implementation or administration is delegated to the provincial governments [Witzani 1997].

Provincial Level („Bundesländer“)

In addition to administering federal laws regarding such areas as waste management (e.g. collection of hazardous waste) and agriculture, Austria’s nine provincial governments („Bundesländer“) have additional areas of authority. Each Province makes its own legislation concerning nature protection, physical planning and construction codes, as well as the administration of environmental impact assessments and some other matters. There are also some agreements among the Provinces (e.g. setting air quality standards) [OECD 1995].

Management of non-hazardous (e.g. household) waste is legally the responsibility of provincial governments, but implementation (collection of solid household waste) is usually delegated to the local level [Janak 1997].

The position of Ombudsman (Lawyer) for the Environment („Umweltanwaltschaft“) appears to be quite unique in Europe. It is a completely independent body, though funded by the Provincial government. Basically they represent the Environment as a client, with the right of standing before the Law. The Ombudsman may bring cases all the way to the highest court of Administrative Law [König 1997]. Each Ombudsman is primarily involved in provincial matters; considerations of land use, roads, highways, airports and during the Environmental Impact Assessment (EIA) for major projects. However, they must be very activist about their involvement, in order to get timely information and review proposals, since they do not always have the right to receive fair notice about proposals [König 1997].

Local Level (City or Municipal)

Local or municipal governments can usually only carry out those functions delegated to them by the Province, such as administration of land use planning, water supply, and solid waste management. There is usually co-operation between districts to manage household waste. A municipal government may collect household waste, and charge service related fees. However, the local level of government has no authority to regulate or tax, with the exception of some special charges on land use (e.g. for landfill) [Hochholdinger 1997]. Local government authority is then quite limited. For example, a local government can implement Provincial land use ordinances, however change in land use within a city or community requires Provincial approval.

European Union Level

Legislative Process

For matters regarding Environment (DG XI), European Community Law is adopted by the European Council (all heads of member states) and by the directly-elected EU Parliament within the “co-decision procedure”, and may take the following forms:

- Recommendations and Opinions: These are not legally binding.
- Directives: which bind Member States as to the objectives to be achieved while leaving the national authorities the power to choose the form and the means.

- Regulations: which are directly applied without the need for national measures to implement them.
- Decisions: which are binding in all their aspects upon those to whom they are addressed. A Decision may be addressed to any and all Member States [European Commission 1996a].
- Under the Treaty Principle of Subsidiarity, the EU Commission should only take legislative action when it will be more effective than if the matter were left to individual Member States. Environmental protection did not become a legal competency of the EU until 1987, with the Single European Act [European Commission 1996a].

Implementation and Enforcement

The EU Commission holds Member States accountable for their treaty obligation to apply EU legislation. Infringement procedures can be initiated against Member States for non-compliance, and in a lengthy process, be brought before the European Court of Justice.

The European Environment Agency (EEA) plays primarily an information / education role. However some EU countries want the EEA to become more of a regulator because implementation EU-wide of legislation lacks effectiveness (e.g. difficulties with trans-boundary issues). The European Chemical Bureau maintains the IUCLID database of new and existing substances, is responsible for classification and labelling, and for risk assessment.

Use of Economic (Market-based) Instruments

A variety of economic instruments, such as environmental taxes, subsidies, exemptions and charges, are used by different EU member states. Denmark, Finland, The Netherlands and Sweden have all introduced diverse forms of CO_2 taxes. Some individual Member States have introduced fertiliser or other product/content-related taxes (e.g. Netherlands-surplus manure tax; Denmark-retail tax on pesticides), while others have hazardous waste charges (e.g. Finland-waste oil and hazardous waste processing charges) [European Commission 1996b].

Social Partnership and Other Spheres of Participation

In Austria, the Social Partnership is the central political mechanism for input from various sectors and interest groups into the policy formation process (e.g. legally-defined advisory role as in the Chemicals Act, Section 44 (2)). Participation through this mechanism of „corporatist“ interest representation is highly-structured, and is strengthened by the fact that there is compulsory membership in the economic (business) chambers and in the chambers of labour [OECD 1995, Talos 1996]. Polling of public opinion and „lobbying“ appear to play a less influential role in Austria, due in part to this social organisation and legal framework.

Experts are regularly sought in the environmental policy formation process as sources of specialised knowledge and/or technical expertise (e.g. the working groups of National Environmental Plan) [Tschulik 1997].

There appears to be relatively little emphasis on citizen environmental activism in Austria with the exception of a few headline cases (e.g. Zwentendorf nuclear plant or the Lambach hydro project). When it occurs, citizen activism over a local environmental issue usually involves one strong lead „personality", to spearhead enthusiasm [Weiss 1997].

Environmental NGOs are usually more focused on federal environmental issues than local ones. While Access to Information legislation does exist in Austria, and public disclosure is often required, the process of actually getting information disclosed can be long and cumbersome. It is possible, especially for private sector players, to circumvent disclosure requirements with claims that disclosure would hamper them or that „trade secrets" are involved [König 1997].

12.2.2 Example of Lead

12.2.2.1 Local or Municipal Level

Vienna is a unique city in Austria, not only due to the atypical size of its population. The "city" government is also the provincial government, with dual roles played by each official (i.e. the City Council is also the Provincial Assembly). Vienna therefore has jurisdictional powers and decision-making authority which exceed those of most cities or municipalities [König 1997]. For example, the federal Waste Management Act specifies that responsibility for collection of hazardous waste is the domain of a provincial government, and not that of a municipality. Usually a local or municipal government can only collect household waste and some small enterprise waste.

12.2.2.2 Provincial Level

Since the Waste Management Act is administered by provincial governments, regarding collection of hazardous waste and construction waste, the province of Vienna carries out this function. With regard to Lead management, all producers and collectors of hazardous waste as well as treatment facilities must be registered at Vienna's Environmental Protection Department. In accordance with Provincial regulations, collectors of waste must inform the Environmental Protection Dept. that they are collecting scrap metal and receive authorisation to do so. These enterprises must gain official approval for their storage facilities [Janak 1997].

There are currently 100 waste collection sites in Vienna, however not all of these collect hazardous waste. Only about 30-40 companies are authorised with facilities to collect specific dangerous wastes.

If the Environmental Protection Dept. discovers a non-compliance problem, there are fines between ATS 50,000 - 500,000. The Bezirks Amt is responsible to administer fines, however it receives technical support from the Environmental Protection Dept.

As a province, Vienna has its own legislation, including the Vienna Waste Management Act, and the Wiener Wasserversorgungsgesetz which prohibited the use of Lead in drinking water pipes in 1983 [Weinhandl 1996].

12.2.2.3 Federal Level

Federal laws apply to Lead and specific Lead content goods [BGBL 514/1990, BGBL 49/1991]. The Waste Management Act is a federal law. Lead coming from industry and waste companies is legally defined as hazardous waste (Household waste is considered „problem waste“).

Specific Lead-content products are cataloged as dangerous waste in ÖNORM S 2100 and S 2101, including car batteries, Lead, Nickel and Cadmium sludge as well as Lead scrap from industry.

Some other Lead-content products do not fall under „waste“ (e.g. glass products, fireworks, crystal). Other laws cover related areas, such as the Austrian Chemical Act, includes labeling for industrial uses, and the Ammunitions and Explosive Materials Act [Janak 1997].

Beginning in the early 1990s, voluntary „take back“ agreements regarding auto batteries/starters were reached between the federal Ministeries of Economic Affairs and of the Environment, and representatives of producers and retailers [Blümel 1996].

12.2.2.4 European Union Level

Significant EU legislative measures relating to Lead include [European Parliament 1994]:

– Council Directive on Classifications and Labeling of Dangerous Substances (67/548/EEC)

– Council Directive on Batteries and Accumulators Containing Dangerous Substances (1991)

– Council Directive on the Approximation of the Laws of the Member States Concerning the Lead Content of Petrol (1985)

– Council Directive on a Limit Value for Lead in the Air (1976)

– Council Regulation on the Supervision and Control of Shipments of Waste Within, Into and Out of the European Community (1992)

12.2.2.5 Private Enterprise

Companies that sell certain products must **„**take back“ the used goods after their use by consumers (e.g. refrigerators, batteries, fluorescent bulbs).

Voluntary programs for business include BMWV-CLEAN Production Program towards better management practices.

12.2.2.6 Public Participation in Lead Management

Each district (Bezirk) in Vienna has a collection site for “problem” household waste (e.g. Lead-content products such as paint, household chemicals, batteries).

Concerned citizens can bring samples of their drinking water for testing of Lead content to the Public Health Dept., at the „Institut für Umweltmedizin der Stadt Wien“ [Weinhandl 1996].

12.2.3 Highlights of Current Environmental Policy Issues and Implementation Status at the Various Levels

12.2.3.1 European Union

- At present, there is little development of EU-wide environmental economic instruments. However interest does exist, to move away from legislative measures with costly regulatory/ enforcement procedures, towards alternative, cost-effective measures.
- E.U. 5th Action Programme on the Environment "Towards Sustainability", strives to integrate the environment into policy and practice [European Commission 1996b].

12.2.3.2 Federal

- Austria's accession to the EU has had an impact on its legislative framework and has required some legal harmonisation efforts (e.g. Chemicals Act is under review at the EU, until mid-March 1997; and the BMWA is reviewing the Industrial Code (Gewerbeordnung § 82, e. g. related to Industrial Permit Process) [Witzani 1997].
- Eco-Management and Audit Scheme (EMAS) - program of voluntary participation by industrial companies, emphasizing preventative measures [BMWA and BMU 1995].
- Environmental taxes do exist in Austria. For example there is a fuels tax (e.g. on electric energy, gas, other fuels). However, all the revenue from this tax goes to general uses (e.g. buildings and infrastructure construction), and not to specific environmental measures. In addition, this tax is relatively low, in order not to disadvantage industry and/or threaten employment in Austria (vis a vis its neighbours). Some would argue that this form of a fuel tax is not truly an environmental instrument because it is ineffective to influence economic decisions and the uses of the tax revenues are not dedicated to environmental measures [Holzer 1997]. The federal Abandoned Site Tax for Landfill Waste is more a true environmental instrument because 1) the tax rate is going to steadily increase over time to further discourage landfilling and favour alternatives, and 2) the revenues from this tax must be used for landfill site remediation [Holzer 1997].
- The National Environment Plan (NUP) has no implementation as of yet. Emphasis on economic concerns (e.g. unemployment and competitiveness) and intra-ministerial rivalry may hamper the implementation process.

12.2.3.3 Provincial

- CO_2 reduction through KLIP program (housing insulation, less buildings and infrastructure)
- Drinking water issues with considerations about supply from Styria
- CLEAN Production Techniques, voluntary eco-auditing for industry
- Various Nature Protection programs exist
- Environmental Impact Assessment legislation came into effect in 1994, to be administered by the provinces, however to date has only been applied a few times.
- Local Agenda 21 projects are under development

12.2.3.4 Local

Vienna is divided into 23 districts (Bezirke) which function as local government. For example each district in Vienna has a collection site for “problem” household waste (e.g. Lead-content products such as paint, household chemicals, batteries). Pertaining to drinking water quality, citizens concerned about possible Lead content can bring samples of their drinking water for testing to the City of Vienna`s Public Health Department (Institut für Umweltmedizin der Stadt Wien) [Weinhandl 1996].

12.2.3.5 Private Sector

- Voluntary agreements with industry (e.g. re: waste management with BMWA and BMUJF)
- Programs include volunteer participation in Eco-Auditing (e.g. PREPARE & EMAS)

12.3 Appendix C - Questionnaire about MAcTEmPo Group Experiences using MFSA/SFSA as a Policy Support Tool

The EAWAG (Daniel Janett, a social scientist) collaborated with IWAG to develop a questionnaire for analysing the practical experiences of MFSA. Each partner was asked to answer the same questionnaire based on the experience of 2 or 3 studies. The questionnaire was designed to assist further policy related investigations. The overall findings of the questionnaire are included in the conclusion of this report. What follows is the more detailed survey findings relating to the two IWAG projects: the Phosphorus balance of the Krems valley and the CFC Balance of Austria. Note: Not all questions are applicable to all projects.

12.3.1 Study 1: „Phosphorus (P) Balance of the Krems Valley“

(answered by Christoph Lampert)

1. General characteristics of the MFSA/SFSA study

a. *Title of the study*

„Phosphorus balance of the Krems valley“

b. *Main topics & research questions*

Objectives:

- to draw up a phosphorus balance for the region
- to detect actual or future resource depletion in soils and environmental impacts on surface waters using the results obtained
- to develop measures in order to protect the soils and surface waters

Questions to be answered:

- Which are the main sources, pathways and sinks of Phosphorus in the region?
- How large are the P-stocks in the region and what is the annual change on the stock?
- What are the most effective measures to direct the region into an environmental sound and resource-saving development?

c. *Spatial scale of the study (local, regional, national etc.)*

Regional level, about 400 km^2

d. *Name of the responsible institute(s):*

Institute for Water Quality and Waste Management

e. *Name of the author(s):*

Glenck E., Lampert, C., Raessi, H., Brunner, P.H.

f. *Who ordered the study?*

State Government of Upper Austria

g. Starting date and duration of the study

October 1994 - July 1995

h. Funding:

State Government of Upper Austria

2. Which circumstances initiated the MFSA/SFSA-study?

a. What original motive induced the study (e.g. methodology development or a specific problem like resource depletion, dangerous substance immission level)?

1. The main motive was to have the knowledge on the P-flows in the region in view of water quality problems.
2. To have more information regarding the control on P from agricultural sources.
3. Capacity building in the Dept. of Waste management /TU Vienna and at the State Ministry of the Environment in the field of SFSA.

b. What other policy support tools were available for problem/solution analysis (e.g. media based systems of environmental observation)?

not investigated

c. Which expectations promoted the selection of the MFSA/SFSA approach?

In the same region in a previous study with a similar topic the MFSA/SFSA approach was applied to Nitrogen flows by our department and satisfying results were obtained.

d. Were there any conflicts for MFSA/SFSA practitioners to deal with these expectations (e.g. between doing a rigorous analysis and providing what may be expected externally)?

Partly the system “region“ had to be adapted, e.g. some new „goods“ were defined, the process „combustion“ was integrated into „industry“ and „private household“.

e. Who suggested the execution of the study (e.g., environmental agency, scientific institute)?

Institute for Water Quality and Waste Management, Department of Waste Management, and the State office for Environmental Protection of Upper Austria.

3. Under which circumstances was the study executed?

a. Was the study related to other research projects (e.g. preliminary study, competing expertise)?

Yes, SFSA of Nitrogen (i) in the same region and (ii) in the entire state.

b. *Did external (public or private) support groups (e.g. advisory boards) participate formally or informally in the study?*

Members of various departments of the funding organisation provided state specific data.

c. *At what stages of the study did they participate (e.g. system analysis, data collection)?*

Data collection

d. *Did any opposition by external (public or private) challengers occur during the execution of the study?*

No.

4. What are the main results and policy recommendations presented to target groups?

a. *What additional information (in comparison to conventional studies within the field) was gained by the MFSA/SFSA study?*

- The regional P balance shows that approximately twice as much P is introduced in the Krems Valley as P leaves this region. The difference accumulates in agricultural soils. Between 930 and 1.500 Mg P enter the region each year. The main part - between 800 and 1.300 Mg P/a - is used in the agriculture (feed and fertilisers). The most important flows into the region are the imported feeds (520-730 Mg P/a), and fertiliser (275-550 Mg P/a).
- The flow of P in the region is determined by the agriculture, which could be described by its most relevant P-flows. The most relevant flows within the region are here the application of feeds (950-1.200 Mg P/a), fertilisers (750-1.000 Mg P/a), manure (550-600 Mg P/a), animal products (200 Mg P/a), production of cement (100-200 Mg P/a), amount of crop residues (170 Mg P/a) as well as the mining of raw materials from the underground (90-150 Mg P/a).
- The total reservoir of P in the region builds up significantly with 200-1.000 Mg P/a. The largest accumulation takes place in agricultural soils. The P-inflow in these soils is approx. twice as high as the crop production. This stock grew in 1993 of about 0,4-1,8 %, which means for the P-reservoir a doubling time in the order of magnitude of one century.
- Measures taken in waste water management can achieve short term reductions. If the accumulation of P in agriculture will still increase in the future, the nutrient input into surface waters caused by erosion will also increase and can compensate the load reductions achieved in waste water treatment.
- Scenario results obtained show that even rigid measures taken in agricultural practice the P-stocks in soils will increase.

b. *Were the results precise and valid enough to be a basis for political-administrative action?*

The P-balance of agricultural soils is precise enough to provide a consistent data base for political administrative actions. Surface waters are strongly influenced by the P-input due to erosion and therefore it bears a high degree of uncertainty. Nevertheless, the P-balance of surface waters indicate an important contribution of erosion to the total P-load.

c. What policy recommendations were made by the authors on the basis of the study?

