Elimination costs for different wastewater compounds

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Abstract The present report presents the system and discusses the results of the cost calculation for the reduction/elimination of different wastewater and sludge compounds. These costs were calculated for different types of processes at 102 wastewater treatment plants of Emschergenossenschaft/Lippeverband and Aggerverband. Comparing enhanced biological phosphorus removal and precipitation, one of the results indicates that in general the costs for elimination of one kilogram of phosphorus are lower in the plants in which only chemical precipitation is used for P reduction. Further results of the cost calculation will be presented with a discussion of their possible influence on planning decisions.
Keywords Benchmarking; costs; elimination costs; wastewater treatment

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General introduction

In recent years, considerable efforts have been commissioned and for the most part realised on the qualitative and quantitative improvement of wastewater treatment. Thus, the development of fees and the economic efficiency of the respective measures, plants, and implements have gained even more importance than in the past, creating a force-field between the high demands for environmental quality and the necessity to limit the increase of costs and fees. Technical/economic method comparisons facilitate the detection of optimisation potentials for both the operation of plants and the strategic management. Such comparisons – known as process benchmarking – have for a long time been run in the industry. In the area of wastewater disposal, the method was at first unknown; the latest discussions, however, show that it has now been introduced there as well.

Emschergenossenschaft/Lippeverband and Aggerverband have been working since the end of 1996 on a method on the basis of technical-economic performance indicator systems. In a recently finished research project supported by the University of the Federal Armed Forces at Munich it was proved that benchmarking is also a suitable instrument for wastewater disposal. Within this project, approximately 100 wastewater treatment plants (WWTPs) of Emschergenossenschaft/Lippeverband and Aggerverband were examined – with the central result that saving potentials between 3% and 12% of the annual operational costs could be detected and confirmed by concrete measure schedules (Schulz *et al.* (2000), Stemplewski *et al.* (2002), Stemplewski *et al.* (2001)).

Crucial prerequisites for such examinations is the allocation of costs to the different tasks which a WWTP has to fulfil. For this allocation, the individual processes have been defined and described in detail (Figure 1).

The individual costs of the wastewater treatment both for investment and for the operation of the plants were allocated to the respective individual processes (Figure 2). This allocation in turn facilitates the allocation of cost differences between different plants to the treatment steps (for instance to the biological treatment, but also to the cost categories (for instance efforts for material or depreciation).

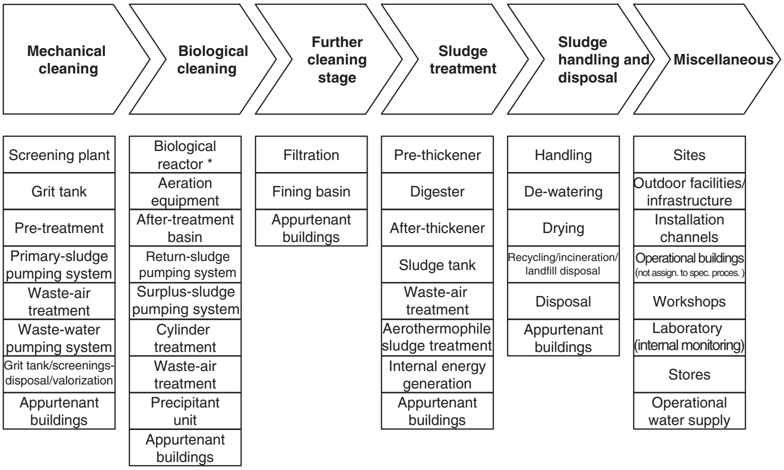

Figure 1 Individual processes, including sub-processes

No.	Indices (totals for 1998 in DM)	Unit	Overall plant: Total for cost group	Individual processes: Mechanical cleaning	Biological cleaning	Further cleaning stages	Sludge stabilisation (Pre- and after-thickener, sludge tank	Sludge handling and disposal	Miscellaneous (Operational buildings, infrastructure, etc.))
54	**Materials**	DM							
540	Power, water, natural gas, TP gas, transmitted heat	DM							
5402	***of which*** other fuels (for motor-vehicles)	DM							
5403	***of which*** water	DM							
543a	Auxiliary and operational utilities (for waste-water treatment)	DM							
5431	***of which*** precipitants	DM							
5432	***of which*** primary and secondary flocculants	DM							
543b	Auxiliary and operational utilities (misc.)	DM							
547	Costs for purchases (services and materials)	DM							
5471	***of which*** Maintenance services	DM							
5472	***of which*** Maintenance materials	DM							
549	Miscellaneous	DM							
55	Wages and salaries	DM							
551/ 552	***of which*** for servicing and maintenance	DM							
57	Depreciation (standardized)	DM							
58	Calculated interest	DM							

Figure 2 Economic indices

In order to compare the specific costs even better to the targets of wastewater treatment, that is to the successes, and to facilitate the comparison of the commonly used method combinations, additional analyses were run in the biological treatment under consideration of sludge stabilisation and disposal. For this, a comparatively simple dimensioning approach was sufficient to allocate the costs for the buildings to the elimination of carbon, nitrogen, and phosphorus.

