Benchmarking of large municipal waste water treatment plants > 100,000 PE in Austria

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Abstract: During a six-year period the Austrian Benchmarking System was developed. The main objectives of this benchmarking system are the development of process indicators, identification of best performance and determination of cost reduction potentials. Since 2004 this system is operated via an internet platform and automated to a large extent. Every year twenty to thirty treatment plants use the web-based access to this benchmarking platform. The benchmarking procedure comprises data acquisition, data evaluation including reporting and organised exchange of experience for the treatment plant managers. The process benchmarking method links the real costs with four defined main processes and two support processes. For waste water treatment plants with a design capacity > 100,000 pe these processes are further split up into sub-processes. For each (sub-) process the operating costs are attributed to six cost elements. The specific total yearly costs and the yearly operating costs of all (sub-)processes are related to the measured mean yearly pollution load of the plant expressed in population equivalents (PE_{110}: 110 gCOD/d corresponding to 60gBOD_5/d)). The specific capital costs are related to the design capacity (PE). The paper shows the benchmarking results of 6 Austrian plants with a design capacity > 100,000 PE representing approximately 30 % of the Austrian municipal waste water treatment plant capacity.

Keywords Process Benchmarking, Waste water treatment, Performance Indicators, Cost efficiency optimisation, full scale results

Introduction

Benchmarking is the continuous comparison of products and services, processes and methods of various enterprises in order to minimise the gap to the "best practice" (Gabler, 1997).

The Austrian Benchmarking System for waste water treatment plants (WWTPs) was developed from 1999 to 2004. During this period more than 80 plants covering a wide range of design capacities from 2,000 to 1 Mio PE were analysed using the developed methodology. The main objectives of the Austrian Benchmarking System are to derive process indicators, to identify best practice and benchmarks using real technical and financial data. Comparing the performance of a waste water treatment plant with the benchmarks, an optimisation and cost reduction potential can be derived. The Austrian system concentrates on process benchmarking, i.e. comparable cost elements are related to clearly defined processes.

Results satisfying all stakeholders can only be obtained if the data base is reliable and if after the analysis of performance and the calculation of process indicators (PIs) the exchange of experience amongst the participants of the benchmarking process is ensured (Kroiss and Lindtner, 2005). The latter is alleviated by the fact that most of the Austrian waste water treatment plants are public property and are operated by either public or publicly owned private utilities. Consequently there is no direct competition of the utilities on the market. Benchmarking enables the utilities to show to the public that they compete for "best practice" and are willing to learn from each other in order to improve cost-efficiency.

The Austrian Benchmarking System for treatment plants is unique as it is performed in a close co-operation of the Austrian Water and Waste Association, two private consulting companies ("k2W" for technical and "Quantum" for economic data processing and information transfer) and a university institute for water quality management at the Vienna University of Technology responsible for quality assurance and development.

In 2003 the IWA report on „Performance Indicators for Waste Water Services" (Matos *et al.*, 2003) created an international basis for the development of performance indicators. These indicators can be related to the performance of processes and of utility management. The actual Austrian system is restricted to process performance indicators (Kroiss and Lindtner, 2005). The chosen performance indicators are to a large extent in agreement with the IWA system.

In 2005 the German Water and Waste Association (DWA) published a benchmarking guideline (DWA, 2005). Based on this guideline several private companies offer benchmarking services in Germany with a similar approach as in Austria. Up to now this resulted in lower numbers of participants in Germany as compared to Austria. The internet platform based version of the Austrian Benchmarking System is actually used by ~20 - 30 waste water treatment plants every year.

Different benchmarking procedures in different countries, performed by different companies, are not in favour of comparable results on an international basis. Therefore, the DACH+NL co-operation (Water and Waste Water Associations from Germany, Austria, Switzerland and The Netherlands) makes efforts to develop a common basis for a number of performance indicators allowing to directly compare their numerical values. This is promoted by the fact that all these countries have also similar minimum treatment efficiency requirements (EU Urban Waste Water Directive 271/91, requirements for sensitive areas).

Termininolgy

All process indicators are related to one year of operation, normally from January to January. The Austrian Benchmarking System uses the following **definitions** and terminology according to Lindtner *et al.* (2004).

