Economic and Environmental Assessment of Water Reuse in Industrial Parks

A Case Study based on a Model Industrial Park

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Pfad

WaReIp Partners:

Technische Universität Darmstadt

- Landmanagement (LM)
- Wastewater Technology (AT)
- Material Flow Management and Resource Economy (SuR)
- Work and Engineering Psychology Research Group (AI)

Institute for Sanitary Engineering and Waste Management of Leibniz Universität Hannover (**ISAH**)

Institute of Environmental Engineering & Management at the Witten/Herdecke University (**IEEM**)

EnviroChemie GmbH (**EC**)

Endress+Hauser Conducta (**EH**)

Kocks Consult GmbH (**KC**)

Case Studies

- Germany
- China
- Vietnam

WaReIp – Concept

Concept

Industrial **W**aste**W**ater **M**anagement **C**oncept with a focus on **R**euse:

IW²MC→R

- Including **sustainable & efficient wastewater treatment**
- Providing **Reuse-Water for several purposes** (different qualities)
- **Reducing demand from (limited) natural resources**

Status quo assessment → Calculation Reuse Potential → Proposal of measures → Examination of transferability

Drivers for Reuse

- Industrial parks usually rely on the **availability of water**
- In times of climate change, shortage of resources and the increasing importance of environmentalism it is important to **ensure a sustainable & efficient water supply**
- **Integrated water management and reuse**:
  - Water demand from natural resources can be reduced
  - Recovery of valuable materials from the wastewater
  - Investments and operational costs can be reduced
  - Opportunity for industrial developments in regions with
    - natural water shortage
    - limited water availability (quantity)
    - unstable supply, poor or varying supply quality

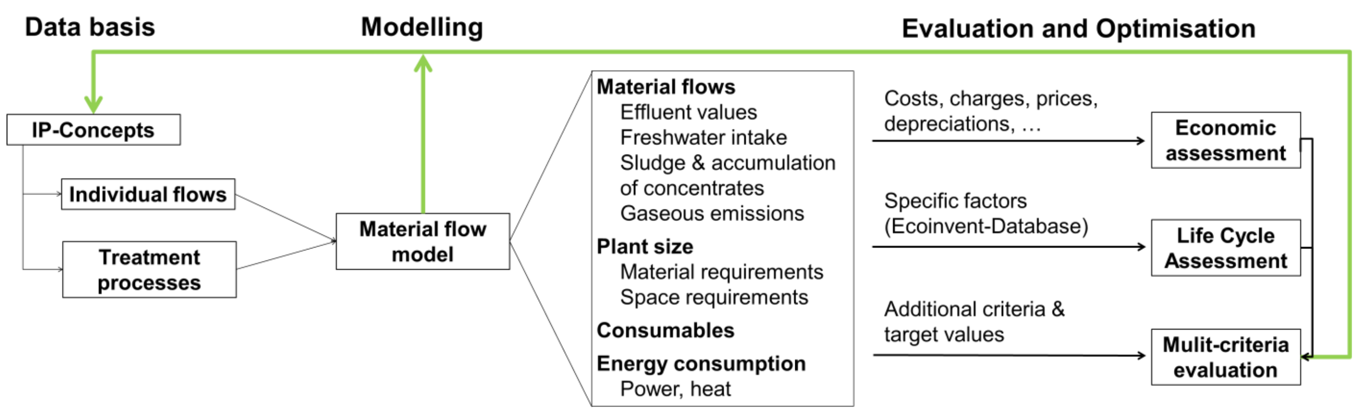
WaReIp – Multi-criteria Assessment

Aim:

Development of a **multi-criteria planning and decision support tool** to assess water reuse potential and opportunities in industrial parks.

Combining a multi-criteria set of environmental criteria based on

- **Economic aspects** (IEEM),
- **Life cycle assessment** (SuR/TU Darmstadt) and
- The **technical performance** of different wastewater treatment technologies (ISAH).



Results:

A model-based approach for planning and evaluating water reuse concepts in industrial parks.

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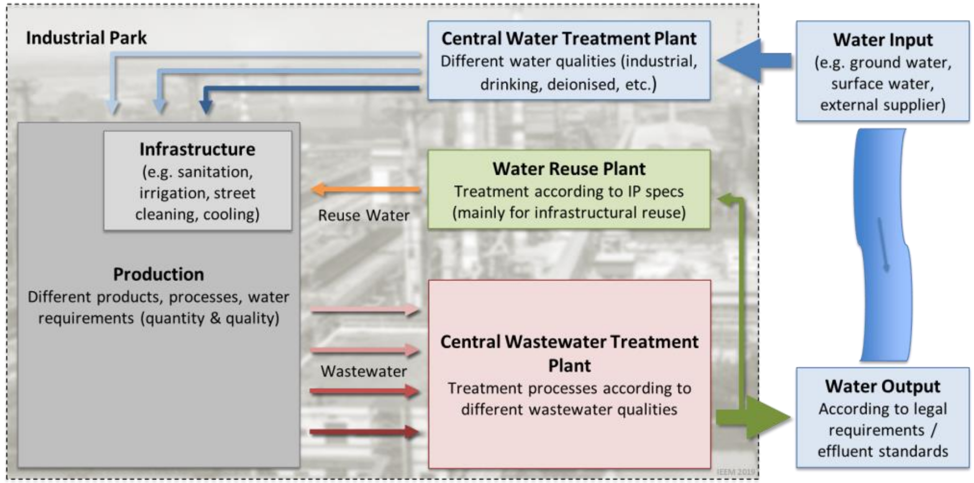