No policy recommendations were made. In the study only results of scenarios on different measures were presented (e.g.: no use of mineral fertiliser; no feed-import into the region; 50% less meat consumption; P-precipitation in the sewage treatment plants)

d. Which target groups were addressed for presenting the results of the study (e.g. public authorities, media, companies)?

- state authorities in the field of environmental protection and
- agricultural experts, and associations

e. When and in which form were the results presented to target groups (e.g. press conference, scientific journal)?

- *seminars on agricultural practice*
- *seminars on water quality*

5. What are the impacts of the study's results on policy decisions?

Not evaluated through the project processing’s.

a. Which agents and arguments in the decision making arena advocated or obstructed policy advice based on the study (e.g. parliamentary motion for new legislation; public criticism by counter experts)?

- the study stems from „non traditional“ sources such as the TU (in contrast to agricultural research institutes)
- existing policy measures will change the P-flows and stock soon (ÖPUL)

b. What decisions were finally taken based on or fostered by the results of the study (e.g. a new law or ordinance, administrative recommendations, new products or processes)?

unknown

c. How successful was the implementation of these decisions?

unknown

d. What were the major obstacles blocking or impeding the formulation and implementation of policies referring to the conclusions of the MFSA/SFSA study (e.g. political obstruction, decision makers faced with an overflow of information)?

- lack of co-operation between agriculture and environmental management
- lack of environmental evidence and need for action

6. What was the outcome of policy measures based on the MFSA/SFSA study?

a. *To what extent has the original problem, which was the focus of the study, been solved?*

There was no specific „problem to be solved“ in terms of the user. All questions of the project were answered.

b. *In case of success, what is the contribution of MFSA/SFSA compared to other factors (e.g. other scientific tools, product innovation, consumer behaviour)?*

(-)

c. *What are the main causes of failure in case of unfulfilled expectations in MFSA/SFSA as a policy support tool (e.g. methodological deficiency, the political-administrative context of applying MFSA/SFSA)?*

(-)

d. Did unintended secondary effects result from policy measures based on MFSA/SFSA

(e.g. problem shifting across environmental media)?

unknown

7. What is the time span of the study and its application?

How much time was used from the starting point...

a. to the beginning of the study?

3 months

b. to the final report of the study?

13 months

c. to first reactions of target groups?

7 months (after the interim report)

d. to first effects in the target area?

unknown

e. to full effects in the target area?

It is expected that SFSA is one of the cornerstones to contribute to changes in agricultural practices on the long run (decades)

8. What are your personal conclusions about the application of MFSA/SFSA within public policy?

a. What lessons can be drawn from practical experience with supporting public policy by MFSA/SFSA studies? What was successful and what were the shortcomings?

unknown

b. Does the spatial scale of the study have an effect on its impacts on policy making?

Yes if the spatial scale coincides with the political boundaries, implementation and persuasion is easier.

c. *Which are the most promising functions of MFSA/SFSA to future policy support (e.g. early recognition, political targeting, policy evaluation)?*

- to provide a consistent data base
- early recognition
- to develop scenarios

d. *Do you wish do add some important experiences or impressions not mentioned above?*

(-)

12.3.2 Study 2: „CFC Balance of Austria“

(answered by Obernosterer Richard)

FUTURE EMISSIONS FROM THE PAST USE OF CFC´S

ABSTRACT of the STUDY

Key-words: halogenated hydrocarbons (CFC), CFC stocks, insulating materials, refrigerators, ozone depletion, construction wastes

In view of future emissions of halogenated hydrocarbons (CFC), a comprehensive analysis of CFC flows and stocks was prepared on a national level (Austria) in order to supply tools for decision making in the area of waste management.

In 1990, approximately 13,000 tons of halogenated hydrocarbons, equivalent to 4,100 ODP-units, were used in Austria. 53% of the total amount of CFCs used were released into the atmosphere. However, 46% were not immediately released but stored in various products with resident times of 10 - 100 years. Those CFCs stored in stocks represent potential future emission sources. About 60,000 ODP-units, i.e. about one third of the total amount of CFCs used to-date, are accumulated in stocks. Due to the life span of the respective goods and the CFC diffusion rates, stored CFCs will be released slowly into the atmosphere over the next decades.

Even if Austria completely bans the use of CFC it will face further long-term CFC-emissions as a result of the decomposition of the stock. Policy decisions should focus on all stocks and their future development (flows resulting from these stocks). The largest stock of CFCs is found in insulating materials (33,000 ODP), which are used in construction materials. 27,000 ODP are stored in other foamed plastics, in landfill sites, and in cooling and fire protection systems. The amount of 1,500 ODP stored in household refrigerators (cooling agents and insulating materials) appears to be rather insignificant.

1. General characteristics of the MFSA/SFSA study

a. Title of the study

„CFC Metabolism of Austria“

b. Main topics & research questions

In view of future emissions of CFCs, a comprehensive analysis of CFC flows and stocks was prepared for Austria. The objective was to supply tools for decision making in the area of waste management.

c. Spatial scale of the study (local, regional, national etc.)

The study was conducted on the national scale of Austria

d. Name of the responsible institute(s)

University of Technology of Vienna

Institute for Water Quality and Waste Management

Department of Waste Management

Karlsplatz 13/226.4, A-1040 Vienna, Austria

e. Name of the author(s)

Richard Obernosterer

f. Who ordered the study?

No one

g. Starting date and duration of the study

starting point October 1993; Duration about 1 year

h. Funding

no funding

2. Which circumstances initiated the MFSA/SFSA-study?

The CFC study was carried out as a master thesis at the civil engineer department of the University of Technology of Vienna. No particular organisation requested that the study be conducted.

a. What original motive induced the study (e.g. methodology development or a specific problem like resource depletion, dangerous substance immission level)?

a.) education in material flow analysis

b.) early recognition of dangerous CFC emissions in the future by examining the stocks.

b. What other policy support tools were available for problem/solution analysis (e.g. media based systems of environmental observation)?

See c.)

c. Which expectations promoted the selection of the MFSA/SFSA approach?

Ordinary observation tools will only detect problems associated with the stock after problem arise. E.g. A large amount of CFCs are likely to be released into the atmosphere long before any detectable levels of CFCs can be measured (measure points: no measure point at insulating materials, measure point in landfills and by the reduction of the Ozone layer - both too late.

SFSA was chosen because it is an appropriate tool to detect stocks due to the methodological steps of this method and combine it with the inputs and the outputs of the entire system. Furthermore, SFSA deals with substance loadings. Therefore it serves as a base to evaluate the environmental impact and necessary management priorities associated with the flows and stocks of a particular substance

d. *Were there any conflicts for MFSA/SFSA practitioners to deal with these expectations (e.g. between doing a rigorous analysis and providing what may be expected externally)?*

The conflicts were not carried out (no discussions with the lawmakers)

e. *Who suggested the execution of the study (e.g., environmental agency, scientific institute)?*

Richard Obernosterer suggested the CFC study. He was interested in the discussions in Austria about the Ozone layer and in particular CFC legislation. Prof. Brunner, of the University of Technology of Vienna supported him in the pursuit of this research project as master theses. The main motivation was capacity building in the field of MFSA.

3. Under which circumstances was the study executed?

a. *Was the study related to other research projects (e.g. preliminary study, competing expertise)?*

Yes, there were other CFC studies which served for comparison.

b. *Did external (public or private) support groups (e.g. advisory boards) participate formally or informally in the study?*

Formally: No

Informally: Representatives of the industry, trade and service sectors (incl. ministries, etc.) supplied data about CFC flows in Austria.

c. *At what stages of the study did they participate (e.g. system analysis, data collection)?*

The interim report was posted to representatives of the industry, trade and service sectors (incl. ministries, etc.). Their input was considered in the final report. Personal communication (mainly through phone calls) formed a large part of the study particularly in the data collection stages.

d. *Did any opposition by external (public or private) challengers occur during the execution of the study?*

No

4. What are the main results and policy recommendations presented to target groups?

a. *What additional information (in comparison to conventional studies within the field) was gained by the MFSA/SFSA study?*

- estimation and evaluation of key CFC stocks
- early recognition of future CFC emissions
- proposal and priority setting for future decisions
- overview: whole information in one picture (key-flows and -stocks)
- evaluation of former decisions

b. *Were the results precise and valid enough to be a basis for political-administrative action?*

Precise: Yes

Valid: No, information about means and costs to solve the problem could not be supplied.

c. *What policy recommendations were made by the authors on the basis of the study?*

The current legislation is likely to be effective at reducing the further use of CFC compounds. However, the main shortcomings with this legislation is that it fails to address the emissions from the CFC stocks. Although the legislation (in terms of stock management) targets the collection of old refrigerators, this only deals with a minor fraction of the total CFCs stocks. There is no particular legislation which addresses the disposal of larger stocks such as those associated with buildings.

The main recommendations of the study focus on the CFC stock problem. It was recommended that the global stock of CFC needs to be investigated in order to assess the global environmental risk of CFC stocks. In addition these studies should investigate the diffusion rates of CFC molecules from insulating boards over time. For the practical world, it was recommended that particular technology and legislation for each CFC stock be developed. A key priority should be legislation relating to insulating materials.

d. *Which target groups were addressed for presenting the results of the study (e.g. public authorities, media, companies)?*

See e.)

e. *When and in which form were the results presented to target groups (e.g. press conference, scientific journal)?*

- The final report was posted to representatives of the industry, trade and service sectors (incl. ministries, etc.).
- The results were published in different kinds of research reports and journals.
- The results were presented at an environmental exhibition, which lead to several reactions in the press.
- The results are included in the education program of the department of Waste Management at the University of Technology of Vienna and in public and scientific lectures of the department.

- The results are presented to the minister of the environment

5. *What are the impacts of the study's results on policy decisions?*

This was not evaluated by the institute. But as far as we know there has now (1998) been an input of the results into the decision making process. Since the report was finished in 1996, it indicates that there is an delay (time-span) between the end of study such as this and the reaction of the „policy world“. The Austrian Environmental Agency (Umweltbundesamt -UBA) planed to publish the results of the study in an actual environmental controlling report of Austria (Umweltkontrollbericht). The Austrian Environmental Agency is instructed by the Austrian government to make this report every two years. The issues in this report are typically discussed broadly in the public and thus we expect further discussions of our results in the policy decision making world.

a. *Which agents and arguments in the decision making arena advocated or obstructed policy advice based on the study (e.g. parliamentary motion for new legislation; public criticism by counter experts)?*

See above

b. *What decisions were finally taken based on or fostered by the results of the study (e.g. a new law or ordinance, administrative recommendations, new products or processes)?*

Up to now - No known

c. *How successful was the implementation of these decisions?*

(-)

d. *What were the major obstacles blocking or impeding the formulation and implementation of policies refering to the conclusions of the MFSA/SFSA study (e.g. political obstruction, decision makers faced with an overflow of information)?*

(-)

6. *What was the outcome of policy measures based on the MFSA/SFSA study?*

Up to now - no measures

a. *To what extent has the original problem, which was the focus of the study, been solved?*

(-)

b. *In case of success, what is the contribution of MFSA/SFSA compared to other factors (e.g. other scientific tools, product innovation, consumer behaviour)?*

(-)

c. *What are the main causes of failure in case of unfulfilled expectations in MFSA/SFSA as a policy support tool (e.g. methodological deficiency, the political-administrative context of applying MFSA/SFSA)?*

(-)

d. Did unintended secondary effects result from policy measures based on MFSA/SFSA (e.g. problem shifting across environmental media)?

(-)

7. What is the time span of the study and its application?

How much time was used from the starting point...

a. to the beginning of the study?

1 month

a. to the final report of the study?

About 1 year

c. to first reactions of target groups?

(-)

d. to first effects in the target area?

(-)

e. to full effects in the target area?

(-)

8. What are your personal conclusions about the application of MFSA/SFSA within public policy?

a. What lessons can be drawn from practical experience with supporting public policy by MFSA/SFSA studies? What was successful and what were the shortcomings?

See above

b. Does the spatial scale of the study have an effect on its impacts on policy making?

Yes if the spatial scale coincides with the political boundaries, implementation and persuasion is easier

c. Which are the most promising functions of MFSA/SFSA to future policy support (e.g. early recognition, political targeting, policy evaluation)?

(-)

d. Do you wish do add some important experiences or impressions not mentioned above?

If there is no close co-operation between the policy makers or the client who induced the study (as was the situation in this project) than one can conclude, that the research alone has little (direct) impact into the policy decision making process. The presentation of the results are of extreme importance in order to bring the results into the public sphere and to initiate discussions. I was actually quite surprised to discover that one NGO did not react to the results, because normally (I thought) they are looking for shortcomings of government policy. Presenting the results to the decision makers in ministries etc.. has not directly influenced the decision making process. In general, results can one lead to decisions when the issue is part of the broader public concern, the environmental protection sector, and also the scientific community etc... This has little to do with the study methodology. It is important to publish the results very often.

Some enterprises reacted against the results because they were afraid of their image (today they have CFC free insulating materials, and special enterprises which do not require CFC for their production process). Furthermore some were afraid that the reaction will be similar to the Asbestos problem - and they are afraid of all the costs which will follow by reconstructing CFC insulating materials.

At the other hand there were also a lot of positive reactions within the scientific world.

12.4 Appendix D - Zn, Fe and Al Calculations for the Anthropogenic Metabolism of the City of Vienna

Based on the good flows and stocks of the anthropogenic system of the City of Vienna (calculated in the project „Anthropogenic Metabolism of the City of Vienna“ [Daxbeck et al. 1996]) the Al, Zn and Fe flows and stocks were calculated. In the following section these calculations are shown. To get the data the good flows and stocks were multiplied with the specific substance concentrations. Data sources are also given in the following section.

12.4.1 Energy Sources

Aluminium, Zinc and Iron flows and stocks related to energy sources in Vienna, 1991

The Al, Zn, Fe flows and stocks related to energy sources were approximately determined by taking into consideration the system definition and the good balance of the energy sources in Daxbeck et al., 1996 (p. 12) and by using substance concentration in the different goods. All data in Table 12-1 originates of available data in literature or assumptions (see below). Since only the order of magnitude is of interest, no minimum or maximum values were considered for the calculations.

Table 12-1: Calculation of flows and stocks of Al, Zn and Fe related to energy sources used in Vienna 1991

