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Costs and optimisation options for monitoring of indirect dischargers

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ABSTRACT

Monitoring of indirect and industrial dischargers, respectively, makes an important contribution to the safe and environmentally sound operation of wastewater systems. As a result of local framework conditions, there is a wide range of monitoring practices across Germany. In a benchmarking project, ten sewerage operators and monitoring bodies representing large German cities have collected data on their work and discussed their practices. The results show that the extent of monitoring is between 244 and 1,457 monitoring points per sewer network (given as 15th and 85th percentile). The median value of the specific expense is 689 EUR per monitoring point and year. In relation to the total wastewater fee volume, the median expense is 0.71%. The sub-process 'sampling' was examined more closely. By means of detailed process mapping and regression analyses, it can be shown that on-site activities and tours have the largest share of working time (total of 72%) and thus the greatest leverage in optimisation measures. Various examples are given.

Key words: benchmarking, discharge regulations, indirect dischargers, monitoring, performance indicators, sampling

HIGHLIGHTS

- Current values of monitoring costs for industrial dischargers.
- Identified best practices for sampling.

INTRODUCTION

Public wastewater systems are used to collect, transport, and treat wastewater from households as well as from commercial and industrial dischargers, so-called 'indirect dischargers' (discharging to the receiving water indirectly via a public wastewater system). In Germany, the operators of public wastewater systems have the obligation and the right to regulate the discharge of non-domestic sewage into their facilities. This demand results from the obligation of proper wastewater treatment according to the water law, the owner position, and from health and safety regulations. The regulation of discharging commercial and industrial wastewater aims:

- to protect the public from harm, danger, and nuisance
- to protect operator's personnel from damage, dangers, and hazards
- to protect the sewerage facilities and to not to impair their optimal functionality
- at the compliance with water law requirements for discharging treated wastewater to receiving waters
- to avoid difficulties in sludge treatment and disposal/recycling.

Operators regulate indirect dischargers via statutes (public) or contracts (under private law). Based on local conditions, such as materials or performance of the sewerage system, requirements are set via discharge bans or concentration and load thresholds (DWA 2013).

The regulation must be supported by suitable monitoring measures. Typical instruments are:

- On-site inspections, inspections of pre-treatment facilities
- Controlling certificates and self-monitoring documents
- Wastewater sampling at pre-treatment facilities or at entrance points to the public sewer system (monitoring of a single discharger)
- Wastewater and biofilm sampling at sewer nodes (monitoring for general purposes and substance tracking).

The regulation and monitoring of commercial and industrial dischargers are one reason why a significant reduction of pollutants in wastewater and sewage sludge has been achieved over the past few decades in Germany. Despite the high standards that the industries have achieved in terms of pollutant reduction, comprehensive monitoring according to uniform standards is still necessary. On one hand, there are still complaints; on the other hand, regular monitoring ensures the achieved status. Due to the individual situations of municipalities regarding resident industries and local policies, as well as due to the complex issue of industrial wastewater, different monitoring extents and foci are applied by sewerage companies and monitoring bodies, respectively.

The identification and comparison of those different approaches and the improvement of monitoring strategies and operations are the aims of the project 'Benchmarking of indirect discharger monitoring'. The project with more than ten monitoring bodies has been running since 2005. Selected results are presented in this paper: on one hand, performance indicators (PI) regarding extent of work, staffing and expenditures; on the other hand, the sub-process of wastewater sampling is examined in more detail in order to identify and evaluate influencing factors and thus optimisation fields.

PERFORMANCE INDICATORS

Process model and reference values

For benchmarking and general comparison of different operators, single tasks and processes must be summarised in a process model (Cabrera *et al.* 2011). Clear and delimiting definition of sub-processes determining relevant activities are particularly noteworthy, as well as the inclusion of framework conditions that influence these activities. The tasks of indirect discharger monitoring are summarised in four sub-processes

- Strategic and operational monitoring (e.g. inspections, maintenance of cadastre, substance tracking, notifications)
- Sampling (e.g. route planning, sampling at facilities, in the sewer)
- Laboratory services (e.g. sample preparation, analysis)
- Supporting processes (e.g. personnel management, IT, procurement).

The activities and performance of the different participants are made comparable by assigning the expenses and results to the corresponding sub-processes and by calculating specific performance indicators with relevant reference values and PI denominators, respectively. Here, particularly important are:

- number of monitoring points: sum of facilities (points of wastewater generation or wastewater pre-treatment facility) and sampling points (place where wastewater samples are taken)
- number of samplings (sampling in a spatial and temporal context regardless of the actual number of samples taken).