Economic and environmental evaluation of a Model IP

- **Assumption: Wastewater has to be treated to effluent standard at any time**
- Water reuse mainly for infrastructure purposes (internal reuse cycles for production)
- Different options
  - no reuse option – total wastewater flow is discharged to water body
  - 5% for street cleaning and irrigation (5,150 m^3/d)
  - 7% (street cleaning, irrigation, toilet flushing – 6,566 m^3/d)
  - 14% (street cleaning, irrigation, toilet flushing, cooling water – 13,479 m^3/d)
- WRP treatment steps: Sandfiltration, UV Disinfection, Chlorination

Economic analysis of status quo including comparison of several wastewater treatment processes

Cost-calculation based mostly on municipal WWTP (due to availability of data, adaption and transfer to industrial treatment)

- **Cost-calculation** including
  - Capital expenditure (CAPEX)
  - Operational expenditure (OPEX)

- **Cost-benefit analysis**
  - Business level / Industrial Park
    - Costs of water supply & wastewater treatment
    - Potential for savings (reduction of water from natural sources, recovery of resources from wastewater etc.)
  - External effects (ecological and social costs)
  - Economic evaluation of locations, technologies and processes

Cost Calculation

Basing on Capital (CAPEX) and Operational Expenditure (OPEX)

- **CAPEX**
  - Earth works
  - Civil works (buildings, fencing, roads, …)
  - Mechanical systems (Pumps, motors, pipes, …)
  - Electrical systems/SCADA
  - Miscellaneous (Lab, vehicles, …)
  - Planning, supervision, commissioning, training

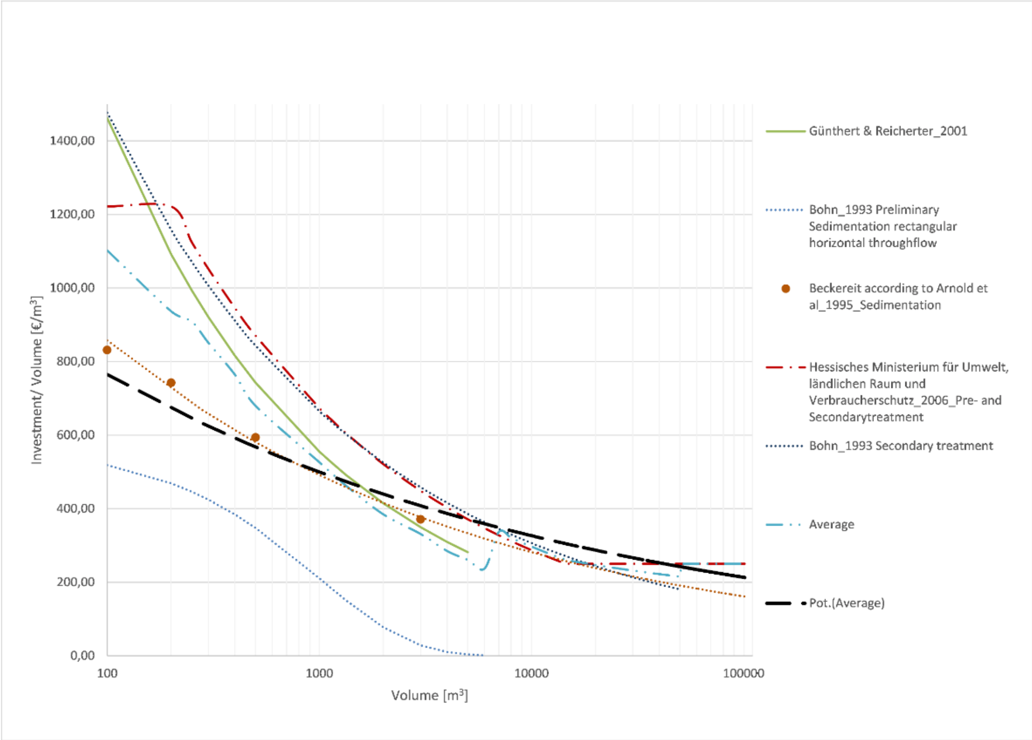
- **OPEX**
  - Maintenance (civil structure, equipment)
  - Manpower/personnel
  - Raw materials, chemicals, consumables & supplies
  - Energy
  - Waste disposal
  - Others (Insurance, lab analysis, external services, …)