Goods		**flows of goods**			**substance concentrations and flows**								
					Al			**Zn**			**Fe**		
		input t/y	**output** t/y	**literature**	**conc. (mg/kg)** mean	**literature**	**flow (t/y)** mean	**conc. (mg/kg)** mean	**literature**	**flow (t/y)** mean	**conc. (mg/kg)** mean	**literature**	**flow (t/y)** mean
private household (phh)													
fuels o	coal	50000		L2, L4	17100	L1, p.50	855	48	L1, p.50	2,4	5530	L1, p.50	277
	wood	41000		L2, L4	0	L3, p.218	0,0	50	L3, p.218	2,1	2000	L3, p.218	82
	oil	188000		L2, L4	1	L3, p.218	0,2	0,05	L3, p.218	0,01	0,1	L3, p.218	0,0
	gas	474000		L2, L4	0	L3, p.218	0,0	0	L3, p.218	0,00	0	L3, p.218	0,0
	total	753000					*855*			*4,5*			*359*
fuels t	gasoline (Benzin)	139200		L2, L4	1	L3, p.218	0,1	0,05	L3, p.218	0,01	0,1	L3, p.218	0,0
	diesel fuel	20800		L2, L4	1	L3, p.218	0,0	0,05	L3, p.218	0,00	0,1	L3, p.218	0,0
	gas	0		L2, L4	0	L3, p.218	0,0	0	L3, p.218	0,00	0	L3, p.218	0,0
	total	160000					*0,2*			*0,01*			*0,0*
air		14500000		L2	0	L3, p.218	0,0	0	L3, p.218	0,00	0	L3, p.218	0,0
offgas phh*			15400000	L2			8,6			0,22			3,6
ash phh**							847			4,2			355
residues***							0,2			0,01			0,0
EEIP private household													
fuels t	gasoline (Benzin)	356700		L2, L4	1	L3, p.218	0,4	0,05	L3, p.218	0,02	0,1	L3, p.218	0,0
	diesel fuel	53300		L2, L4	1	L3, p.218	0,1	0,05	L3, p.218	0,00	0,1	L3, p.218	0,0
	gas	0		L2, L4	0	L3, p.218	0,0	0	L3, p.218	0,00	0	L3, p.218	0,0
	total	410000	410000				*0,4*			*0,02*			*0,0*
private household	**total In**	**15800000**					**856**			**4,5**			**359**
	output Atmos.		**15800000**				**9,0**			**0,2**			**3,6**
	other output		**0**				**846,8**			**4,2**			**355**
IEEP- private household													
fuels t	gasoline (Benzin)	13920		L2, L4	1	L3, p.218	0,0	0,05	L3, p.218	0,00	0,1	L3, p.218	0,0
	diesel fuel	2080		L2, L4	1	L3, p.218	0,0	0,05	L3, p.218	0,00	0,1	L3, p.218	0,0
	gas	0		L2, L4	0	L3, p.218	0,0	0	L3, p.218	0,00	0	L3, p.218	0,0
	total	16000					*0,0*			*0,00*			*0,0*
air		301000		L2	0	L3, p.218	0,0	0	L3, p.218	0,00	0	L3, p.218	0,0
offgas phh*			317000	L2			0,0			0,00			0,0
ash phh**							0,0			0,00			0,0
residues***							0,0			0,00			0,0
Industry, trade and service (ITS)													
fuels o	coal	116000		L2, L4	18200	L1, p.50	2111	50	L1, p.50	5,8	5400	L1, p.50	626
	wood	6000		L2, L4	0	L3, p.218	0,0	50	L3, p.218	0,3	2000	L3, p.218	12
	oil	510000		L2, L4	1	L3, p.218	0,5	0,05	L3, p.218	0,03	0,1	L3, p.218	0,1
	gas	810000		L2, L4	0	L3, p.218	0,0	0	L3, p.218	0,00	0	L3, p.218	0,0
	total	1442000					*2112*			*6,1*			*638*
fuels t	gasoline (Benzin)	51000		L2, L4	1	L3, p.218	0,1	0,05	L3, p.218	0,00	0,1	L3, p.218	0,0
	diesel fuel	153000		L2, L4	1	L3, p.218	0,2	0,05	L3, p.218	0,01	0,1	L3, p.218	0,0
	gas	0		L2, L4	0	L3, p.218	0,0	0	L3, p.218	0,00	0	L3, p.218	0,0
	total	204000					*0,2*			*0,01*			*0,0*
air		26900000		L2	0	L3, p.218	0,0	0	L3, p.218	0,00	0	L3, p.218	0,0
offgas its****			28540000	L2			2,1			0,01	0		0,6
ash its*****							2110			6,1			638
residues******							0,2			0,01			0,0
EEIP ITS													
fuels t	gasoline (Benzin)	60250		L2, L4	1	L3, p.218	0,1	0,05	L3, p.218	0,00	0,1	L3, p.218	0,0
	diesel fuel	180750		L2, L4	1	L3, p.218	0,2	0,05	L3, p.218	0,01	0,1	L3, p.218	0,0
	gas	0		L2, L4	0	L3, p.218	0,0	0	L3, p.218	0,00	0	L3, p.218	0,0
	total	241000	241000				*0,2*			*0,01*			*0,0*
ITS	**total In**	**28780000**					**2112**			**6,1**			**638**
ITS	**output Atmos.**		**28780000**				**2,4**			**0,02**			**0,7**
ITS	**other output**		**0**				**2110**			**6,1**			**638**

Source of data:
L1: Frischknecht et al. (1995); L2: Daxbeck et al. (1996); L3: Baccini et al. (1993); L4: Sedlacek (1991)

Information to Table 12-1:

Table 12-2: Transfer of substances from fuels into off-gas, ash or residues, estimated according to own assumptions.

		Zn	**Al**	**Fe**
*	transfer into off-gas (PHH):	0.05	0.01	0.01
**	transfer into ash (PHH):	0.95	0.99	0.99
***	transfer into residue (PHH):	0.95	0.99	0.99
****	transfer into off-gas (ITS):	0.01	0.001	0.001
*****	transfer into ash (ITS):	0.99	0.999	0.999
******	transfer into residue (ITS):	0.99	0.999	0.999

12.4.2 Water System

General Information

Table 12-3: Overview of the total flows of the Water-System

process of origin	process of destination	goods	goodflux	Al	Fe	Zn
			1000kg/c.y	kg/c.y	kg/c.y	kg/c.y
process supply		input				
import	private & public water supply service	spring- and surface water	90	0,00	0,00	0,00
import	private & public water supply service	groundwater	6	0,00	0,00	0,00
import	private & public water supply service	groundwater, domestic supply	10	0,00	0,00	0,00
		total input	**105**	**0,00**	**0,00**	**0,00**
		output				
private & public water supply service	private household	water, private household	54	0,00	0,00	0,00
private & public water supply service	incineration	water supply network losses	6	0,00	0,00	0,00
private & public water supply service	export	water, incineration	1	0,00	0,00	0,00
private & public water supply service	sewerage system	water, private consumption	3	0,00	0,00	0,00
industry, trade and service	sewerage system	waste water, industry, trade and service	42	0,00	0,10	0,02
		total output	**107**	**0,00**	**0,10**	**0,02**
process private household		input				
private & public water supply service	private household	water, private household	54	0,00	0,00	0,00
		total input	**54**	**0,00**	**0,00**	**0,00**
		output				
private household	sewerage system	waste water, private household	50	0,36	0,04	0,02
private household	export	offgas, private household	4	0,00	0,00	0,00
		total output	**54**	**0,36**	**0,04**	**0,02**
process waste and waste water management		input				
private & public water supply service	export	water, incineration	1	0,00	0,00	0,00
private & public water supply service	sewerage system	water, private consumption	3	0,00	0,00	0,00
industry, trade and service	sewerage system	waste water, industry, trade and service	42	0,00	0,10	0,02
private household	sewerage system	waste water, private household	50	0,36	0,04	0,02
import	sewerage system	outside water	20	0,00	0,00	0,00
import	sewerage system	rainwater	22	0,00	0,00	0,00
import	waste water treatment plant	precipitant			0,60	
		total input	**138**	**0,36**	**0,74**	**0,04**
		output				
waste water treatment plant	export	treated waste water	127	0,09	0,04	0,02
incineration	export	offgas, incineration	0	0,00		
sewerage system	export	waste water, seperate sewerage system	4	0,00	n.b.	
sewerage system	export	storm weather overflow	7	0,02	0,01	0,00
waste water treatment plant	export	offgas, waste water treatment plant				
		total output	**138**	**0,11**	**0,05**	**0,02**
subprocess waste water treatment plant						
		output				
waste water treatment plant	incineration	sewage sludge	0	0,25	0.7	0.02
waste water treatment plant	export	treated waste water	127	0,11	0,04	0,02
waste water treatment plant	export	offgas, waste water treatment plant	0	0,00	0,00	0,00
		total output	**127**	**0,36**	**0.74**	**0.04**

Water is one of the most important conveyer belts for substances through Vienna. The processes under consideration are: public and private water supply; industry trade & service, private household, sewerage system, waste water management. Table 12-3 gives an overview of the results. The calculations and references are given in Table 12-4, 12-5, Table 12-6 and Table 12-7.

Table 12-4: Calculation of the Aluminium flows of the Water-System Vienna

processes:		**goods:**			**substances:**						
process of origin	**process of destination**	**good**	**flow**	**Ref.**	**concentration in mg/kg**				**flow in kg/c.y**		
			kg/c.y		min.	Ref.	max.	Ref.			MW
import	private & public water supply service	spring- and surface water	90.009	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
import	private & public water supply service	groundwater	5.650	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
import	private & public water supply service	groundwater, domestic supply	9.741	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
private & public water supply service	industry, trade and service	water, industry, trade and service	41.692	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
private & public water supply service	private household	water, private household	54.031	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
private & public water supply service	incineration	water supply network losses	6.040	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
private & public water supply service	export	water, incineration	1.299	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
private & public water supply service	sewerage system	water, private consumption	3.442	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
industry, trade and service	sewerage system	waste water, industry, trade and service	41.692	L1	2,20	C2	2,20	C2	0,09	0,09	0,05
private household	sewerage system	waste water, private household	50.460	L1	3,83	C1	10,59	C1	0,19	0,35	0,27
private household	export	offgas, private household	3.572	L1	n.a.		n.a.		n.a.	n.a.	n.a.
incineration	export	offgas, incineration	130	L1	n.a.		n.a.		n.a.	n.a.	n.a.
sewerage system	export	waste water, seperate sewerage system	3.896	L1	n.a.		n.a.		n.a.	n.a.	n.a.
sewerage system	export	storm weather overflow	7.144	L1	1,91	C1	3,99	C1	0,01	0,03	0,02
sewerage system	waste water treatment plant	waste water	127.220	L1	1,91	C1	3,99	C1	0,24	0,51	0,34
import	sewerage system	outside water	19.612	L1	0,00	A	0,50	A	0,00	0,01	0,00
import	sewerage system	rainwater	21.755	L1	0,00	A	1,00	A	0,00	0,02	0,01
waste water treatment plant	incineration	sewage sludge	50	L1	14.782,00	C1	31.522,00	C1	0,74	1,58	1,18
waste water treatment plant	export	treated waste water	127.090	L1	0,34	C1	1,02	C1	0,04	0,13	0,09

L1: Daxbeck et al. (1996)
I2: pers. information 4.12.1996, Dr. Tsaka Inst. f. Umweltmedizin der MA 15;
C1: Calculation on the base of Baccini et al. (1993) (see table below)
C2: calculated concentration on the base of the balanced load

Table 12-5: Calculation of the Zinc flows of the Water-System Vienna

processes:		goods:			substances:						
process of origin	**process of destination**	**good**	**flow**	**Ref.**	**concentration in mg/kg**				**flow in kg/c.y**		
			kg/c.y		min.	Ref.	max.	Ref.	min	max	MW
import	private & public water supply service	spring- and surface water	90.009	L1	0,00	L2	0,02	L2	0,00	0,00	0,00
import	private & public water supply service	groundwater	5.650	L1	0,00	I2	0,02	L3	0,00	0,00	0,00
import	private & public water supply service	groundwater, domestic supply	9.741	L1	0,00	L2	0,02	L2	0,00	0,00	0,00
private & public water supply service	industry, trade and service	water, industry, trade and service	41.692	L1	0,00	L2	0,02	L2	0,00	0,00	0,00
private & public water supply service	private household	water, private household	54.031	L1	0,00	L2	0,02	L2	0,00	0,00	0,00
private & public water supply service	incineration	water supply network losses	6.040	L1	0,00	L2	0,02	L2	0,00	0,00	0,00
private & public water supply service	export	water, incineration	1.299	L1	0,00	L2	0,02	L2	0,00	0,00	0,00
private & public water supply service	sewerage system	water, private consumption	3.442	L1	0,00	I2	0,02	L3	0,00	0,00	0,00
industry, trade and service	sewerage system	waste water, industry, trade and service	41.692	L1	0,13	L3	0,60	L3	0,01	0,03	0,02
private household	sewerage system	waste water, private household	50.460	L1	0,28	C1	0,54	C1	0,01	0,03	0,02
private household	export	offgas, private household	3.572	L1	n.a.		n.a.		n.a.	n.a.	n.a.
incineration	export	offgas, incineration	130	L1	n.a.		n.a.		n.a.	n.a.	n.a.
sewerage system	export	waste water, seperate sewerage system	3.896	L1	n.a.		n.a.		n.a.	n.a.	n.a.
sewerage system	export	storm weather overflow	7.144	L1	0,13	L3	0,60	L3	0,00	0,00	0,00
sewerage system	waste water treatment plant	waste water	127.220	L1	0,13	L3	0,60	L3	0,02	0,08	0,05
import	sewerage system	outside water	19.612	L1	0,00	I2	0,17	L3	0,00	0,00	0,00
import	sewerage system	rainwater	21.755	L1	0,01	C1	0,22	C1	0,00	0,00	0,00
waste water treatment plant	incineration	sewage sludge	37	L1	800,00	I1	900,00	I1	0,03	0,03	0,03
waste water treatment plant	export	treated waste water	127.090	L1	0,05	C1	0,16	C1	0,00	0,04	0,02

L1: Daxbeck et al. (1996)
L2: Merian et al. (1984)
L3: Henseler et al. (1990)
C1: Calculation on the base of Baccini et al. (1993) (see table below)
I1: pers. information 6.12.1996, DI Papp, Leiterin Chemie der EBS
I2: pers. information 4.12.1996, Dr. Tsaka Inst. f. Umweltmedizin der MA 15;

Table 12-6: Calculation of the Iron flows of the Water-System Vienna

processes:		goods:			substances:						
process of origin	**process of destination**	**good**	**flow**	**Ref.**	**concentration in mg/kg**				**flow in kg/c.y**		
			kg/c.y		min.	Ref.	max.	Ref.	min.	max.	MW
import	private & public water supply service	spring- and surface water	90.009	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
import	private & public water supply service	groundwater	5.650	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
import	private & public water supply service	groundwater, domestic supply	9.741	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
private & public water supply service	industry, trade and service	water, industry, trade and service	41.692	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
private & public water supply service	private household	water, private household	54.031	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
private & public water supply service	incineration	water supply network losses	6.040	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
private & public water supply service	export	water, incineration	1.299	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
private & public water supply service	sewerage system	water, private consumption	3.442	L1	0,00	I2	0,01	I2	0,00	0,00	0,00
industry, trade and service	sewerage system	waste water, industry, trade and service	41.692	L1							
private household	sewerage system	waste water, private household	50.460	L1	0,21	C1	1,33	C1	0,01	0,07	0,04
private household	export	offgas, private household	3.572	L1	n.a.		n.a.		n.a.	n.a.	n.a.
incineration	export	offgas, incineration	130	L1	n.a.		n.a.		n.a.	n.a.	n.a.
sewerage system	export	waste water, seperate sewerage system	3.896	L1	n.a.		n.a.		n.a.	n.a.	n.a.
sewerage system	export	storm weather overflow	7.144	L1	0,67	C1	2,17	C1	0,00	0,02	0,01
sewerage system	waste water treatment plant	waste water	127.220	L1	0,67	C1	2,17	C1	0,09	0,28	0,15
import	sewerage system	outside water	19.612	L1	0,00	A	0,01	A	0,00	0,00	0,00
import	sewerage system	rainwater	21.755	L1	0,04	A	0,66	A	0,00	0,01	0,01
waste water treatment plant	incineration	sewage sludge	37	L1					0,00	0,00	0,00
waste water treatment plant	export	treated waste water	127.090	L1	0,17	C1	0,71	C1	0,00	0,09	0,04

L1: Daxbeck et al. (1996)
I2: pers. information 4.12.1996, Dr. Tsaka Inst. f. Umweltmedizin der MA 15;
C1: Calculation on the base of Baccini et al. (1993) (see table below)
C2: calculated concentration on the base of the balanced load

Table 12-7: Calculation C1 of the of the Al, Zn and Fe flows of the Water-System Vienna, given as reference in the tables above

	A	B	C	D	E	F	G	H	I	J	K	L
2	**Waste water PHH**	**Al**	**Fe**	**Zn**	**capita**	**Al**	**Fe**	**Zn**	**amount of waste water**	**Al**	**Fe**	**Zn**
3		**Substanceflux in mg/c.y**			**1.539.848**	**Substanceflux in kg/Vienna.y**			**1000 t/Vienna.y**	**Concentration in mg/kg**		
4	water of food praparation	32	100	550	1.539.848	49	154	847				
5	feces	1.980	2.200	4.380	1.539.848	3.049	3.388	6.745				
6	urine	16	30	180	1.539.848	25	46	277				
7	drinking water	1	2	14	1.539.848	2	3	22				
8	corrosion			2.700	1.539.848	0	0	4.158				
9	laundry	443.000	560	1.660	1.539.848	682.153	862	2.556				
10	dishwashing	100	200	1.300	1.539.848	154	308	2.002				
11	cleaning	14.700	15	130	1.539.848	22.636	23	200				
12	toilet	64.600	6.300	6.600	1.539.848	99.474	9.701	10.163				
13	pers. care	150	610	2.750	1.539.848	231	939	4.235				
14	cosmetic				1.539.848	0	0	0				
15	car washing	10.000	410	7.100	1.539.848	15.398	631	10.933				
16	**total**	**534.579**	**10.427**	**27.364**	**1.539.848**	**823.171**	**16.056**	**42.136**	**77.700**	**10,59**	**0,21**	**0,54**
17	Check accountg of the fluxes about measured concentration in waste water of PHH	193.260	67.111	14.129	1.539.848	297.591	103.341	21.756	77.700	3,83	1,33	0,28
18												
19	**treated waste water 1**	**77.000**	**90.000**	**12.000**	**1.539.848**	**118.568**	**138.586**	**18.478**	**195.700**	**0,61**	**0,71**	**0,09**
20	treated waste water 1	43.211	49.565	6.355	1.539.848	66.538	76.323	9.785	195.700	0,34	0,39	0,05
21	**treated waste water 2**	**130.000**	**30.000**	**20.000**	**1.539.848**	**200.180**	**46.195**	**30.797**	**195.700**	**1,02**	**0,24**	**0,16**
22	treated waste water 2	98.241	21.860	14.234	1.539.848	151.276	33.660	21.918	195.700	0,77	0,17	0,11

Zelle B,C,D 9-14 and 16: Baccini et al. (1993) S56 and S 221.