System of cost allocation

The costs for eliminating a mass unit of one wastewater compound or for reaching a similar treatment target are one possible performance indicator which leads to decisions in planning and construction or operation. Necessary for a compound-related calculation of elimination costs is an allocation of the overall yearly costs for wastewater treatment to the eliminated loads of each relevant parameter. In the second case, all the costs for the processes which leads to a specific treatment target (e.g. sludge stabilisation) have to be added up. An overview of the allocation approach is presented in Table 1.

Comparison of plants/processes

In general, the application of the performance indicators mentioned above facilitates not only a comparison of plants with similar targets of effluent quality. However, in regard to specific parameters it is reasonable that a plant which was originally designed for carbon removal eliminates only small amounts of nitrogen (only incorporation of nitrogen). This causes comparatively high specific costs for the reduction of this parameter. Another possible way of thinking in that case would be that the elimination of nitrogen is a side-effect that comes for free, because no part of the plant (blowers, aerated volume) was designed exclusively for elimination of nitrogen. According to these arguments, the following comparisons seem to be useful and likely to influence decisions in planning or operation:

- Plants with and without separate sludge digestion (simultaneous stabilisation), both types designed for N-removal: it can be more useful (and economical) on smaller plants to work with a simple process without much auxiliary equipment.
- Plants with different ways of P-removal: in this case, the costs for precipitation chemicals and the dosing devices have to be compared with the cost effect of the additional tank volume for enhanced biological phosphorus removal (EBPR).

Results

Removal of organic sludge compounds (sludge stabilisation)

Plants with aerobic sludge stabilisation necessitate a comparatively larger aeration tank than plants with anaerobic sludge stabilisation in a digester. On the other hand, there are no costs for the construction and operation of the digesters. The question is: from which dimension onwards it is economically sensible to accept the costs for the construction and operation of digesters. Considering only the annual costs for the biological treatment in Figure 3, it becomes apparent that the person equivalent (PE)-specific costs of both types of processes overlap in the range of the categories from 10,000 to 30,000 PE. In regard to the costs for biological treatment, then, both types of processes must be classified as equivalent in their economic efficiency.

For a complete comparison, however, it is necessary to consider also the costs for sludge stabilisation (already contained in type A: simultaneous sludge stabilisation) and sludge disposal for both types of processes. Figure 4 presents the comparison that includes this aspect. The differences between the two plant types do now become more apparent. The simultaneous aerobic sludge stabilisation is more economically efficient for a plant size up

Table 1 Cost allocation (operation and investment)

Parameter	Process resp. treatment target	Assigned main part of investments	Assigned main part of operation
COD BOD	Carbon removal	Tank volume (partly)	Staff, aeration energy (partly) and maintenance
N_{total} NH_4-N	Nitrogen removal	Tank volume (partly)	Staff, aeration energy (partly) and maintenance
P_{total}	Phosphorus removal	Anaerobic volume devices for dosing chemicals	Staff, chemicals and maintenance
Organic matter	Sludge stabilisation	1. Tank volume (partly) 2. Digester volume and auxiliary equipment	1. Staff, aeration energy (partly) and maintenance 2. Staff, power consumption and maintenance

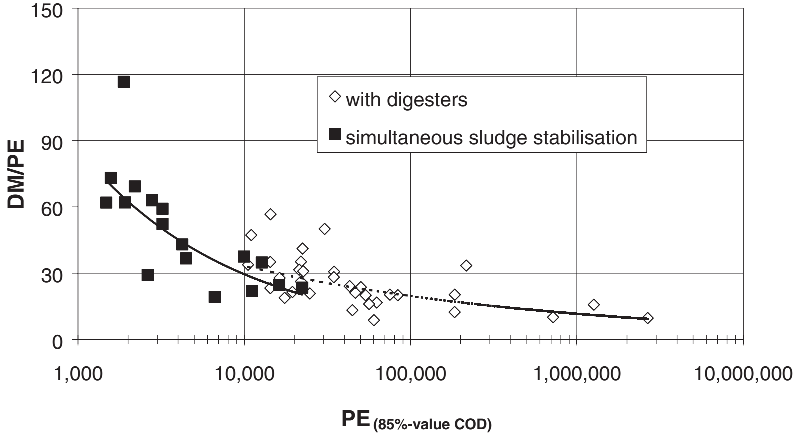

Figure 3 Specific annual costs for the biological treatment on plants with extra sludge digesters and simultaneous stabilisation plants

