Material Flow Analysis as a Tool for Resource Accounting

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Why resource accounting?

- Some resources are classified as *critical*.

- Communication from the commission: Roadmap to a Resource Efficient Europe
  3. Transforming the economy:
     “...better management of resources over their whole life cycle.“

- Large and growing anthropogenic stocks.
Build-up of large urban stocks (US)

Separate collection of
- Plastics: 18 kg/cap.yr
- Metals: 15 kg/cap.yr
- Wood: 23 kg/cap.yr

Comparison between US and reserves
- Copper: 300 Mio. t  580 Mio. t
- Iron: 14 800 Mio. t  77 000 Mio. t
- Zinc: 205 Mio. t  200 Mio. t

Source: BAWP 2011
Source: Rechberger, 2004; Rauch 2009, USGS 2011
What is Material Flow Analysis (MFA)?

- MFA is a systematic assessment of flows and stocks of materials within a system defined in space and time.
- It connects the sources, the pathways, and the sinks of a material.
- MFA is based on the law of the conservation of matter.

\[
\sum_{i=1}^{n} I = \sum_{j=1}^{m} O + \Delta S
\]
MFA before STAN
Free software STAN: www.stan2web.net
MFA with STAN

The Austrian budget for Aluminium for 2011, flows in kt/yr

Source: Bucher et al., 2014
Advantages of a software: Error propagation

Influent \rightarrow \text{WWTP} \rightarrow \text{Effluent} \rightarrow \text{Sludge}

\[ M_{\text{effluent}} = 10\,000 \text{ kg/h} \]
\[ c_{P,\text{effluent}} = 2 \text{ mg/kg} \]
\[ X_{P,\text{effluent}} = M \cdot c = 20 \text{ g/h} \]

Considering uncertainty of data:
\[ M_{\text{effluent}} = 10\,000 \pm 1000 \text{ kg/h} \]
\[ c_{P,\text{effluent}} = 2 \pm 0.3 \text{ mg/kg} \]
\[ X_{P,\text{effluent}} = M \cdot c = 20 \pm 24\% \text{ g/h} \]

Mathematical basics
\[ C = f(A, B, \ldots) \]
\[ S_C^2 = \left( \frac{\partial C}{\partial A} \right)_{A, B}^2 \cdot S_A^2 + \left( \frac{\partial C}{\partial B} \right)_{A, B}^2 \cdot S_B^2 + \ldots \]

\[ C = A \cdot B \text{ : } S_C^2 = B^2 \cdot S_A^2 + A^2 \cdot S_B^2 \]

\[ S_X = (10\,000^2 \cdot 0.0003^2 + 0.002^2 \cdot 1000^2)^{1/2} = 4.7 \text{ g/h} \]

\[ X_{P,\text{effluent}} = 20 \text{ g/h} \pm 24\% \]
Advantages of a software: Data reconciliation

Influent: 100

WWTP

Effluent: 15

Sludge: 90

Input ≠ Output
Advantages of a software\textsuperscript{2}: Data reconciliation

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{diagram.png}
\end{figure}
Why Phosphorus?

Source: Ad hoc Working Group on defining critical raw materials, 2014
A time series for the Austrian P-budget
P-budget: Comparison between 1990 and 2011

Source: Zoboli et al., 2014
Statistical evaluation of flows

4a) Categorization according to the change with respect to the reference year 1990
4b) Categorization according to annual change.

Source: Zoboli et al., 2014
Detection of systematic errors

Comparison between input and reconciled values of the Composting sub-process; 6a) sum of input flows; 6b) sum of output flows.

Source: Zoboli et al., 2014
Monitoring of flows

7a: Total P to Waste Management
7b: Total P recovery within Waste Management
7c: Total P used in cement kilns
7d: Total disposal of P in landfills

Source: Zoboli et al., 2014
Conclusions

- Resource accounting is feasible in practice
- It helps to better understand a resource system (detect points of action)
- It helps to detect systematic errors
- It helps to define sectors/branches where better data is needed

The example of P shows that
- a single-year analysis is not adequate
- the system shows considerable variance over time