12.4.3 Private Household

The data base for the consumer goods of the private household was taken as the same reason as in the project „Anthropogenic metabolism of Vienna“ [Daxbeck et al. 1996] from Baccini et al. (1993). The values are given in the following table.

Table 12-8: Magnitude of Al, Zn and Fe flows and stocks of consumer goods of the private household [Baccini et al. 1993]

kg/c.y	Al	Zn	Fe
consumer goods	6	0.8	44
stock	34	5	410
stock increase	1	0.2	11
waste flows	5	0.6	33

12.4.4 Building Sector

The substance flows and stocks of TOC, N, Pb, Al, Fe and Zn in the construction sector were investigated in the project „Construction wastes in Upper Austria - Substance balance of construction activities“ [Glenck et al. 1997]. To calculate the Al, Fe and Zn flows and stocks for Vienna, the substance concentration of construction wastes of the Austrian Province Upper Austria [taken from Glenck et al. 1997] were multiplied with the good flows and stocks of the construction sector of Vienna [Daxbeck et al. 1996, p. 130]. In Table 12-9 the calculation and the results are given. In order to check the method, the same step was applied to C, N and Pb. A comparison of the flows and stocks of these substances (TOC, N and Pb) calculated in Table 12-9 with the Vienna investigation of these substances in construction materials of the Project „Anthropogenic metabolism of Vienna“ [Daxbeck et al. 1996] shows, that per capita the results are similar. Therefore, it is assumed that the substance flows and stocks of Al, Fe and Zn of Table 12-9 represent the order of magnitude for the Vienna construction sector.

In the project of Upper Austria, the construction material flow and stock where calculated and multiplied with substance concentration of the particular goods (references for substance concentrations used in this study are mainly (Original Sources): Sieber Cassina & Partner (1991), Lechner et al., (1991), Walker & Dohmann (1994), Merian (1985), Ellenberg et al. (1986), Brunner & Stämpfli (1993), Schachermayer et al. (1995), Reiner et al. (1996), Fehringer & Brunner (1997)).

Table 12-9: Calculation of Al, Zn and Fe flows and stocks in the construction sector per capita [based on Glenck et al. 1997, Daxbeck et al. 1996].

	C		N		Pb		Al		Fe		Zn	
	min	max	min	max	min	max	min	max	min	max	min	max
Input [kg good/c.y]	5.000	10.000	5.000	10.000	5.000	10.000	5.000	10.000	5.000	10.000	5.000	10.000
Substance content [mg/kg]	64.000	247.000	200	2.400	5	131	11.456	37.990	10.624	14.160	8	318
Input [kg/c.y]	**320**	**2.470**	**1,0**	**24**	**0,03**	**1,3**	**57**	**380**	**53**	**142**	**0,04**	**3**
Stock [kg good/c.y]	320.000	320.000	320.000	320.000	320.000	320.000	320.000	320.000	320.000	320.000	320.000	320.000
Substance content [mg/kg]	64.000	247.000	200	2.400	5	131	11.456	37.990	10.624	14.160	8	318
Stock [kg/c]	**20.480**	**79.040**	**64**	**768**	**1,6**	**42**	**3.666**	**12.157**	**3.400**	**4.531**	**3**	**102**
Stock variation [kg good/c.y]	4.000	9.000	4.000	9.000	4.000	9.000	4.000	9.000	4.000	9.000	4.000	9.000
Stock variation [kg/c.y]	**224**	**2.100**	**0,7**	**20**	**0,02**	**1,11**	**16**	**321**	**35**	**116**	**- 0,0**	**2,4**
Output [kg good/c.y]	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500
Substance content [mg/kg]	64.000	247.000	200	2.400	5	131	27.850	39.247	12.127	17.076	41	491
Output waste ITS [kg /c.y]	**96**	**371**	**0,3**	**3,6**	**0,01**	**0,2**	**42**	**59**	**18**	**26**	**0,06**	**0,7**
Export [kg good/c.y]	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200
Export waste [kg/c.y]	**77**	**296**	**0,24**	**2,88**	**0,01**	**0,16**	**33**	**47**	**15**	**20**	**0,05**	**0,59**
Landfill [kg good/c.y]	300	300	300	300	300	300	300	300	300	300	300	300
Landfill [kg/c.y]	**19**	**74**	**0,06**	**0,72**	**0,00**	**0,04**	**8**	**12**	**4**	**5**	**0,01**	**0,15**
Soil excavation [kg good/c.y]							3000	3000	3000	3000	3000	3000
Substance content [mg/kg]							50.000	50.000	17000	17000	280	280
Soil waste ITS [kg /c.y]							**150**	**150**	**51**	**51**	**0,84**	**0,84**
total waste export							**123**	**137**	**45**	**51**	**1**	**1**
total landfill input							**68**	**72**	**31**	**36**	**0**	**1**

12.4.5 Industry, Trade and Service Sector (ITS)

For the project „Anthropogenic Metabolism of the City of Vienna“ [Daxbeck et al. 1996] the statistical administrative Department of the City of Vienna provided a special information for the input and output data of the industry and trade sector of Vienna [ÖSTAT 1996]. This information was also available for this project. In the industry and trade statistics of 1991 the consumption of raw materials on the one hand and the production of goods on the other is counted. The substance content of Al, Fe and Zn in each good is not shown in these statistics, therefore estimations are necessary.

In order to determine the order of magnitude of the Iron-, Zinc- and Aluminium flows of Vienna’s industry, trade and service sector (ITS-process) the weights of these goods were summarised, which includes the name of the chosen substances in its term (e.g. Aluminium window frames, Zinc alloys). Therefore the weights of all other goods which contain one substances, but are not highlighted this in the statistics by way of the substance being included in the product name, were not taken into account (e.g. window frames). The following data gives the order of magnitude of the good flow through the process ITS which contents one of the substances under consideration. In the following tables one can see the different goods and the summarised total weight of the good input. The particular data are hidden since the particular data are under security. After the good flows were known estimations are necessary to get a number for the substance flows. This is explained more in detail below.

Table 12-10: Calculation of Al and Zn containing goods of the industry, trade and service sector (ITS) in Vienna [based on ÖSTAT 1996]

Aluminium- und Zinkhältige Roh- und Hilfsstoffe und Halbfabrikate	t Zn containing goods	t Al containing goods
INPUT:		
Metallbe- und verarbeitendes Gewerbe (BIG 480)		
Aluminium, Aluminiumlegierungen, roh		
AltAluminium, AltAluminiumlegierungen, roh		
Zink- und Zinklegierungen, roh		
Verzinkte Bleche		
Chemische Industrie (FV 50)		
Aluminiumhydrat		
Aluminiumoxyd		
Aluminiumsulfat		
Zinkprodukte, Zinklegierungen		
Stahl- und Metallverarbeitende Ind. (FV140,160 170,180 190)		
Aluminium, Aluminiumlegierungen, roh		
AltAluminium, AltAluminiumlegierungen		
Zink- und Zinklegierungen, roh		
Summe Input (gerundet)	**8,100**	**700**

OUTPUT:		
Metallbe- und verarbeitendes Gewerbe (BIG 480)		
Türen und Fensterrahmen aus Aluminium		
sonst. Leichte Bauteile aus Aluminium oder anderen NE-Metallen		
Metallindustrie (FV150)		
Aluminiumdrähte (Einheit 62 = unbekannt oder t??)		
Stahl- und Metallverarbeitende Industrie (FV 140, 180)		
Druckguß aus Aluminium		
Türen und Fensterrahmen aus Aluminium		
sonst. Leichte Bauteile aus Aluminium oder anderen NE-Metallen		
Haushaltsgeräte, verzinkt		
Dosen aus Aluminium und sonst. NE-Metallen		
Summe Output (gerundet)	**15**	**1,300**

Table 12-11: Calculation of Fe containing goods of the industry, trade and service sector (ITS) in Vienna [based on ÖSTAT 1996]

Stahl- und Metallverarbeitende Industrie (FV 140, 160, 170, 180, 190)		**Metallbe- und verarbeitendes Gewerbe (BIG 480)**	
INPUT:			
Roh- und Hilfsstoffe und Halbfabrikate	t Fe containing goods		t Fe containing goods
Gießereiroheisen Stahlschrott Ferrosilizium sonst. Ferrolegierungen Gußbruch Walzmaterial aus Stahl Kaltbandeisen Stahlrohre		Gießereiroheisen Gießereistahlroheisen Edel- und Werkzeugstahl Gießereiprodukte aus Eisen und Stahl Walzmaterial aus Stahl Kaltbandeisen Stahlrohre Stahldraht, gezogen Weißbleche Elektrobleche	
Summe Rohstoffe	**11,000**		**58,000**
Gesamtsumme Rohstoffe I+G	**70,000**		
OUTPUT:			
Gießereiindustrie (FV 140) Maschinen-und Stahlbauindustrie (FV 160) Fahrzeugindustrie (FV 170) Eisen- und Metallwarenindustrie (FV 180) Elektro- und Elektronikindustrie (FV 190)		Gießereiindustrie (FV 140) Maschinen-und Stahlbauindustrie (FV 160)	
Summe Erzeugnisse	**225,000**		**345,000**
Gesamtsumme Erzeugnisse I+G	**260,000**		

Results referring to the Aluminium flows

The input of 700 t of Aluminium containing goods is mainly due to pure metal and Aluminium alloy use in the branch of metal-working trade and industry and as Aluminium compound in the branch of the chemical industry. Corresponding products do not exist in the chemical industry. The main products of the branch of metal-working trade and industry are Aluminium frames of windows and doors and other structural components of Aluminium or other non-iron metals.

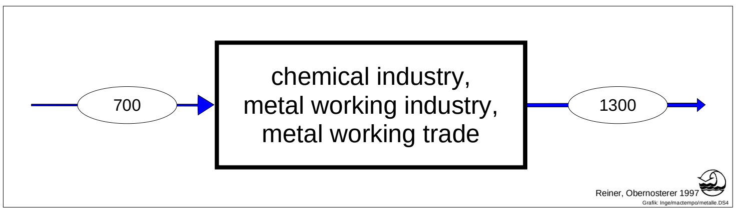


Figure 12-1: Amount of input and output flows of Aluminium-containing goods of the ITS-sector [ÖSTAT 1996] in (t goods/y)

It is assumed that there is no stock in the industry sector. Therefore the input must equal the output. Because the input consists of mainly of pure Aluminium the throughput in the ITS process is minimum 700 t Al. Compared with the output of 1.300 t of Al-containing goods, which are also more or less pure Al-goods, it could be suggested that not the whole amount of the inputs is known. **For further calculation it is suggested that more than 1,000 t Al equal 0.65 kg /c.y flows through Vienna's industry and trade sector.**

Results referring to the Zinc flows

On the input side, Zinc is used mainly in form of Zinc-coated sheet metal in the branch of metal-working trade. The same branch documents no corresponding products, containing Zinc. The only Zinc-containing products of the ITS sector are Zinc-galvanised household products of the steel and metal working industry-branch.

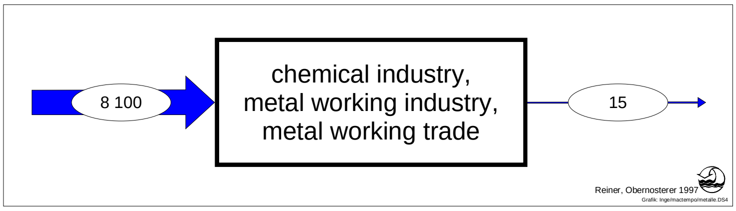


Figure 12-2: Amount of input and output flows of Zinc-containing goods of the ITS-sector [ÖSTAT 1996] in (t goods/y)

It is assumed that there is no stock in the industry sector. Therefore the input must equal the output. To calculate the throughput the input flow is important. It is assumed that for Zinc-coated sheet metal is build up by 2 mm steel metal and the Zn-sheet is 2*20µm to calculate the Zn input into the process. This leads to: **For further calculations it is suggested that more than 0.2 kg Zn /c.y flows through Vienna's industry and trade sector.**

Results referring to the Iron flows

The input goods containing Iron are mainly raw Iron and cast-iron scrap, of the steel and metal working industry and trade branch. Assuming that the input goods consists of 100 % Iron and that no losses during the production processes occur, the average Iron concentration of the output goods would be about 5%. This Fe-concentration seems to be too low for products of the steel and metal working industry, and therefore it is suggested that the input of Fe must be higher. However, for a first rough estimation the input of 70,000 t raw Iron is taken into account for the throughput of Vienna's industry and trade sector.

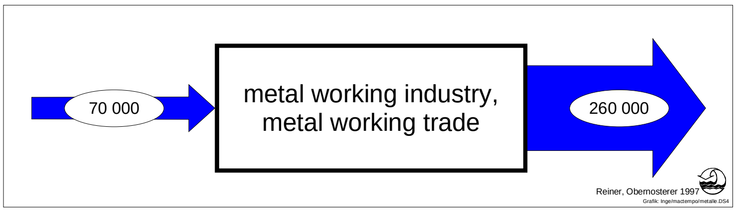


Figure 12-3: Amount of input and output flows of iron-containing goods of the ITS-sector [ÖSTAT 1996] in (t goods/y)

For further calculations it is suggested that more than 45 kg Fe /c.y flows through Vienna's industry and trade sector.

Conclusion

The estimation on the level of substances which was made above, presents following conclusion: In the following Table 12-12 the assumption of the calculated substance throughput in the ITS sector are compared with other key-flows through the city system. Comparing the minimum input into the process ITS it is obvious, that at least for Fe and Zn the ITS sector is a key-process because the amount is similar to the other numbers. For Al it is not possible to detect, if the ITS sector is a key-process for the Al- metabolism of the city or not. This is because it is possible that the Al input is higher then given in Table 12-12.

Table 12-12: Comparison ITS-process with other processes of the City of Vienna

goods	kg Al/c.y	kg Zn/c.y	kg Fe/c.y
energy sources	2	0.01	0.7
construction materials	50-465	0.1-4.3	120-170
consumer goods PHH	6.6	0.8	45
raw materials throughput ITS	>0.65	>0.2	>45

Based on the industry and trade statistic of Vienna it is not possible to balance (input equals output) the ITS-sector of Vienna, neither on the level of goods nor on the level of single substances. With this database it is only possible to find some key branches for the selected substances.

12.4.6 Waste Management

The majority of data, needed to get an overview of the waste management sector of Vienna are included in the other above sections. What is missing is the emission flows of the incineration plants of Vienna into the atmosphere. To get a first estimation, the two incineration plants for household waste (355.000 t of burned waste) were taken under consideration in 1991. The dry substance of this waste is (355.000 t/y .0,7) 250.000 t. The substance concentrations were taken from Schachermayer et al. (1995) and the transfer coefficient were taken from Morf et al. (1997).

Table 12-13: Calculation of the emissions into the atmosphere from the two incineration plants of Vienna [Schachermayer et al. 1995, Morf et al. 1997].

Waste Input (TS) in t	250,000	250,000	250,000
	Pb	**Zn**	**Fe**
Substance content g/kg	0.6	0.94	50
Transfer coefficient	0.002	0.001	0.001
Substance Flow to atmosphere kg/c.y	0.0002	0.00015	0.008

12.5 Appendix E - Calculations of the Natural Al, Zn and Fe Flows and Stocks of the City of Vienna

The following section gives the calculation for the Al, Zn and Fe flows and stocks of the City of Vienna for the link of the anthropogenic with the natural metabolism.