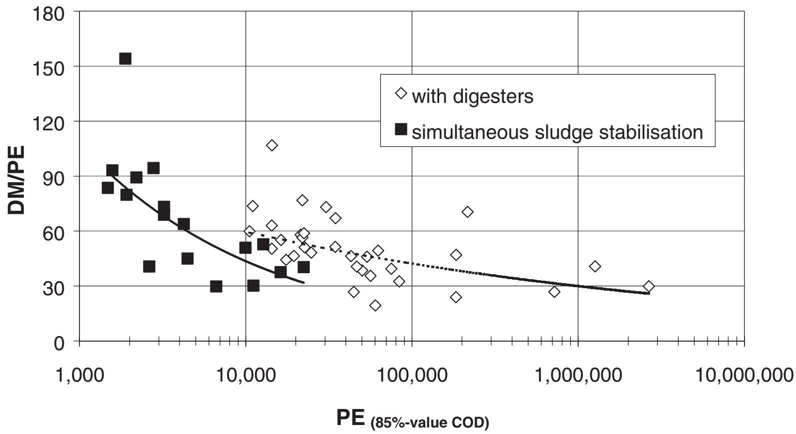

Figure 4 Specific annual costs for biological treatment, sludge stabilisation and sludge disposal on plants with extra sludge digesters and simultaneous stabilisation plants

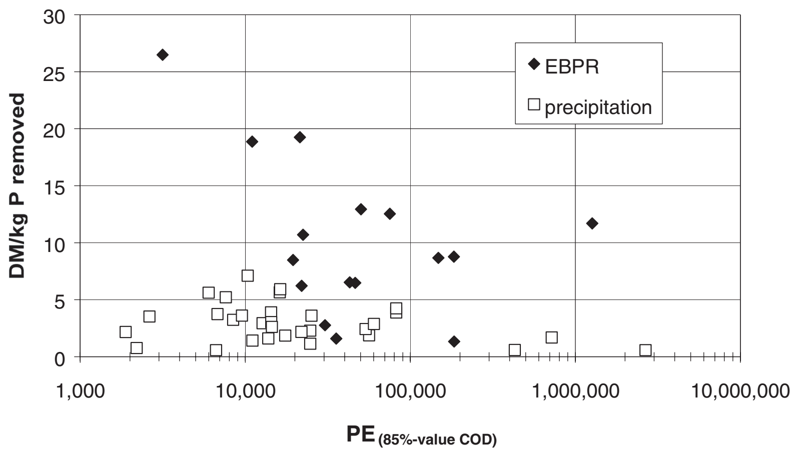

Figure 5 Costs (regarding the biological treatment) for elimination of one kilogram P_{total} on plants with and without EBPR

to approximately 30,000 PE, which obviously is due to the different costs for sludge stabilisation. The same result occurred with the calculation of the specific elimination costs for N_{total} and COD (not represented in this report).

P-removal

A comparison was made between plants with different processes for elimination of phosphorus. The result is shown in Figure 5. The result indicates that in general the costs – regarding the biological treatment – for elimination of 1 kilogram phosphorus are lower in the plants with chemical precipitation, which is due mainly to the higher capital costs for the anaerobic tank volume.

The comparison is also influenced by the fact that in Germany EBPR-plants are in almost every case additionally equipped with a precipitation unit to cater for the requirements on the effluent quality (requirements have to be met in a spot sample).

Conclusions

The results of this project have confirmed that the optimisation of the economic efficiency of wastewater disposal on the basis of technical/economic performance indicator systems is possible and that a exclusive comparison of the performance indicators is not sufficient to detect and realise concrete saving measures. It is necessary to derive benchmarks from the performance indicators and to calculate deviations from these benchmarks. The reasons for deviations must be analysed, and it is crucial to create a measure schedule for the realisation of the knowledge gained from the analysis.

The results have shown that all size classes of wastewater treatment plants can be compared to each other with the help of technical/economic performance indicators. In order to achieve reasonable quality results in such a benchmarking project, the following aspects were of particular interest:

- Unequivocal definition of the targets and of the individual cost and process categories.
- Detailed plausibility checks and continuous checking of the compiled data.
- High acceptance of the project by all personnel involved.
- Good co-operation between technical and economic departments.

For the evaluation of the economic efficiency from a technical/economic perspective, it has been confirmed that the method of aerobic sludge stabilisation in the previously given dimensioning range of 20,000 to 30,000 PE may be economically more efficient than anaerobic sludge stabilisation. Moreover, the comparison of different aerator systems within the same project (Stemplewski *et al*. (2001)) showed that the surface aeration is still more likely to be more economically efficient than the compressed air aeration for a dimension of up to approximately 30,000 PE, provided that there is a sufficient control range.

In plants with or without biological phosphorus elimination, the method of chemical precipitation is, due to the conditions which prevail today (precipitation agent costs, influent loads) generally more economically feasible than the combined method of enhanced biological phosphorus removal and chemical precipitation.

Acknowledgements

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