Derivation of cost-functions for several treatment steps and processes

→ Modular evaluation of different process chains and reuse options

Cost functions for different treatment processes

Process	X	y	Average Cost function Investment
Screen	m^3/d	€/m^3/d	y = 734,94x^-0,305
Grit chamber	m^3/d	€/m^3/d	y = 2848,8x^-0,416
Pre-/Secondary treatment	m^3	€/m^3	y = 1791,5x^-0,185
Activated sludge	m^3	€/m^3	y = 1682,7x^-0,148
Phosphate precipitation/ Flocculation	m^3	€/m^3	y = 11950x^-0,574
UV Disinfection	m^3/d	€/m^3/d	y = 1048.3x^-0.321
Ozonation	m^3/d	€/m^3/d	y = 4599,3x^-0,202
Sandfiltration	m^3/d	€/m^3/d	y = 651.24x^-0.15
Chlorination	m^3/d	€/m^3/d	y = 1004.4x^-0.29
Digestion/ Stabilization	m^3	€/m^3	y = 8192,8x^-0,322
Sludge thickening	m^3	€/m^3	y = 2220,8x^-0,226
Mechanical sludge dewatering	m^3/d	€/m^3/d	y = 10844x^-0,52



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Reuse Costs

Depending on application of treated wastewater, e.g. process water, cooling water, irrigation, toilet flushing, road cleaning, fire fighting, …

Wastewater has to be treated to required reuse quality (“fit for purpose”)

Benchmarks

Cost of (regular) water supply / water from natural resources (if available)
Cost of wastewater treatment to effluent standard

First Conclusion

On IP level

Without water scarcity or legal requirements, **the costs of water reuse have to be lower or similar to the costs of regular water supply and wastewater treatment**.
Else reuse will not be an economically efficient option for Industrial Parks and/or producers.

Economic Efficiency

Reuse costs ≤ Water supply costs + Wastewater treatment costs + External effects

IP level (Water supply costs + Wastewater treatment costs)

National economy (Water supply costs + Wastewater treatment costs + External effects)

Second Conclusion

Considering external effects, **reuse may be a viable option on national economic level**.

Result of the economic assessment:

- The economies of scale are an important factor when considering different reuse purposes and options.
- The costs per m³ of reuse water produced is slightly increasing over time.

Environmental Assessment (TU Darmstadt SuR)

Aim is to quantify and compare, for the specific case of the exemplary MIP, the environmental impacts of the different specified reuse options and the no-reuse reference case in order to identify the environmentally most advantageous alternative.

Life Cycle Assessment to highlight the shifting of burdens from one life cycle or process stage to another (e.g. environmental impacts of WRP versus wastewater discharge to river), from one protective good to another (e.g. air, soil and water) as well as from one impact category to another (e.g. climate change, eutrophication and toxicity).

Despite the great uncertainty, it can be concluded from the LCA results that the installation of the WRP seems to be environmentally beneficial for all examined reuse options in comparison to the NRO, but there are some detrimental effects (with regard to high treatment efforts for low value applications)

Depending on the **focus of the comparison**, different reuse options were identified as favourable:

- the economic versus ecological dimension
- different environmental impacts

Decision makers need to weight the results depending on individual situations, circumstances and local requirements of the specific Industrial Park.

In addition to the environmental and economic perspective, further (external) factors like

- legal requirements,
- water scarcity/availability
- planning security and
- the company's strategy
- Economic development and job creation

play an important role and must be considered in decision-making concerning water reuse strategies in IPs.

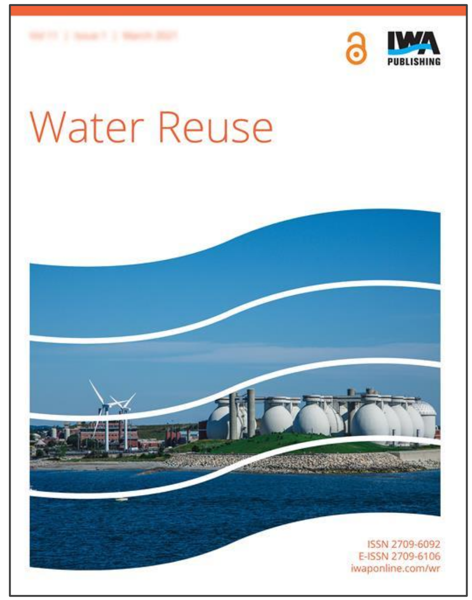
Thank you!

Further information available:

WavE Special Issue / Journal of Water Reuse and Desalination, Vol 10(4), 2020

J. Hilbig et al. (2020) Economic evaluation of different treatment options for water reuse in industrial parks using modular cost functions, https://doi.org/10.2166/wrd.2020.032

B. Boysen et al. (2020) Economic and environmental assessment of water reuse in industrial parks: case study based on a Model Industrial Park, https://doi.org/10.2166/wrd.2020.034



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