Table 12-14: Flows of Aluminium in environment and anthroposphere of the City of Vienna

Substance:	Aluminium (Al)											
System:	Anthroposphere and Environment											
goods:					substances:							
	flow min	Ref.	flow max	Ref.	concentration in mg/kg				taken value		flow in t	
	1000 t/a		1000 t/a		min.	Ref.	max.	Ref.	min.	max.	min.	max.
offgas	*)	L1	*)	L1	*)	L1	*)	L1	*)	*)	<15	15
leachate landfill	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
waste water [1)]	218.000	L1	218.000	L1	0,34000	L1	1,02000	L1	0,34000	1,02000	74,12	222,36
water losses	9.300	L1	9.300	L1	0,00000	L1	0,01000	L1	0,00000	0,01000	0,00	0,09
fertilizer, compost	*)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
surface run off	12.170	L2	12.170	L2	0,00000	L1	1,00000	L1	0,00000	1,00000	0,00	12,17
excavated soil	175	L1	175	L1	40.000	L1	50.000	L1	40.000	50.000	7.000	8.750
products and waste export	7.500	L1	13.300	L1	*)	*)	*)	*)	*)	*)	193.574	193.574
air export	1.400.000.000	C2	1.400.000.000	C2	*)	*)	*)	*)	*)	*)	599	4.682
deposition unbuilt area	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
deposition built area	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
fixation	0	0	0	0	0	0	0	0	0	0	0	0
groundwater supply	23.700	L1	23.700	L1	0,00000	L1	0,01000	L1	0,00000	0,01000	0,00	0,24
water infiltration	37.000	L1	37.000	L1	0,00000	L1	0,01000	L1	0,00000	0,01000	0,00	0,37
water export	52.000.000	C1	52.000.000	C1	*)	*)	*)	*)	*)	*)	2.624	12.462
soil	3.300	L1	3.300	L1	40.000	L1	50.000	L1	40.000	50.000	132.000	165.000
drinking water	138.600	L1	138.600	L1	0,00000	L1	0,01000	L1	0,00000	0,01000	0,00	1,39
product import	14.200	L1	22.400	L1	*)	*)	*)	*)	*)	*)	205.227	664.978
air import	1.400.000.000	L3	1.400.000.000	L3	0,00042	L4	0,00333	L4	0,00042	0,00333	583	4.667
water import	51.000.000	L3	51.000.000	L3	0,05000	L5	0,24000	L5	0,05000	0,24000	2.550	12.240
harvest	106	L3	106	L3	0,76500	L6	21,90	L6	0,77	21,90	0,1	2,3
soil material	1.100	L1	1.150	L1	40.000	L1	50.000	L1	40.000	50.000	44.000	55.000
release	0	A1	0	A1	0	A1	0	A1	0	0	0	0
percolation groundwater	9.140	L2	9.140	L2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
surface run off (incl. interflow)	53.000	L2	53.000	L2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

1) including treated wastewater, storm weather overflow and water of separate sewerage system
A...Assumption, L...Literature, C...Calculations, n.d. ...not determined,
*)...calculation see quoted literature, <d.l....< detection limit
A1 drift of dust particles not taken into consideration
C1 sum of exported loads in water
C2 sum of exported loads in air
L1 calculations see present study: 'results system I - anthropogenic metabolism of Vienna'
L2 Paumann et al., 1997
L3 Maier et al., 1996
L4 Fiedler & Rösler, 1993: average Aluminium concentration in urban air
L5 ÖGNU, 1988
L6 Fiedler & Rösler, 1993

Table 12-15: Stocks of Aluminium in environment and anthroposphere of the City of Vienna

Substance: **Aluminium (Al)**
System: **Anthroposphere and Environment**

goods:					**substances:**							
good	**stock min.**	**Ref.**	**stock max**	**Ref.**	**concentration in mg/kg**				**taken value**		**stock in t**	
	(1000 t)		**(kg/c)**		min.	Ref.	max.	Ref.	min.	max.	min.	max.
*)	*)	L9	*)	L9	*)	L9	*)	L9	*)	*)	6.005.407	19.094.115
Soil	199.000	L1	199.000	L1	25.000	L4	25.000	L4				
Soil	199.000	L1	199.000	L1	80.000	L4	80.000	L4				
Soil	199.000	L1	199.000	L1	4.200	L4	4.200	L4	39.050	39.050	7.770.950	7.770.950
Vegetation	4.300	L2	4.300	L2	0,7650	L5	21,9000	L5	0,7650	21,9000	3,28950	94,17000
Air	254.000	L3	254.000	L3	0,00042	L6	0,00333	L6	0,00042	0,00333	0,1058	0,8467
Surface water	44.800	L3	44.800	L3	0,05000	L7	0,06400	L7				
Surface water	44.800	L3	44.800	L3	0,0500	L8	0,2400	L8	0,0500	0,2400	2,2	10,8
Groundwater	216.000	L3	216.000	L3	0,0500	L7	0,0640	L7	0,0500	0,0640	10,8	13,8

A...Assumption, L...Literature, C...Calculations, n.d. ...not determined,
*)....calculation see quoted literature, <d.l. ...< detection limit
L1 Paumann et al., 1997: an average density of 1dm3 soil = 1,5 kg has been assumed
L2 Maier et al., 1994
L3 Maier et al., 1996
L4 Blume, 1990: average Aluminiumcontent of sandstone (25 mg/g), clay (80 mg/g) and Carbonates (4,2 mg/g), taken value bases on 40% sandstone, 35% clay and 25 % Carbonates
L5 Fiedler & Rösler, 1993
L6 Fiedler & Rösler, 1993: average Aluminiumconcentration in urban air
L7 Fiedler & Rösler, 1993: backgroundconcentration in surface water
L8 ÖGNU, 1988
L9 calculations see present study: 'results system I - anthropogenic metabolism of Vienna'

Table 12-16: Flows of Zinc in environment and anthroposphere of the City of Vienna

Substance: **Zinc (Zn)**
System: **Anthroposphere and Environment**

goods:					**substances:**							
good	**flow min**	**Ref.**	**flow max**	**Ref.**	**concentration in mg/kg**				**taken value**		**flux in t**	
	1000 t/a		**1000 t/a**		min.	Ref.	max.	Ref.	min.	max.	min.	max.
offgas	*)	L1	*)	L1	*)	L1	*)	L1	*)	*)	2	2
leachate landfill	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
waste water [1]	218.000	L1	218.000	L1	0,05000	L1	0,16000	L1	0,05000	0,16000	10,90	34,88
water losses	9.300	L1	9.300	L1	0,00000	L1	0,02000	L1	0,00000	0,02000	0,00	0,19
fertilizer, compost	*)	n.d.	*)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
surface run off	12.170	L2	12.170	L2	0,00500	L1	0,22000	L1	0,00500	0,22000	0,06	2,68
excavated soil	175	L1	175	L1	10	L1	300	L1	10	300	2	53
products and waste export	7.500	L1	13.300	L1	*)	L1	*)	L1	*)	*)	1.849	1.849
air export	1.400.000.000	C2	1.400.000.000	C2	*)	*)	*)	*)	*)	*)	94	42
deposition unbuilt area	*)	n.d.	*)	n.d.	270g/ha.a	L5	980 g/ha.a	L5	270	980	7,2	26,0
deposition built area	*)	n.d.	*)	n.d.	365 g/ha.a	L4	730 g/ha.a	L4	270	980	3,5	12,8
fixation	0	0	0	0	0	0	0	0	0	0	0	0
groundwater supply	23.700	L1	23.700	L1	0,00000	L1	0,02000	L1	0,00000	0,02000	0,00	0,47
water infiltration	37.000	L1	37.000	L1	0,00000	L1	0,02000	L1	0,00000	0,02000	0,00	0,74
water export	52.000.000	C1	52.000.000	C1	*)	*)	*)	*)	*)	*)	613	1.055
soil	3.300	L1	3.300	L1	10	L1	300	L1	10	300	33	990
drinking water	138.600	L1	138.600	L1	0,00000	L6	0,02000	L6	0,00000	0,02000	0,00	2,77
product import	14.200	L1	22.400	L1	*)	*)	*)	*)	*)	*)	3.057	6.720
air import	1.400.000.000	L3	1.400.000.000	L3	0,00007	L7	0,00006	L7	0,00007	0,00006	103	79
water import	51.000.000	L3	51.000.000	L3	0,01180	L8	0,02000	L8	0,01180	0,02000	602	1.020
harvest	106	L3	106	L3	4,50000	L9	45,00	L9	4,50	45,00	0,48	4,77
soil material	1.100	L1	1.150	L1	10	L1	300	L1	10	300	11	330
release	0	A1	0	A1	0	A1	0	A1	0	0	0	0
percolation groundwater	9.140	L2	9.140	L2	0,0247	L5	0,0619	L5	0,02470	0,06190	0,23	0,57
surface run off (incl. interflov	53.000	L2	53.000	L2	*)	C3	*)	C3	*)	*)	1,58	4,16

1) including treated wastewater, storm weather overflow and water of separate sewerage system
A...Assumption, L...Literature, C...Calculations, n.d. ...not determined,
*)...calculation see quoted literature, <d.l. ...< detektion limit
A1 drift of dust particles not taken into consideration
C1 sum of exported loads in water
C2 sum of exported loads in air
C3 sum of erosion, surface run off and interflow basing on a soil removal of 0,2 - 2 t/ha.a and a Zincconcentration in soil of 52-165 mg/kg
L1 calculations see present study: 'results system I - anthropogenic metabolism of vienna'
L2 Paumann et al., 1997: an average density of 1dm3 soil = 1,5 kg has been assumed
L3 Maier et al., 1996
L4 Meyer, 1991: average Zinc-deposition in urban areas
L5 Kernbeis, 1995
L6 Henseler et al.,1992
L7 Ober & Puxbaum, 1988: Zinccontent of suspended dust particels (0,1-25 µm), detected at two sampling points in vienna (Arsenal, Exelberg)
L8 Fleckseder, 1986: Zinc-concentration in the danube before and after vienna
L9 Merian, 1984

Table 12-17: Stocks of Zinc in environment and anthropospere of the City of Vienna

Substance: **Zinc (Zn)**
System: **Anthroposphere and Environment**

goods:					**substances:**							
good	**stock min. (1000 t)**	**Ref.**	**stock max (kg/c)**	**Ref.**	**concentration in mg/kg**				**taken value**		**stock in t**	
					min.	Ref.	max.	Ref.	min.	max.	min.	max.
*)	*)	L15	*)	L15	*)	L15	*)	L15	*)	*)	4.620	153.985
Soil	199.000	L13	199.000	L13	43,7	L4	92,4	L4				
Soil	199.000	L13	199.000	L13	59,4	L5	99,4	L5				
Soil	199.000	L13	199.000	L13	31,4	L6	77,6	L6				
Soil	199.000	L13	199.000	L13	65,9	L7	230,6	L7				
Soil	199.000	L13	199.000	L13	66,8	L8	407,9	L8				
Soil	199.000	L13	199.000	L13	39,0	L9	267,0	L9	51,6	165,0	10.258	32.835
Vegetation	4.300	L1	4.300	L1	4,50000	L12	45,000	L12	4,5	45,0	19	194
Air	254.000	L2	254.000	L2	0,00007	L11	0,00006	L11	0,00007	0,00006	0,01863	0,01439
Surface water	44.800	L2	44.800	L2	0,01180	L3	0,01430	L3				
Surface water	44.800	L2	44.800	L2	0,00000	L12	0,02000	L12	0,01180	0,02000	0,52864	0,8960
Groundwater	216.000	L2	216.000	L2	0,00000	L14	0,02000	L14				
Groundwater	216.000	L2	216.000	L2	<0,0100	L10	<0,0100	L10	<0,0100	0,02000	< 2,16000	4,32000

A...Assumption, L...Literature, C...Calculations, n.d. ...not determined,
*)...calculation see quoted literature, <d.l. ...< detektion limit
L1 Maier et al., 1994
L2 Maier et al., 1996
L3 Fleckseder, 1986: Zinc-concentration in the danube before and after vienna
L4 Meyer,1991: widespread Zincconcentration of agricultural used soil (0-20cm) in Swizerland
L5 Meyer,1991: widespread Zincconcentration of soil of area under special cultivation (0-20cm) in Swizerland
L6 Meyer,1991: widespread Zincconcentration of soil in forests (0-20cm) in Swizerland
L7 Meyer,1991: widespread Zincconcentration of soil in settled areas (0-20cm) in Swizerland
L8 Meyer,1991: widespread Zincconcentration of soil in high polluted areas (0-20cm) in Swizerland
L9 Brunner & Stoye, 1995: Zinconcentrations of urban soil (Leipzig)
L10 Fiedler & Rösler, 1993
L11 Ober & Puxbaum, 1988: Zinccontent of suspended dust particels (0,1-25 µm), detected at two sampling points in vienna (Arsenal, Exelberg)
L12 Merian, 1984
L13 Paumann et al., 1997: an average density of 1dm3 soil = 1,5 kg has been assumed
L14 Henseler et al.,1992
L15 calculations see present study: 'results system I - anthropogenic metabolism of vienna'

Table 12-18: Flows of Iron in environment and anthroposphere of the City of Vienna

Substance: **Iron (Fe)**
System: **Anthroposphere and Environment**

goods:					**substances:**							
good	**flow min**	**Ref.**	**flow max**	**Ref.**	**concentration in mg/kg**				**taken value**		**flux in t**	
	1000 t/a		**1000 t/a**		min.	Ref.	max.	Ref.	min.	max.	min.	max.
offgas	*)	L1	*)	L1	*)	L1	*)	L1	*)	*)	154	154
leachate landfill	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
waste water [1)]	218.000	L1	218.000	L1	0,39000	L1	0,71000	L1	0,39000	0,71000	85,02	154,78
water losses	9.300	L1	9.300	L1	<d.l.	L7	0,42000	L7	<d.l.	0,42000	<3,91	3,91
fertilizer, compost	n.d.	n.d.	*)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
surface run off	12.170	L2	12.170	L2	0,03800	L1	0,66000	L1	0,03800	0,66000	0,46	8,03
excavated soil	175	L1	175	L1	17.000	L1	20.000	L1	17.000	20.000	2.975	3.500
products and waste export	7.500	L1	13.300	L1	*)	L1	*)	L1	*)	*)	192.481	192.481
air export	1.400.000.000	C2	1.400.000.000	C2	*)	*)	*)	*)	*)	*)	1.043	2.427
deposition unbuilt area	*)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
deposition built area	*)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
fixation	0	0	0	0	0	0	0	0	0	0	0	0
groundwater supply	23.700	L1	23.700	L1	<d.l.	L7	0,42000	L7	0,00000	0,42000	0,00	9,95
water infiltration	37.000	L2	37.000	L2	<d.l.	L7	0,42000	L7	0,00000	0,42000	0,00	15,54
water export	52.000.000	C1	52.000.000	C1	*)	*)	*)	*)	*)	*)	3.145	19.535
soil	3.300	L1	3.300	L1	17.000	L1	20.000	L1	17.000	20.000	56.100	66.000
drinking water	138.600	L1	138.600	L1	0,00000	L1	0,01000	L1	0,00000	0,01000	0,00	1,39
product import	14.200	L1	22.400	L1	*)	L1	*)	L1	*)	*)	237.549	381.634
air import	1.400.000.000	L3	1.400.000.000	L3	0,00064	L4	0,00162	L4	0,00064	0,00162	889	2.273
water import	51.000.000	L3	51.000.000	L3	0,06000	L6	0,38000	L6	0,06000	0,38000	3.060	19.380
harvest	106	L3	106	L3	2,04000	L5	18,30	L5	2,04	18,30	0,22	1,94
soil material	1.100	L1	1.150	L1	17.000	L1	20.000	L1	17.000	20.000	18.700	22.000
release	0	A1	0	A1	0	A1	0	A1	0	0	0	0
percolation groundwater	9.140	L2	9.140	L2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
surface run off (incl. interflow)	53.000	L2	53.000	L2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

1) including treated wastewater, storm weather overflow and water of separate sewerage system
A...Assumption, L...Literature, C...Calculations, n.d. ...not determined,
*)...calculation see quoted literature, <d.l. ...< detektion limit
A1 drift of dust particles not taken into consideration
C1 sum of exported loads in water
C2 sum of exported loads in air
L1 calculations see present study: 'results system I - anthropogenic metabolism of vienna'
L2 Paumann et al., 1997
L3 Maier et al., 1996
L4 Krivan & Egger, 1986
L5 Fiedler & Rösler, 1993
L6 ÖGNU, 1988
L7 BMfLF, 1995: ironcontent of vienna's groundwater

Table 12-19: Stocks of Iron in environment and anthropopshere of the City of Vienna

Substance:	**Iron (Fe)**
System:	**Anthroposphere and Environment**

goods:					**substances:**							
good	**stock min.**	**Ref.**	**stock max**	**Ref.**	**concentration in mg/kg**				**taken value**		**stock in t**	
	(1000 t)		**(1000 t)**		min.	Ref.	max.	Ref.	min.	max.	min.	max.
*)	*)	L11	*)	L11	*)	L11	*)	L11	*)	*)	6.467.362	8.315.179
Soil	199.000	L1	199.000	L1	9.800	L4	9.800	L4				
Soil	199.000	L1	199.000	L1	47.000	L4	47.000	L4				
Soil	199.000	L1	199.000	L1	3.800	L4	3.800	L4	21.320	21.320	4.242.680	4.242.680
Vegetation	4.300	L2	4.300	L2	2,0400	L5	18,3000	L5	2,04	18,30	8,77200	78,69000
Air	254.000	L3	254.000	L3	0,00008	L6	0,00100	L6				
Air	254.000	L3	254.000	L3	0,00064	L7	0,00162	L7	0,00064	0,00162	0,16129	0,41233
Surface water	44.800	L3	44.800	L3	0,6700	L8	0,6700	L8				
Surface water	44.800	L3	44.800	L3	0,0600	L10	0,3800	L10	0,06000	0,38000	2,68800	17,02400
Groundwater	216.000	L3	216.000	L3	<d.l.	L9	0,42000	L9	0,03125	0,03125	6,75000	6,75000