Structure of the project participants

In the three survey years 2017–2019, ten monitoring bodies had taken part in the benchmarking project with a complete collection of data. Within this group there are differences in:

- the legal form: municipal departments, owner-operated enterprises, private limited companies
- the organisational form: part of the sewerage operator or part of (other) municipal authorities
- the size: measured in terms of network length and number of employees
- the degree of outsourcing: conducting of the sub-process 'laboratory services' in-house or external
- the extent of monitoring: measured by the number of monitoring points and samplings.

A comparability of the results and the PI values, respectively, is given within the group (Franz & Peters 2011). However, a statement about the representativeness in an urban context or even for the entire industry cannot be made.

The legal and organisational forms are not relevant. Both have no impact on the core monitoring processes. However, they may play a role in the implementation of supporting processes, for example, the extent of IT or human resources support or the type of procurement.

Although all participants represent large cities (>150,000 inhabitants), there is a significant range in terms of size (Figure 1). The network length (foul and combined sewer only) ranges from 572 to 1,701 km (due to anonymity reasons, 15th and 85th percentiles are given for minimal and maximal values in this chapter). The number

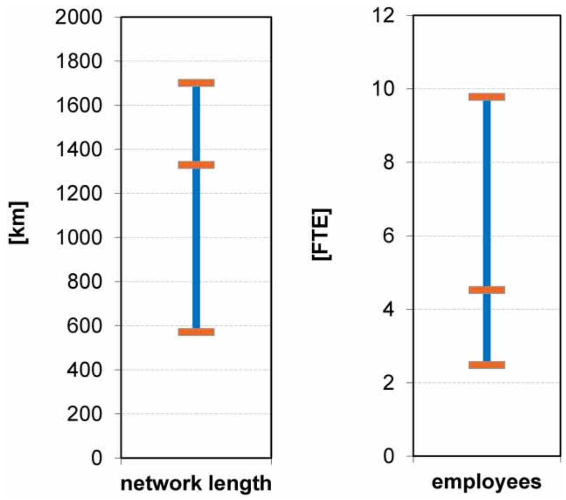

Figure 1 | Size of the participants (15th, 50th and 85th percentile).

of employees responsible for indirect discharger monitoring shows a similar picture. This value – without the sub-process of laboratory services – ranges between 2.5 and 9.8 full-time equivalents (Figure 1). Thirty percent of the participants have completely outsourced laboratory services, thus no internal staff resources are necessary.

The differences in size and in the amount of commercial and industrial dischargers result in differences in the absolute extent of monitoring (Figure 2). The number of monitoring points within the group is between 244 and 1,457. The ratio of monitored facilities and sampling points fluctuates due to type and structures of local industries. Additionally, there are also 15 to 59 sewer nodes, which are monitored for general purposes and substance tracking, but cannot be assigned to an individual discharger. The number of wastewater samplings taken each year is between 556 and 2,144. These figures include the monitoring stations monitored and samples taken in one year, only. The actual extent of monitoring also includes points that are monitored perennially.

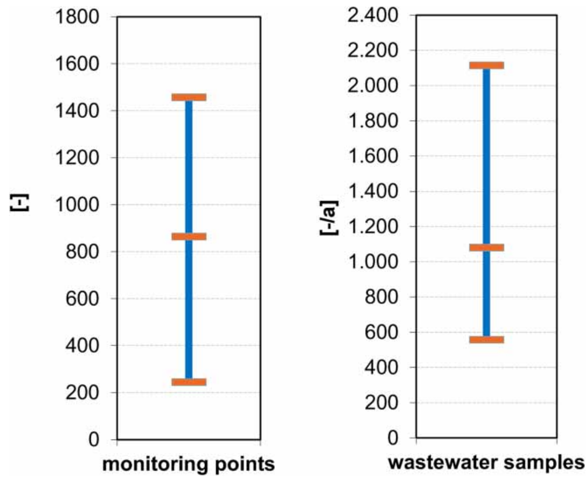

Figure 2 | Extent of monitoring (15th, 50th and 85th percentile).

Specific expense

The expense of indirect discharger monitoring is dominated by personnel costs. On average, the expenses for wages and salaries amount to 75% of the total expenses (sum of operating expenses and depreciation, interest is not included as it cannot be linked to individual assets). This proportion is very high compared to those of the core processes of wastewater collection, transport, and treatment.