Benchmark plants are defined for yearly total, capital and operating costs. Regarding the yearly total and the yearly operating costs *benchmark plants* obligatory have to meet all the following criteria:

- The effluent quality must comply with the Austrian legal requirements for effluent quality and treatment efficiency (5mg NH_4-N/l, 1mgTP/l, 70% N-reduction, 70 mgCOD/l, 15 -20 mgBOD_5/l)
- Minimum quality of technical data checked by mass balance and other reliability criteria
- No dominant industrial influence (checked by COD/N ratio and similar criteria)
- Lowest specific total operating costs related to the mean yearly COD-load as compared to all other plants investigated meeting the previous 3 criteria.

These criteria are not applied to assess and compare capital costs as these are mainly depending on the design capacity and are strongly influenced by the historic development of design, construction and equipment. A standardised cost calculation procedure is used.

A *process benchmark* is defined as the lowest specific operating costs for one of the processes shown in Figure 1.1 at plants meeting the first 3 criteria for benchmark plants mentioned above. Process benchmarks for capital costs are not calculated as the data basis does not allow fair comparison.

Benchmark bands have been developed in order to take into account the inaccuracy of the data and to be able to communicate the actual best performance to the professional society and to the public. A *benchmark band* represents the lowest specific total yearly costs of a benchmark plant increased by 10 percent. Benchmark bands are not relevant for the optimisation of treatment plant operation.

In order to create comparable process indicators it is necessary to group the treatment plants into a number of capacity ranges as the specific costs increase with decreasing design capacity (expressed in PE). This paper concentrates on the group of treatment plants with more than 100,000 PE .

Benchmarking method

The benchmarking process can be sub-divided into three steps, following the timeline of a benchmarking year:

1. data acquisition
2. data processing consisting of evaluation (data quality assessment), interpretation and the creation of reports for the participants.
3. exchange of experience between plant managers or operators by consulting and workshops

Data acquisition is organised via an internet platform (www.abwasserbenchmarking.at) located at the Austrian Water and Waste Association. The complete data transfer and the communication between stakeholders is conducted via internet (Kroiss and Lindtner, 2005). This provides simple accessibility for waste water treatment plants not only in Austria, but worldwide (only minor adaptation to foreign languages would be necessary) and results in low costs as it makes optimal use of automated data management.

The technical data is registered in a master file data sheet. There are two types of data: operating data changing from year to year and conservative data, such as design capacity, tank volumes, etc. only changing in the case of upgrading and replacement procedures. Operating data are taken from the operation journal and require an update for each benchmarking year, whereas conservative data remain stored in the system and can be edited if necessary. In the future a direct link to the WWTP's operation journal will be created in order to automate the yearly update.

In order to process the financial data, a specific electronic accounting system has to be applied. In the first year of participation at the benchmarking process an interface between the accounting system of the treatment plant and the benchmarking platform is set up. In the case of continuous benchmarking the financial data can be updated automatically.

Completeness and quality of the data input are prerequisites for the quality and acceptance of the results.

Data processing of the technical data starts with a plausibility check. The most effective data quality assessment method applied is based on mass balances for COD, nitrogen, phosphorus and total solids. The operating data are introduced into a semi-automatic mass balance algorithm resulting in quality indicators. Financial data quality is checked by a variance analysis comparing the input data to those from the previous year.

After the data quality assessment by mass balances performance indicators are computed automatically. The results are assessed by comparing the values with "default values" (derived from long term experience) and with those from other participating plants. Finally a draft final report for each participant is generated, containing the indicators, their interpretation and conclusions regarding performance improvement.

The exchange of experience consists of an individual consulting and workshops.

The individual consulting is a meeting of a benchmarking expert at the waste water treatment plant where data quality problems as well as the draft final report are discussed with the treatment plant manager. After this consulting and the introduction of corrected or improved data into the benchmarking process the final report is generated and can be downloaded at the treatment plant.

In order to safeguard the exchange of experience and to enhance "learning from the best" (best practice), workshops became an inherent part of the benchmarking process (Lindtner, 2004). Workshops offer an excellent opportunity for an open discussion of specific issues with all participants. This might be difficult if the plants are operated by private utilities competing on the market

Besides the workshops confidentiality is an important issue both regarding the data and the results. Each participant receives his/her own rights to access the platform and to download his/her individual report. Publication of benchmarking results to the wider public is restricted to aggregated sets of data and anonymous made information. (www.abwasserbenchmarking.at/home/berichte).