A...Assumption, L...Literature, C...Calculations, n.d. ...not determined,
*)...calculation see quoted literature, <d.l. ...< detektion limit
L1 Paumann et al., 1997: an average density of 1dm3 soil = 1,5 kg has been assumed
L2 Maier et al., 1994
L3 Maier et al., 1996
L4 Blume, 1990: average ironcontent of sandstone (9,8 mg/g), clay (47 mg/g) and Carbonates (3,8 mg/g), taken Value bases on 40% sandstone, 35% clay and 25 % Carbonates
L5 Fiedler & Rösler,
L6 Merian, 1984
L7 Krivan & Egger, 1986
L8 Merian, 1984
L9 BMfLF, 1995: ironcontent of vienna's groundwater
L10 ÖGNU, 1988
L11 calculations see present study: 'results system I - anthropogenic metabolism of vienna'

12.6 Appendix F - Detailed Figures of the Anthropogenic Metabolism of the City of Vienna

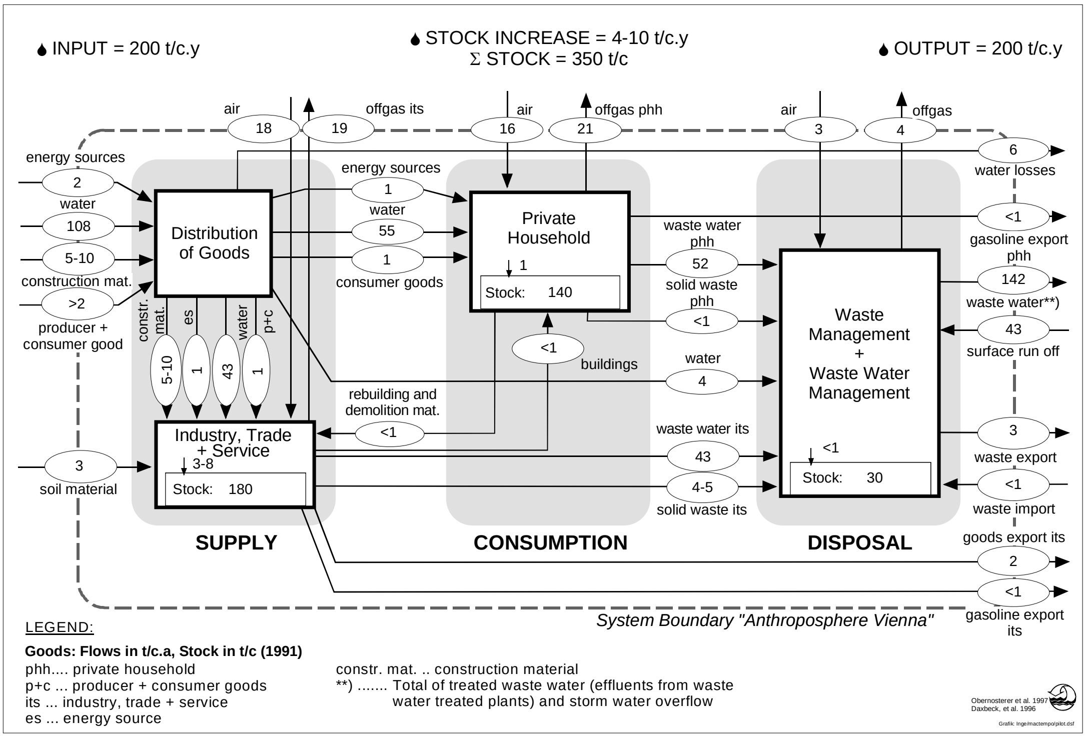


Figure 12-4: Flows and stocks of Goods in the Anthroposphere of the City of Vienna

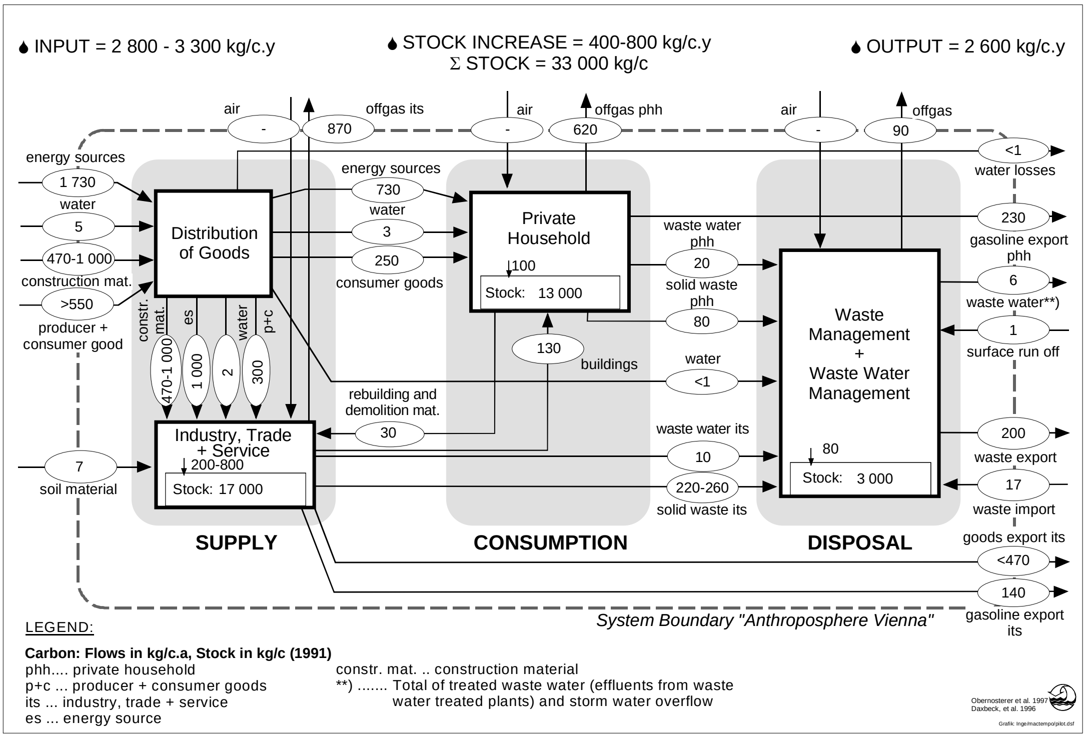


Figure 12-5: Flows and stocks of Carbon in the Anthroposphere of the City of Vienna

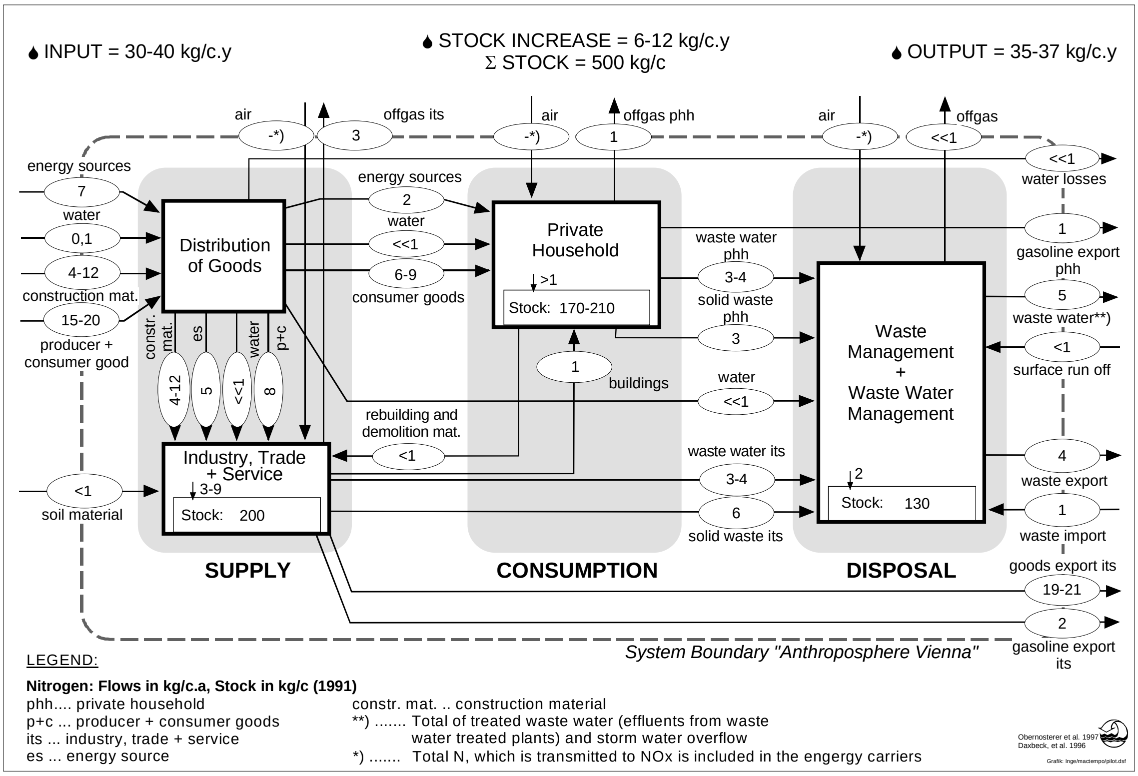


Figure 12-6: Flows and stocks of Nitrogen in the Anthroposphere of the City of Vienna

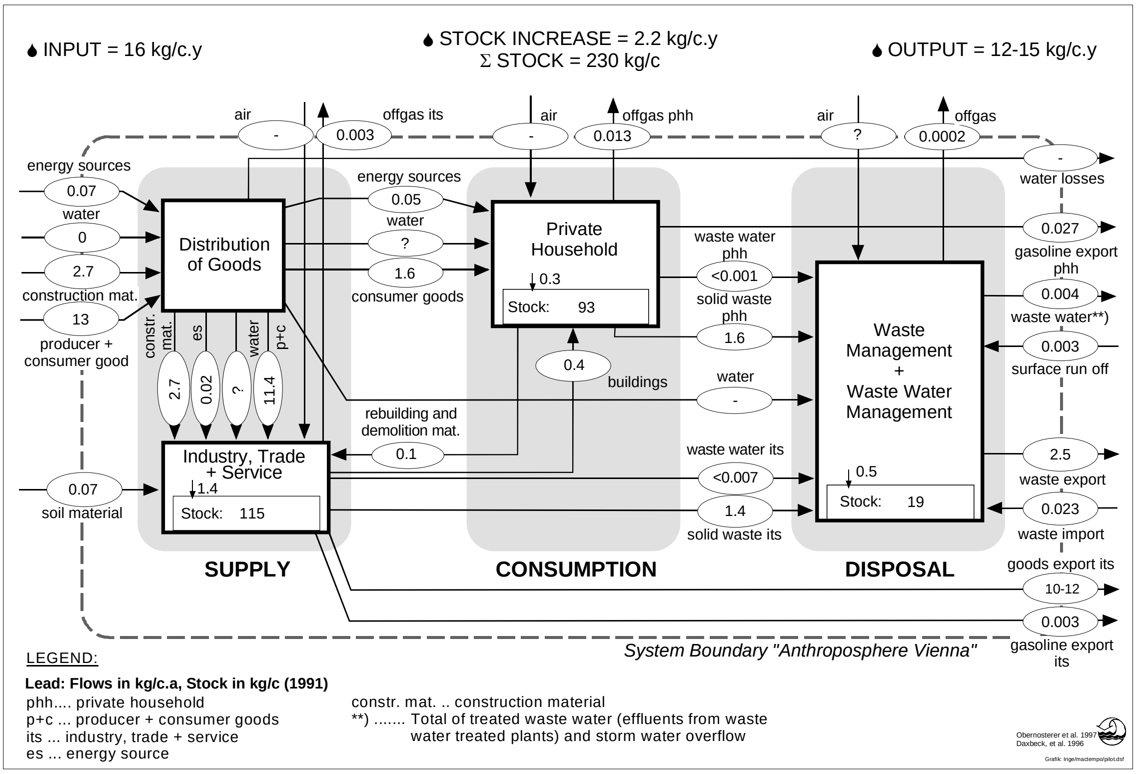


Figure 12-7: Flows and stocks of Lead in the Anthroposphere of the City of Vienna

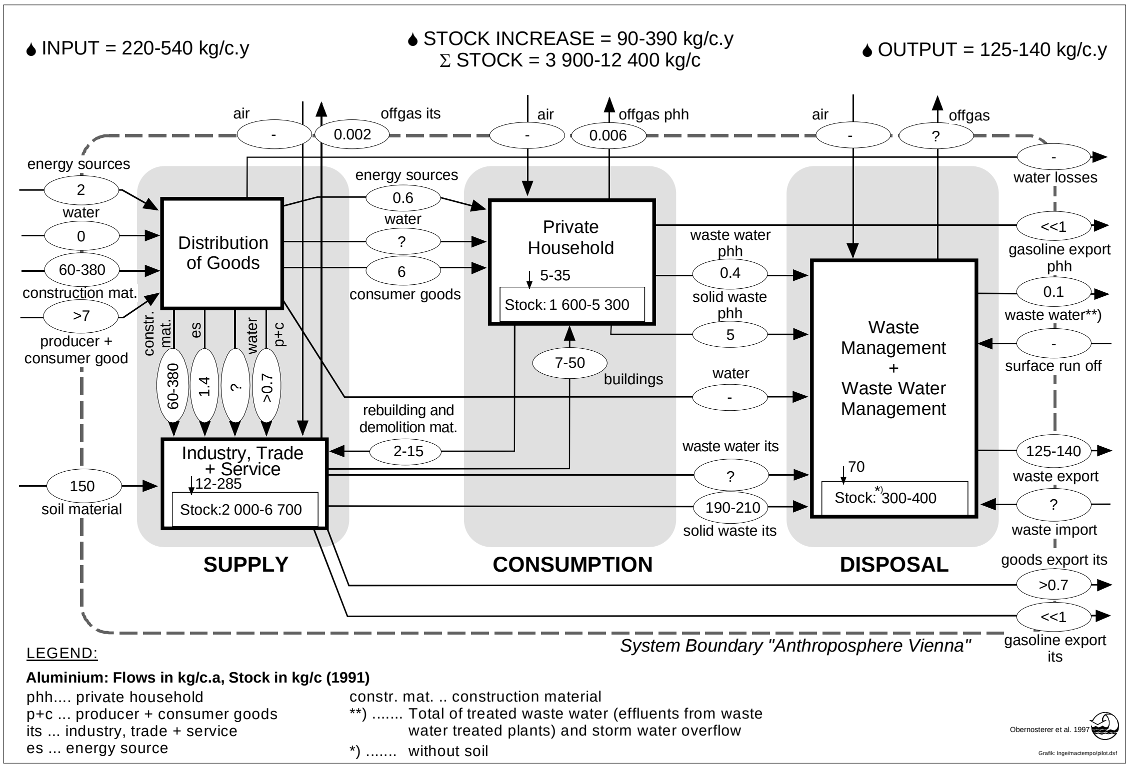


Figure 12-8: Flows and stocks of Aluminium in the Anthroposphere of the City of Vienna

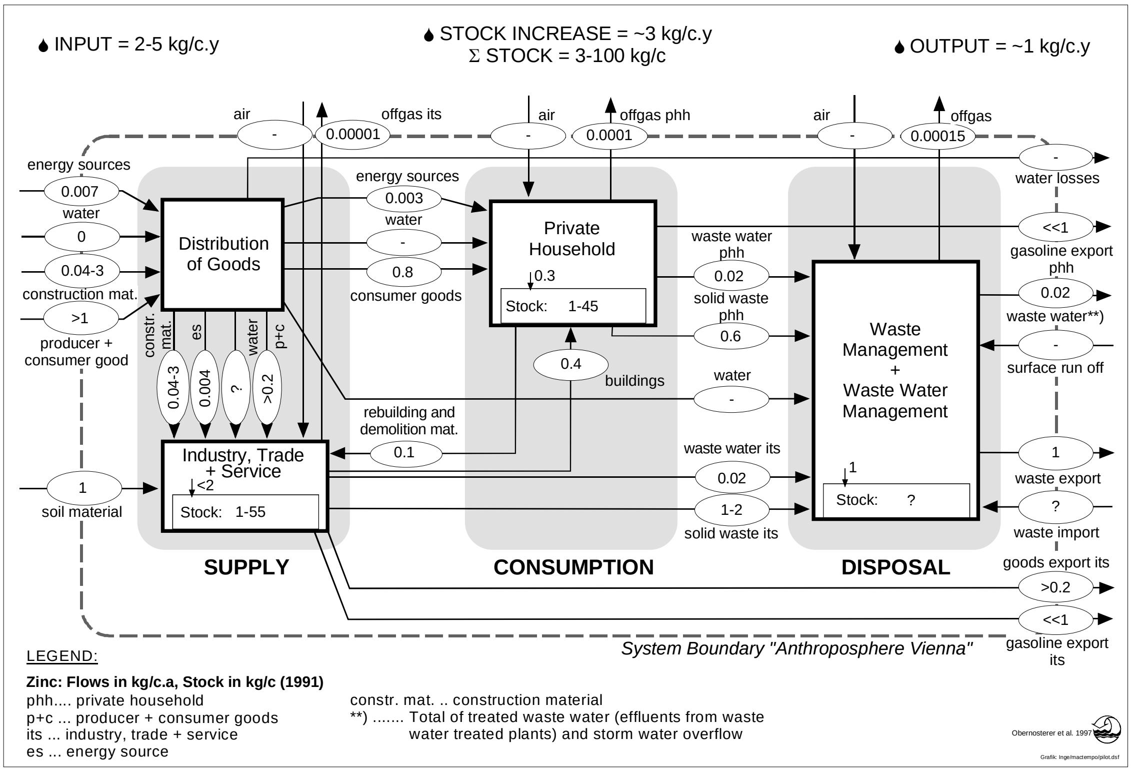


Figure 12-9: Flows and stocks of Zinc in the Anthroposphere of the City of Vienna