The median value of the annual specific expense is 689 EUR per monitoring point (Figure 3). Considering working hours only, the median values are 14.4 hours per monitoring point without and 17.2 with laboratory

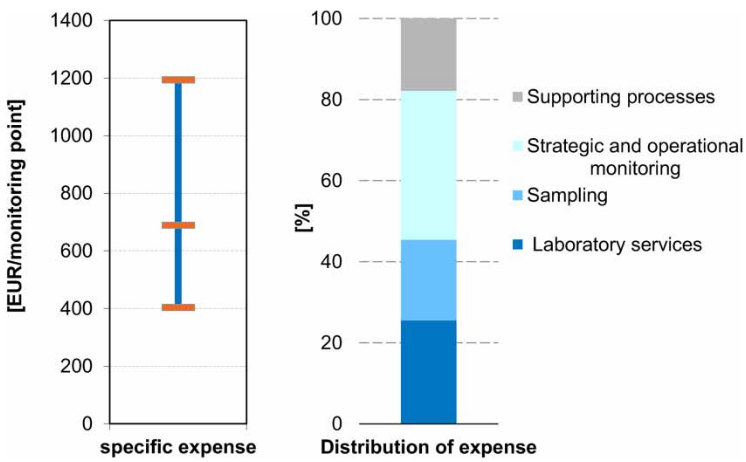

Figure 3 | Monitoring body point of view: annual specific expense (15th, 50th and 85th percentile) and mean expense distribution.

services. These times include overhead, absence due to illness and vacation, and so on. The mean distribution of the specific expense regarding the defined sub-processes is shown in Figure 3.

The individual performance-related expense ('What does the monitoring of a monitoring point cost?') depends on several factors. Some examples are given in following chapter. However, the size-related expense ('How much do I spend per network length?') shows a scale effect: smaller participants have on average higher specific values (<1,000 km network length: 668 EUR/km) than larger participants (>1,000 km: 520 EUR/km). Apparently, the resources of monitoring do not increase linearly, but rather degressively with the size of the monitored network.

Annual specific expenses focused on fee payers and customers, respectively, are shown in Figure 4. The monitoring of indirect dischargers, with a median of 2.4 EUR-cents per m^3 or 0.71% of the total wastewater fee volume, accounts for a very small proportion of the fee burden.

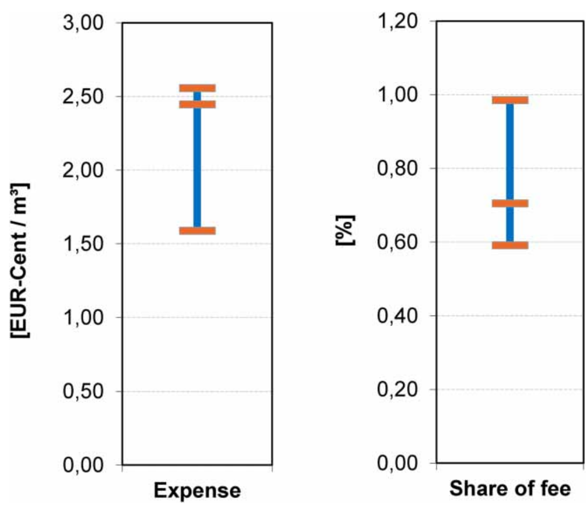

Figure 4 | Fee payer point of view: annual specific expense per water volume and share of fee (15th, 50th and 85th percentile).

SUB-PROCESS 'SAMPLING'

Analysis approach

Sampling as one of the four defined sub-processes accounts for 20% of the total expense, on average (Figure 3). The relevant economic performance indicator is the specific expense per sampling. To explain the individual PI values and to identify potential for improvements, 35 influencing factors were analysed; for example, team size, distance travelled, parameters measured on-site.

Within a benchmarking project, these factors are discussed mainly qualitatively. Although this leads to findings and potential improvement measures, differences in the specific expense cannot be attributed to individual factors. Furthermore, it is difficult to assess the relative importance of the factors. In order to deepen the analysis, a very detailed process mapping was carried out. Assuming a typical working day, the participants recorded working hours for individual sub-process steps (Table 1). Process times were recorded, only, the team size and number of employees was neglected.