Practical application – funding - costs

The development of the benchmarking internet platform was financed by the Federal Ministry of Agriculture, Forestry, Environment and Water Management. The running costs (dependent on the size of the plant) have to be recovered from the participants. The yearly costs for WWTP > 100,000 PE of participation are calculated as follows:

First year of participation: 7,000 € + 0.01 € * design capacity in PE

Continuous participation: 3,000 € + 0.005 € * design capacity in PE

Technical data processing

In order to be able to compare the performance of different treatment plants waste water treatment has to be split up into a number of well defined processes (process benchmarking). At the Austrian Benchmarking System waste water treatment is split-up into 4 main and 2 support processes, see Figure 1.1. For large WWTPs these processes are further subdivided into sub-processes in order to increase comparability and transparency. The accounting system for the operating costs has to be adapted to the process model (Fig. 1.1).

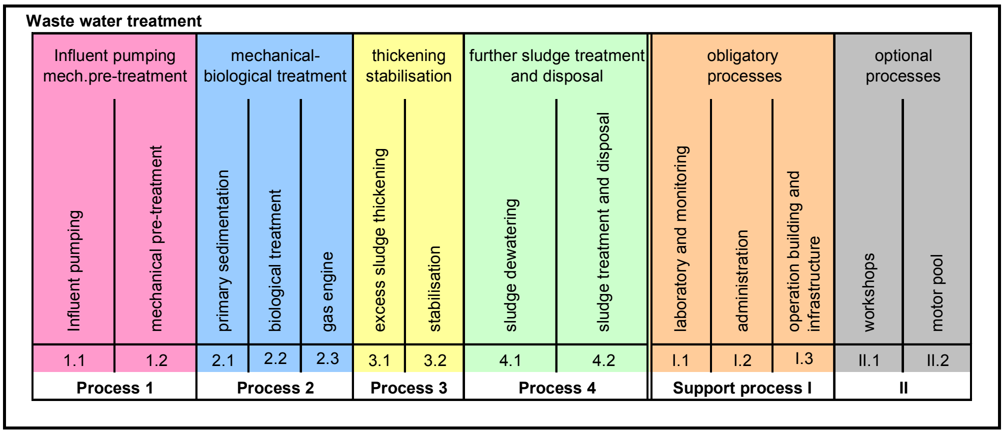


Figure 1.1 Extended process model for waste water treatment plants > 100,000 pe

Once the data quality is assessed the aggregated data are used for the calculation of performance indicators and benchmarks. The performance indicator system is shown in Figure 1.2. The so-called key performance indicators represent indicators with a high potential for assessing and optimising the process performance. Financial indicators relate costs to specific processes, technical indicators describe a correlation between specific technical data.