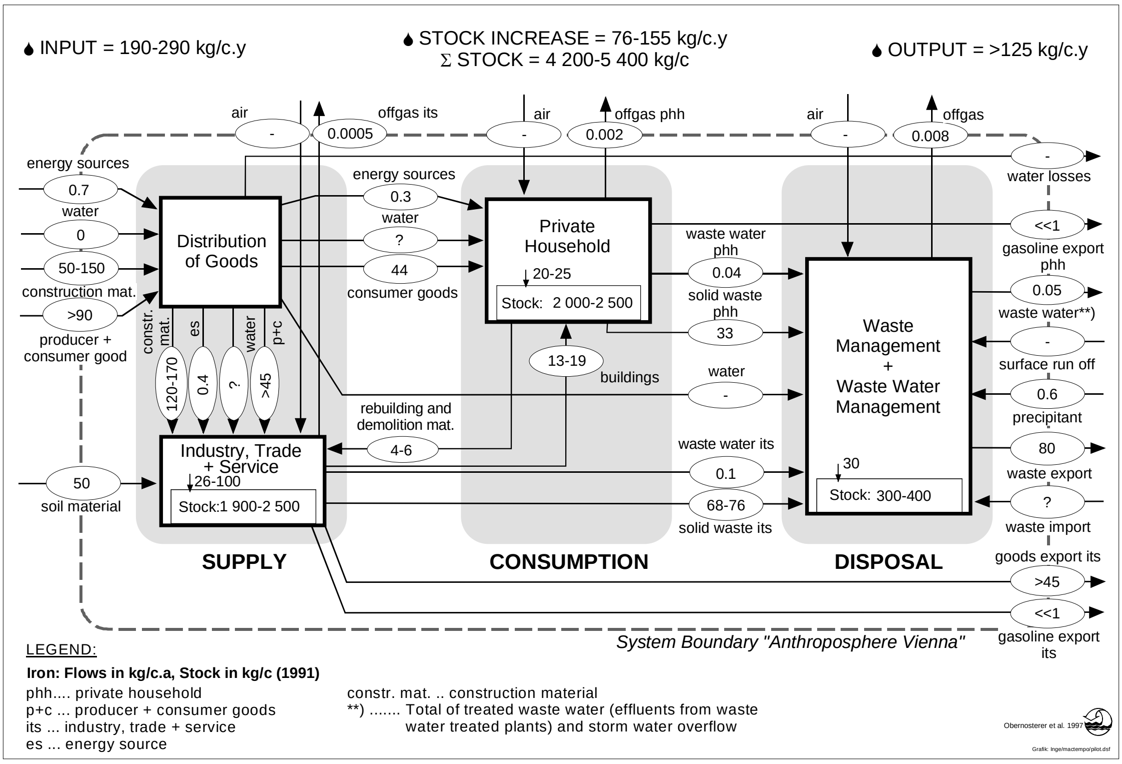


Figure 12-10: Flows and stocks of Iron in the Anthroposphere of the City of Vienna

12.7 Appendix G - Figures of the Link Environmental and Anthropogenic Metabolism for Al, Zn and Fe

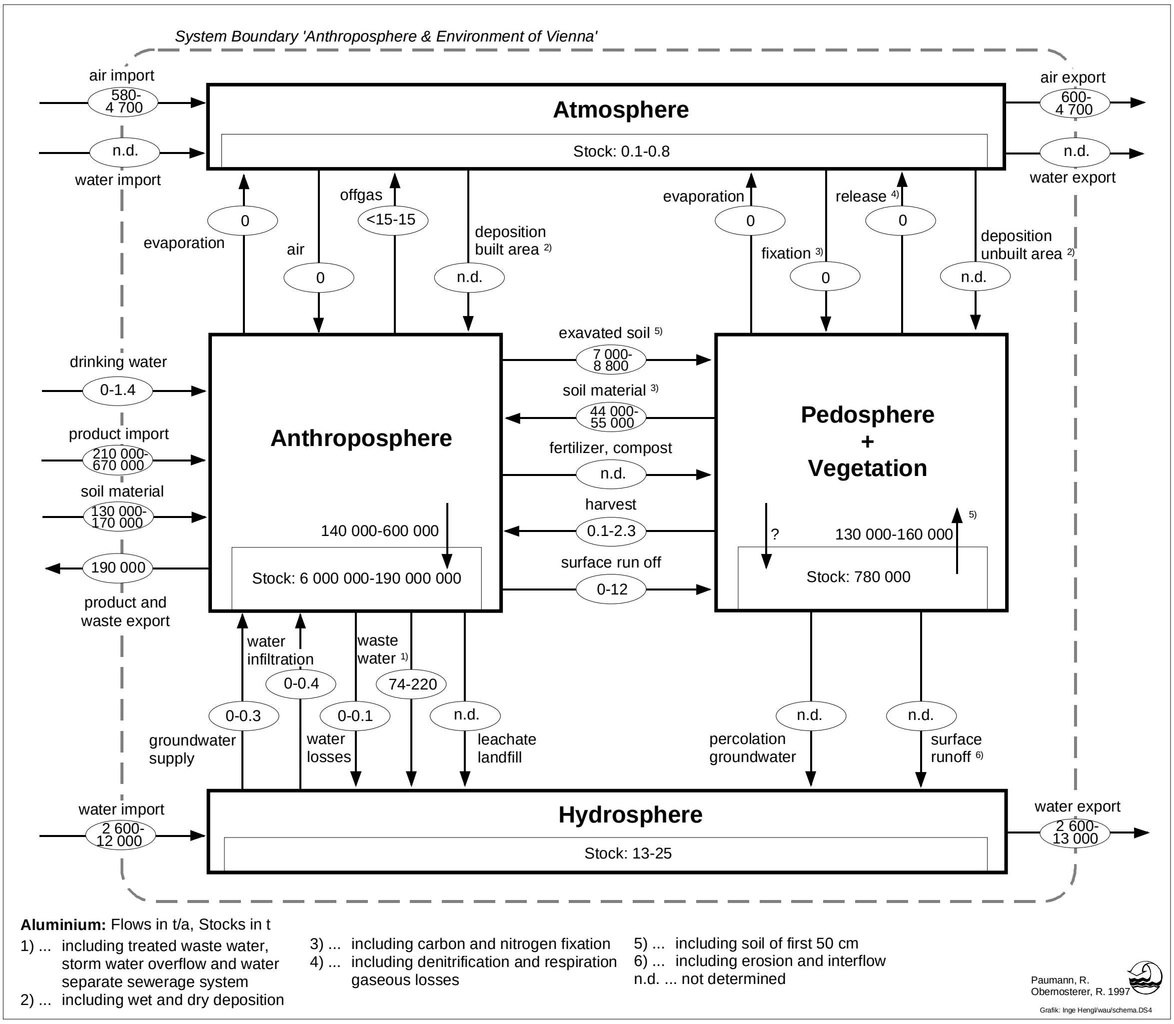


Figure 12-11: Flows and stocks of Aluminium in environment and anthroposphere of the City of Vienna

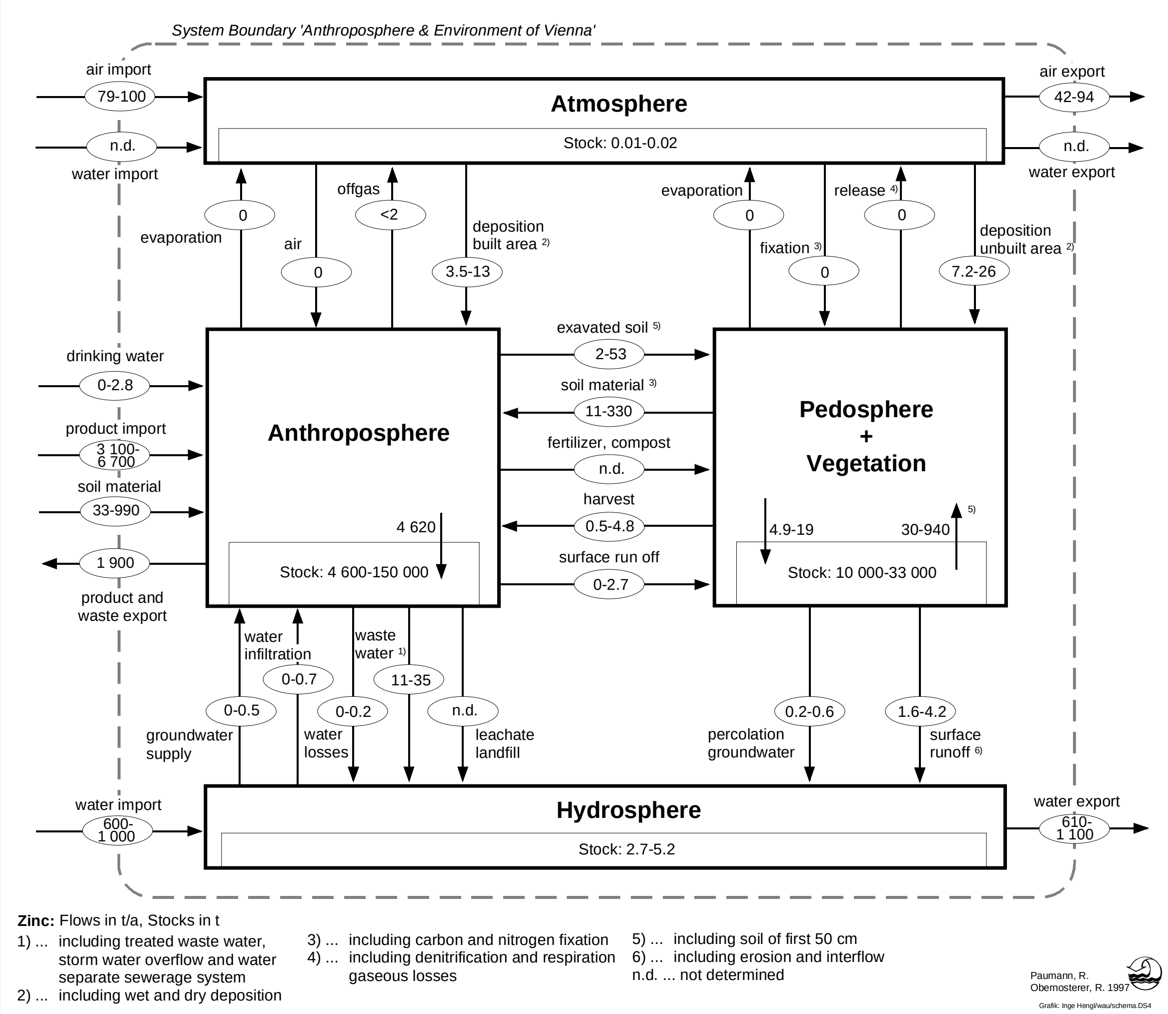


Figure 12-12: Flows and stocks of Zinc in environment and anthroposphere of the City of Vienna

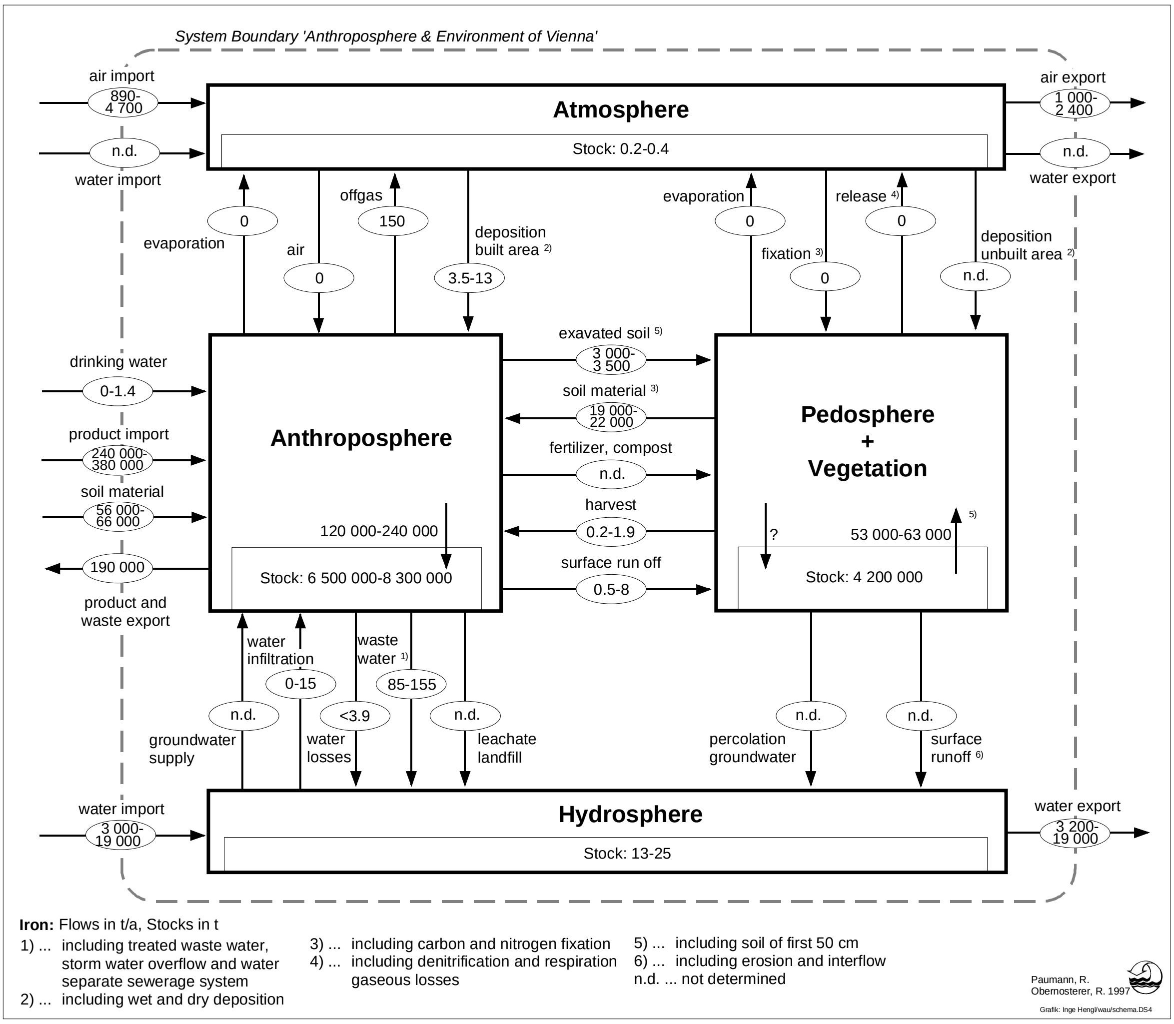


Figure 12-13: Flows and stocks of Iron in environment and anthroposphere of the City of Vienna

12.8 Appendix H - Calculations of Specific Case Studies used in this Report

12.8.1 MFSA as a Tool to Measure the Potential Effect of the Current Construction Waste Regulations

Introduction

As the MFSA results from Vienna reveals, construction wastes are the main quantity flow in the waste management system and also one of the key-flows of the whole metabolism. The bulk flow of construction waste is a mixture of soil, stones and gravel, concrete, plastics, wood, metals and other materials. Approximately 95% of construction materials consumed in Vienna in 1991 consists of inert, inorganic and non-metal materials. Due to construction and demolition practices the construction waste fraction is currently mixed with organic materials and metals. This heterogeneous waste product essentially means that quality problems can be encountered in both the recycling and the after use phase of materials management.