Table 1 | Detailed process model 'sampling'

Sub-process step	Tasks
Process initial	Start of the working day
Tour planning	Selection and sequence of the sampling points Staffing
Preparation	Preparation of the sampling vessels Preparation of devices (sampling devices, pH meters, etc.) Labelling vessels Loading vehicle
Tours	Outbound run to the first sampling Intermediate runs Inbound run from last sampling
Empty runs	Empty runs (w/o sampling, e. g. between base and laboratory)
On-site activities	Parking On-site walking Registration at the discharger Safety measures, accessing the sampling point Setting up and dismantling of measuring equipment Sampling on-site including quality assurance Measurement of parameters (temperature, pH value, etc.) Documentation of the samples Cooling and preservation of the samples Creating a reserve sample for the discharger Gas measurements Controlling certificates and self-monitoring documents Inspection of pre-treatment facilities Acknowledgment by the discharger/deregistration
Process completion	Incoming inspection Labelling vessels Create dataset in the laboratory information management system Homogenise, divide, mix, preserve sample if necessary Sample distribution within the laboratory

Results of process mapping

The distribution of the standardised process times across the sub-process steps and across the participants is shown in Table 2. Based on the values and the discussions among the participants, the following general conclusions can be drawn:

- The main emphasis regarding working hours is on on-site activities and tours.
- Even if laboratory services are carried out in-house, there may be substantially empty runs.
- The location of the sampling point (at a pre-treatment facility, in a sewer, on private property or in public space) has a major influence on workload, especially for safety measures and setting up equipment.
- Differences in preparation time result mainly from the vehicle equipment (e.g. whether devices are stored in the vehicle or not) and from the time of preparation (the day before, the actual day).
- Differences in the process completion result mainly from in- or outsourcing of laboratory services.
- Differences in work breaks (in bases, en route) lead to different route planning and tour times.

Table 2 | Distribution of process times

Sub-process step	Minimum	Mean	Maximum
Process initial	0%	3%	13%
Tour planning	0%	5%	8%
Preparation	2%	9%	18%
Tours	14%	24%	30%
Empty runs	0%	4%	7%
On-site activities	14%	48%	63%
Process completion	2%	8%	17%

The knowledge gained was backed up with regression models. Regression analyses are statistical methods that use a function or model to determine relationships between a dependent (performance indicator) and one or more independent characteristics (influencing factors) (Hedderich & Sachs 2012).

Since the sampling expense is personnel-driven (on average, 91% is personnel expense), the specific working time in [FTE/10,000 samples] was selected as a performance indicator to simplify the model. The main influencing factors determined by the final model are:

- the distance travelled per sampling,
- on-site activities (the individual activities were summarised using a point system) and
- the team size.

The relative importance or the contribution to the explained variance of the model was highest for the specific distance travelled at 51%. The on-site activities make a smaller contribution at 34%, although they account for the highest proportion of working hours in absolute terms (Table 2). The reason is due the fact that they fluctuate less within the group. The same applies to the team size.

The knowledge gained through process mapping and regression analyses was neither new nor surprising; it confirmed existing assumptions. However, with these approaches it was possible first to determine the importance or leverage of the influencing factors on the specific expense and second to show areas of optimisation more clearly. The following exemplary and not exclusively cost-oriented measures and best practices could be found:

- Purchase of navigation devices with congestion warning: Reducing time spent on the road is one major lever for saving working time (Table 2). A real-time optimisation of routes avoids unproductive time in heavy traffic or congestions, respectively.
- Measurement of settleable solids when required only: With a net measuring time of 0.5 hours, the measurement of settleable solids is one of the most time-consuming on-site activities. The limited use of this parameter saves working time.
- Application to the discharger on short term notice, no confirmation by the discharger: Frequently, a special contact person is required on the dischargers' premises. Short term notice before arriving (approximately. 10 min) avoids waiting time without losing the 'surprise element' of monitoring. Further time savings are possible, if a confirmation of the measurements or measurement results by the discharger is not necessary.
- Sampling planning in a monthly cycle: by using a sampling specification for a whole month (in particular sampling points, number of samples, but no dates), the sampling personnel can organise and process their work self-determined and thus are more motivated.

CONCLUSION

Monitoring of indirect dischargers makes an important contribution to the safe and environmentally sound operation of wastewater systems. As a result of local framework conditions, there is a wide range of monitoring practices across Germany. Benchmarking helps to compare these practices, to rethink and improve one's own activities.

Compared to the total expenditure for the wastewater collection, transport and treatment, the expenses for the indirect discharger monitoring are very low; nevertheless, the process should and can be subjected to a continuous optimisation. However, this must not be exclusively cost-oriented.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

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