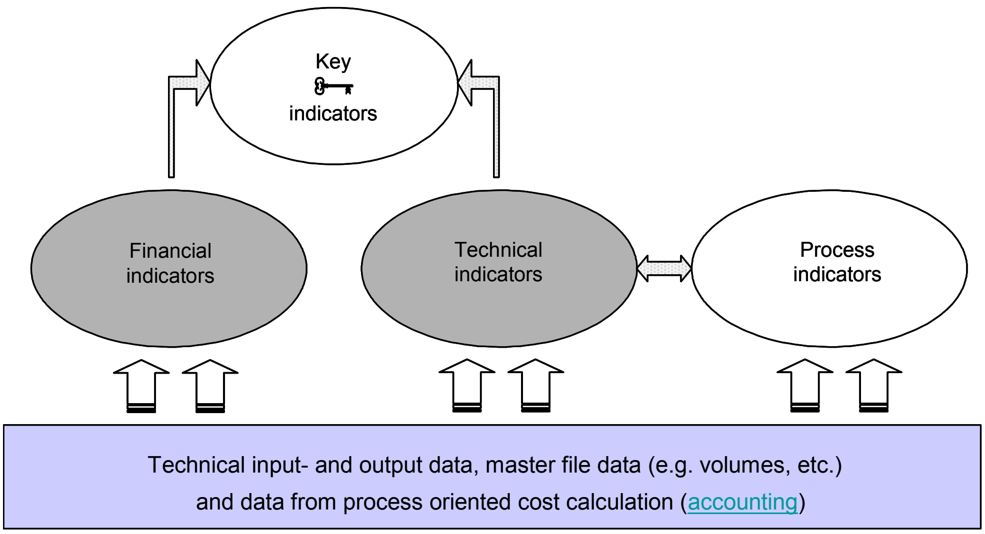


Figure 1.2 Performance indicator system

Results and discussion

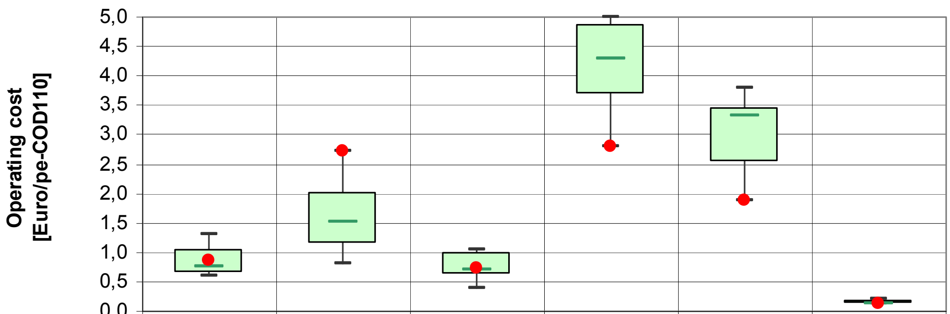
The following results are derived from the data of 6 large WWTPs > 100.000 PE and the benchmarking process for the year 2005. The participating plants represent 32 % of the total Austrian treatment plant design capacity.
Table 1.1 shows the benchmark, the median and the benchmark band for the yearly total costs, the operating and the capital costs (standardised cost calculation method). The total yearly costs of the benchmark are 23.2 €/PE_{110}. The lowest specific operating costs (benchmark) amount to 9.1 €/PE_{110}/a, the yearly capital costs to 8,5 €/PE design capacity.

Table 1.1 Benchmark, median and benchmark bend for yearly, operating and capital costs

	Yearly costs [€/pe-COD 110]	Operating costs [€/pe-COD 110]	Capital costs [€/pe design capacity]
Benchmark	23.2	9.1	8.5
Median	26.0	10.9	11.6
Benchmark band	25.5	9.9	9.4

The operating costs are the most important parameter for the short term cost reduction potential since they can be continuously influenced while the capital costs are mainly influenced by the historic development and only change in the case of upgrading, extension or replacement activities.

Table 1.1 shows that the best large Austrian WWTPs have specific yearly operating costs below 10 €/PE_{110}. If operating costs are higher than 10 €/PE_{11} a more detailed cost analysis is necessary in order to detect the causes. At the Austrian Benchmarking System the operating costs are assigned to 6 processes (Figure 1.1), and the costs are split up into six cost categories (Fig. 1.3).



	inf. pumping mech.pre-treatment	mechanical-biological treatment	thickening stabilisation	sludge treatment disposal	obligatoriy support process	optional support process
75%-Percentile	1,1	2,0	1,0	4,9	3,5	0,2
Maximum	1,3	2,7	1,1	5,0	3,8	0,2
Minimum	0,6	0,8	0,4	2,8	1,9	0,1
Median	0,8	1,5	0,7	4,3	3,3	0,1
25%-Percentile	0,7	1,2	0,6	3,7	2,5	0,1
Benchmark	0,9	2,7	0,7	2,8	1,9	0,1

Figure 1.3 Boxcharts of process related specific operating costs

Figure 1.3 shows the operating costs related to the main and support processes and their sub-processes. From Fig. 1.3. it can be concluded that the process “sludge treatment and disposal” results in costs of 4.3 €/PE_{110} (median) which is more than 40% of the total operating costs. The second largest contribution is caused by the “obligatory support process I”, comprising costs for laboratory, administration and infrastructure. Process 2 “mechanical-biological treatment”, the core process for water protection, results in costs of only ~1.5 €/PE_{110} /a (median), i.e. less than 15% of the total operating costs. Process 1 (influent pumping, screening, grit removal) and process 3 (sludge thickening and stabilisation) are even less relevant with costs < 1 €/PE_{110}/a. The optional support process II (workshop and motor pool) can be neglected in all the cases investigated.