A key discussion point in the management of construction wastes is the reduction of waste to landfill. There are also quality problems associated with the disposal of construction waste to landfill e.g. groundwater pollution may result from leaking or non-existent landfill seals. Furthermore, the organic Carbon content in landfills also leads to biological activities in landfills, e.g. generating methane and other greenhouse gases. In order to prevent these problems arising in the future, the Austrian Government have recognised that recycling of construction wastes must increase in the future and implemented certain flow regulations. These Austrian policies are not yet fully implemented and in many areas it is still relatively inexpensive to landfill large volumes of construction wastes.

This chapter discusses how MFSA could be used to assess how these policies could operate in the future in order to fulfil the goals of the regulations. In particular, the effectiveness of the current policy is discussed in relation to reducing environmental impact and resource depletion for Vienna.

Current Policy Situation

The general waste management law [BGBL. 325 1990] provides the basis and guideline for all waste management activities in Austria. Waste management activities in this context must be guided by the following four goals:

- the impact to human and the environment must minimal
- protection of resources and energy
- consumption of landfill volume as small as possible
- precaution principle, final storage quality

To reach these goals, three principles ”avoid, recycle/ utilise, and disposal” are also recommended in that order of priority.

In January 1993 a regulation to separate construction and demolition waste was introduced in Austria [BGBL 259 1991]. If, on one single building site the defined quantity of different waste compartments (e.g. mineral construction waste 40 t, concrete 20 t etc.) is exceeded then construction and demolition waste must be separated into these compartments. The separated products must have a level of quality well suited for recycling.

System definition and assumptions

As mentioned above, this example is based on the current construction waste flows through Vienna. The example does not show the current situation of the construction and demolition waste streams but rather it simulates how the system could respond when the current policy is fully operational. Furthermore, this scenario depends on a number of assumptions. It is prepared mainly to show the use of MFSA, in particular on the level of goods for measure the effectiveness of policies. For further discussion it is essential to check the assumptions made by the department of IWAG. This section provides one possible and realistic scenario with following assumptions:

The magnitude of the mass and substance flows and stocks were taken from the case study Vienna [Daxbeck et al. 1996]. The spread of the flows (e.g. input flow between 8 - 16 mio.t) and stocks of the Vienna case study are not taken into account. Based on the results from the Vienna case study, it appears that about 10 mio. t of construction materials are used in Vienna each year. The composition of these input-flows consist of approximately 8.8 mio. t of gravel, sand, cement and concrete; 0.9 Mill t of asphalt (bitumen and gravel) and 0.3 mio. t of other goods like plastics, wood and metals.

The corresponding output flows of Vienna calculated in previous studies assumed 7.2 mio. construction and demolition waste in Vienna ([GUA 1988] see Table 12-20). This amount includes about 5.6 Mill t soil excavation associated with construction activities, which goes mainly to landfill.

Table 12-20: Calculation of the amount of the different output flows into the sorting plants (based on [GUA 1988]).

fraction	in 1,000 t [GUA 1988]
soil excavation	5,600
mineral construction waste	660
waste from road building sites	340
building site waste	585
total	7,200

According to the legislation a large percentage of these construction flows should be recycled. Separation for recycling could be performed either in a sorting plant, or directly by the reconstruction of buildings on-site or by a combination of the two. It is assumed in this case study that the current legislation is closely adhered to. And therefore for the scenario it is assumed, that 100 % of the construction wastes go to recycling plants.

Results from two MFSA-studies on construction waste sorting plants on the enterprise level [Brunner & Stämpfli 1993, Schachermayer et al. 1997] were used in order to get the information how much of the flow can be recycled in a way, that the quality is well suited for re-use. That means that it is assumed, that the correspondent sorting plants can be characterised by these two enterprises. The systemboundary relate to construction activities for Vienna, means that e.g. there is no difference between landfills within or without the administrative boundaries of Vienna.

A recycling plant for mineral construction waste was investigated in [Schachermayer et al. 1997]. According to this study from the amount of the mineral construction waste coming into the plant, about 80% (for the scenario here: 530,000 t) can be used again after the recycling process. This is mainly because the quality of the input materials is high due to a first separation process on the site.

A recycling plant for building site waste was investigated in [Brunner & Stämpfli 1993]. According to this study the products of the separation are not suited for re-use. However, the quality of the products improve for disposal. This is mainly due to the separation of one fraction where organic Carbon is enriched. This fraction is well suited for incineration. Taking the above assumptions and the results of the investigation of Brunner & Stämpfli (1993) for Vienna a fraction of about 150,000 t would need to be incinerated (transfer coefficient for this fraction 0.25). What this means for Vienna is the need of a further incineration plant. However, this rough assumption shows a need for further management for the stock and for disposal of the construction waste. In order to further define strategies and to evaluate the above mentioned conclusion, further studies on the substance level are needed.

Because of lacking of data a recycling rate of road waste is assumed at 50% (170,000 t).

Results

Resource depletion of about 10,000,000 t for providing the City with mass construction materials from the Hinterland on one hand must be traded against soil excavation of about 5,600,000 t by building activities within the city at the other hand. The whole amount of waste from construction activities is about 7,200,000 t. Under the assumptions of the scenario 700,000 t of virgin resources could be avoided by recycling construction wastes.

Conclusion

The MFSA results from the City of Vienna allows one to discuss the effect of recycling policy to the current bulk flows in the construction sector. Using today’s demolition techniques the current policy might, when fully implemented, reduce the amount of construction waste flows going to landfill by 45%. Including excavated soil, which goes mainly to landfill by construction activities, this amount decreases by 10%. Due to the bulk flows of construction waste it could be concluded that in view of reducing landfill volume soil management is more needed than recycling of construction and demolition waste. Comparing the recycling potential of construction waste with resource depletion, the amount useful for recycling could only reduce the use of virgin materials of gravel and sand by 7%. In order to further reduce the use of virgin materials, alternative construction and planning approaches should be adopted such as focusing on higher density settlements. MFSA on a good level, is well suited to discuss the effect in a quantity sense. To evaluate the quality related goals: human and environmental impact and final storage quality of the Austrian waste management law substance related investigations would be necessary.

12.8.2 Calculations of Nitrogen Flows in the „Hinterland" induced by Vienna

ASSUMPTIONS

- for the purposes of this study the „Hinterland" was limited to Austria only, and in reality the „Hinterland" for any city now extends into the global domain
- it is assumed that the „Hinterland" for Vienna represents approximately 20% of the flows of the whole of Austria. This is based on the fact that the Viennese population represents approximately 20% of the Austrian population.
- the influence of tourism in Vienna and in the „Hinterland" is considered negligible since the inflow and outflow of tourists is not significantly different.
- the N flows from the household and industry in the „Hinterland" is not considered (i.e. effluent WWTP (waste water treatment plant) in the „Hinterland" is not included)

ANALYSIS

- The following relationship was used to calculate the N flows in the „Hinterland" induced by Vienna

$$\boxed{HL = 0{,}2 * A - V}$$

where HL = the N flow in the Hinterland induced by the metabolism of Vienna
A = total flow of N contributing to surface water in Austria [Somlyódy et al 1997] V= a particular flow of N contributing to surface water in Vienna [Paumann et al. 1997]

Table 12-21: Calculation of Nitrogen flows in the Hinterland into the River Danube induced by the metabolism of Vienna

Nitrogen Flow	(1) Total Flow in Austria kt/year	(2) Flow in the Hinterland + Vienna = 20% * (1)	(3) Flow in Vienna kt/year	(4) Total in Hinterland =(2) - (3) Hinterland kt/year
percolation to groundwater from agriculture land	47	9.4	0.203	9.2
percolation from forested land and other	34	6.8	0.226	6.8
base flow	60	12	0.362	11.6
surface runoff from forest and from land types other than agriculture	9	1.8	0.036	1.7
erosion and runoff from agricultural land	8	1.6	0.026	1.58
effluents from WTTP (industry and PHH) into Danube	-	-	6.6	-
TOTAL	**-**	**-**	**7.02**	**14.88**

(1) Data taken from *Nutrient Balances for Danube Countries.* Project EU/AR/102A/91 [Somlyódy et al 1997]
(3) Data taken from the Metabolism of Vienna - Link with anthroposphere and natural flows [Paumann et al. 1997]

The „Hinterland“ flows were calculated for the main flows into the surface water[10]:

- base flow in groundwater (from percolation from both agriculture and „other“ land)
- erosions and runoff from agricultural land
- erosion and surface runoff from forested and from „other“ land

12.8.3 Comparison of Linear, Current and Cyclical Use of Car Batteries in Vienna

This Annex discusses the results of a study [Smutny 1998] investigating the Lead emissions resulting from two different management scenarios and the current case for the use of car batteries in Vienna. The two scenarios are linear versus the cyclic use. In the linear use it is suggested that no car battery is recycled leaving Vienna. In the cyclic case a recycling rate from 100 % and no need for mining is suggested. That means that the losses from recycling procedures are filled up with the city stock (e.g. of the Lead stock in water pipes, see stock management chapter 6.2). The Lead emissions resulting for the use of car batteries in Vienna into the environment (atmosphere, hydrosphere and pedosphere) were calculated over a period of one year within Vienna as well as in the corresponding Hinterland. Long term atmospheric and hydrospheric emissions from the landfilled portions are not included in the calculations.

<u>Emissions into the Atmosphere:</u>

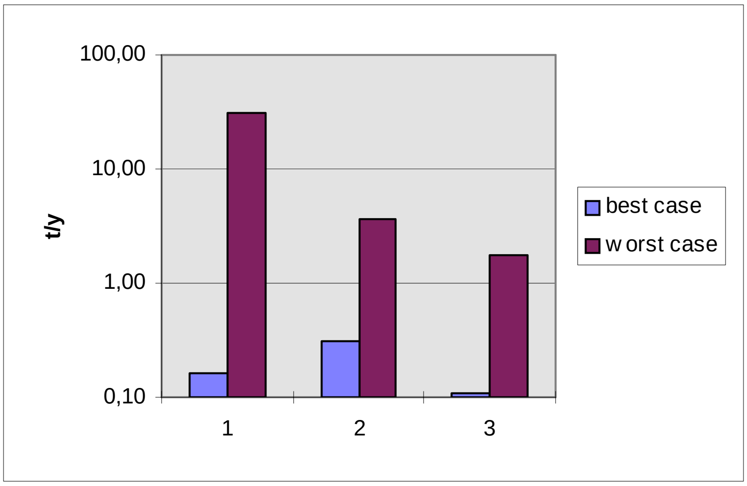


Figure 12-14: Emission into the Atmosphere by the use of car batteries of the Viennese in one year, Lead emitted within Vienna and induced emissions in the Hinterland (1: linear use, 2: current use, 3: cyclic use) [Smutny 1998]

[10] Not considering effluent flows from WTTP in the Hinterland

The results indicate a general difference of the strategies by 2 orders of magnitude. Depending on the used technology (best-worst case) in the scenario „linear use“ between 0.2 and 30 t of Lead would be emitted into the atmosphere and in the „cyclic use“ between 0,1 and 2 t. The current situation generates emissions between 0.3 and 4 t, depending on the technology used in mining and primary industry.

Emissions into the hydrosphere:

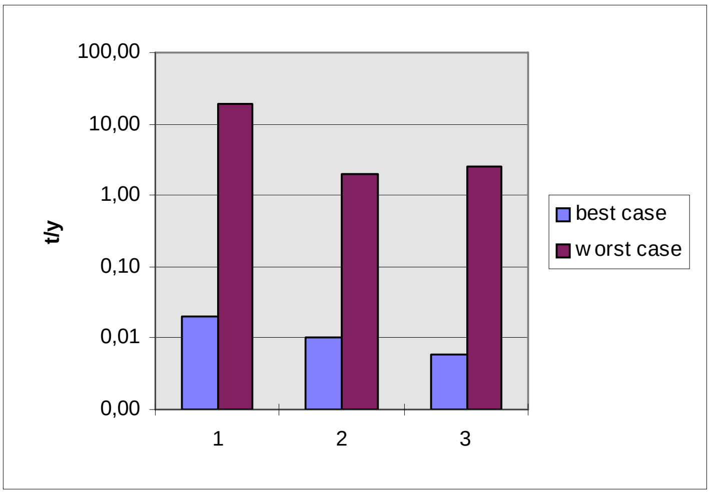


Figure 12-15: Emission into the Hydrosphere by the use of car batteries of the Viennese in one year, Lead emitted within Vienna and induced emissions in the Hinterland (1: linear use, 2: current use, 3: cyclic use) [Smutny 1998]

The results indicate a difference (3 orders of magnitudes) common to all strategies. Depending on the used technology (best-worst case) in the scenario „linear use“, between 0.02 and 20 t of Lead would be emitted into the hydrosphere and in the „cyclic use“ between 0.01 and 2.5 t. The current situation leads to emissions between 0.01 and 2 t, depending on the technology used in mining and primary industry.

Emissions into the landfill:

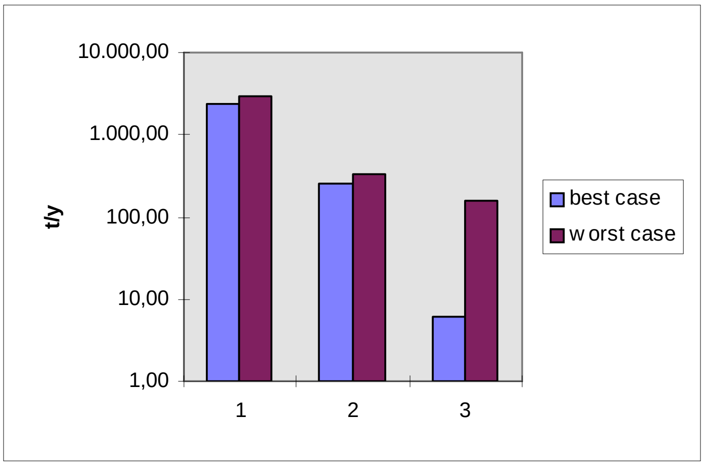


Figure 12-16: Emission into the landfill (pedosphere) by the use of car batteries of the Viennese in one year, Lead landfilled within Vienna and induced amounts in the Hinterland (1: linear use, 2: current use, 3: cyclic use) [Smutny 1998]

The results indicate a general difference of the strategies by 2 orders of magnitude. In the scenario „linear use", depending on the used technology (best-worst case), between 2,400 and 3,000 t of Lead in one year could be landfilled. In the scenario „cyclic use", this amount is between 6 and 160t. The current situation leads to output flows into the pedosphere between 250 and 325 t depending on the used technology in the mining and primary industry.

12.8.4 Specific Calculation for Early Recognition

Forecasting of Lead content in Vienna's soil:

- Today the average Lead content in Vienna's' soil (50 cm) is approximately 60 mg Pb/kg [Maier et al. 1996]. Measured values reach from 21 mg Pb /kg in non polluted areas (Vienna's forests) up to 716 mg Pb /kg near high frequented streets [MA 22 1995]. The increase of the stock of Lead in soil has been calculated as 12,1 - 12,7 t/a in 1991 [Paumann et al. 1997]. This accumulation rate has decreased to 6 - 6,3 t/a since 1991 as a result of the total ban of leaded petrol. Nevertheless, the standard of 100 mg/kg [Eikmann & Kloke, 1993] will be exceeded in 253 - 265 years in the first 10 cm of the pedosphere, which is mainly exposed to humans, especially to children, all over Vienna (calculation bases on the average lead-content of 60 mg/kg).

Table 12-22: Calculation for forecasting the Lead content in Vienna's soil

Parameter		from	to	Reference
stock of soil (50 cm)	1000 t	199.000	199.000	Paumann et al.1997
Range of Lead concentration in soil	mg Pb/kg	21	715,7	MA 22 1995
average Lead concentration (50 cm)	mg Pb/kg	60	60	Maier et al. 1996
stock of Lead in soil (50 cm)	t Pb	11.881	11.882	Maier et al. 1996
Increase in Lead stock	kg Pb/a	6.050	6.350	Paumann et al.1997
standard	mg Pb/kg	100	100	Eikmann & Kloke 1993
Violation of env. standard limits (10 cm)	years	265	253	

Forecasting of Nitrogen content in Vienna's groundwater:

- Currently the concentrations of Nitrogen in Vienna's groundwater range from <1 - 190 mg NO_3/l, the average concentration is 53,7 mg NO_3/l [BMLF 1995]. Thus, the environmental standard for NO_3 in Groundwater of 50 mg NO_3/l [BGBl. 557/89] has been exceeded in much cases. The increase in stock mainly caused by high percolation rates from soil as a result of high fertiliser input but also high inputs from deposition rates has been calculated as 73 - 92 t N/a [Paumann et al. 1997]. If no measures take place in 10 years a average Nitrogen concentration of 68,7 - 72,6 mg NO_3/l, in 100 years of 203,4 - 242,4 mg NO_3/l will be reached.

12.9 Appendix I - Index of Tables

12.10 Appendix J - Index of Figures