The *benchmark plant* depicted as a dot in Figure 1.3 is also benchmark in processes 4 and support process I and has low specific costs except for process 2. A more detailed analysis for different cost categories showed that this plant has relatively high energy costs as compared to the other large plants investigated.

In Figure 1.4. the total operating costs are related to different cost categories expressed as percentage. The main cost contribution with 36 % of the total operating costs are personnel costs. The high costs of sludge disposal are to a large extent caused by the cost for “residue treatment”. Interesting is the fact that the energy costs amount to less that 10 % of the operating costs. However, it has to be taken into account that the energy costs depend on several (also site specific) factors as: energy consumption, energy production from biogas including repair and maintenance costs and external energy cost. The comparison of both the financial and the technical indicators (Figure 1.2) related to energy costs and consumption is included in the analysis. All investigated WWTPs are characterised by low yearly energy consumption ranging from 20 to 30 kWh/PE_{110}.

A very cost relevant technical indicator is the plant utilisation factor, i.e. the ratio between the 85%ile of the yearly COD-load (representing the “design” loading and the design capacity expressed as percentage. Between ~50 to 65% of the total operating costs are independent of the actual COD-loading situation at the WWTP. Therefore, the specific operating costs €/PE_{110}/a are significantly influenced by the plant utilisation factor. Specific operating costs below 10 €/PE_{110}/a can only be achieved with a utilisation factor > 80 %.

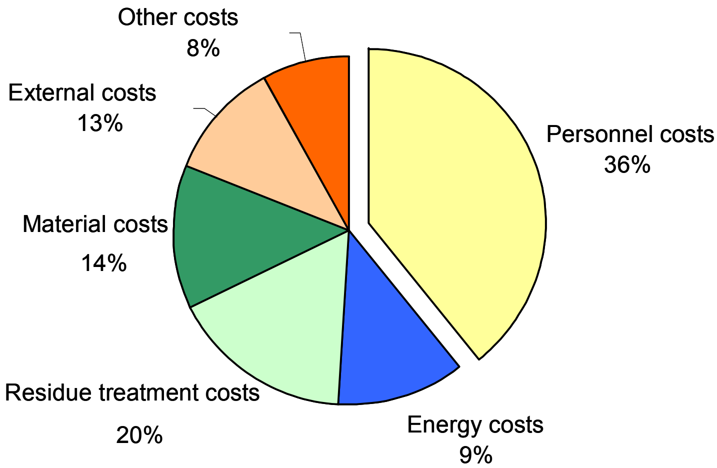


Figure 1.4 Distribution of cost categories as percentage

Conclusion

The Austrian Benchmarking System developed since 1999 has successfully been applied in practice to more than 80 treatment plants ranging from 2000 to 1 Mio PE. It represents a powerful tool to increase cost efficiency. The internet-based benchmarking platform went into operation in 2004 (www.abwasserbenchmarking.at) and has facilitated an economical data management and information transfer between the treatment plant operators and the technical and financial experts working in close co-operation with the Austrian Water and Waste Association and Vienna University of Technology. The actual platform version is based on German language but can easily be adapted to other languages. The Austrian Benchmarking System offers the potential for a global comparison of specific process related costs.

The Austrian System was applied to 6 large WWTPs with a design capacity > 100,000 PE_{110} for the year 2005. From this investigation the following major conclusions can be drawn:

- Sludge treatment and disposal cause ≥40% of the total operating costs.
- 50 to 65% of the operating costs are independent of the actual COD-loading of the plant. The utilisation factor, therefore, has a significant influence on the specific operational costs.
- There is no correlation between treatment efficiency and operating costs for treatment plants with similar requirements. Excellent treatment efficiency often coincides with low specific costs, indicating the relevance of the quality of the staff.

For large waste water treatment plants continuous benchmarking represents a powerful management tool. It enables the managers and operators to find and realise cost reduction potentials. By the comparison with the benchmarks and by information exchange between the benchmark plant managers it is possible to increase cost-efficiency relation. However, benchmarking is not only a tool to enhance cost-efficiency, but offers the opportunity to prove excellent performance of treatment plant operation. It is planned to include asset management performance indicators as an additional criterion for benchmark plants in order to avoid cost minimisation at the expense of decreasing asset value. This can only be achieved considering long term cost development for repair and maintenance and of capital costs for investments.

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