Debating the Urban Water Cycle —The Destination of Rainwater

Steffen Koch

Abstract

This case study seeks to show, from an engineering perspective, the importance of historical insights. Urban water infrastructures and particularly the case of rainwater will be used as an example, since this is an issue that became increasingly controversial in Germany in the 1970s. This is remarkable, since the issue had apparently been settled during the development period of the conventional approach (closure). As the controversy emerged again, not only did it return to the engineering agenda, but by then engineering itself had specialized into separate sub-disciplines. The analysis focuses on why and how the infiltration of rainwater succeeded in becoming established as an innovation in sewage disposal rather than in water supply. Conclusions point to the context in which debates take place and decisions are made. Special consideration is given to the boundaries between these two most important sub-disciplines of engineering, as well as to those between experts and lay people. Apart from knowledge of certain techniques, history provides insights into the construction of the context and the interrelatedness of technology and society—into the co-construction of socio-technical solutions by society.[1]

Introduction

Engineers and history

Attempts by engineers to draw on historical information are neither unique nor novel. Publications by Burian et al.[2] can be cited for recent examples from the field of urban water management. In these texts some of the motivations and conclusions characteristic of engineers become apparent. In their first article, for example, the authors start with the intention 'to revisit the historical development' in order to identify and understand past strategies. Concerned with the design of wet-weather flow management (WWF management), they assumed that this approach would help them to elaborate guiding principles for present and future tasks (Burian et al. 1999, 3).

Three out of their seven 'lessons to be learned' are significant, both overall and for my study: 'WWF-management techniques have been developed in response to societal demands or existing problems', 'user-friendly design methods and tools are required' and 'designs must consider political, societal and economic ramifications' (Burian et al. 1999, 14). Whereas their first conclusion obviously points to a perception of technological development processes widely recognized within engineering (the demand / supply relation), the second and third statements suggest that engineers still see themselves primarily as those who design technology. Consequently they hold that a consideration of the particular political, societal and economic circumstances would provide them with indications as to how currently used technologies could be further optimised in order to meet future demands.

I do not claim that the views of Burian et al. are the only historical insights engineers have taken up so far. But I would state—and this marks the starting point of my analysis—that such a perception of the history of technology (history as a 'tool box') still constitutes the predominant view among engineers. More importantly, I would claim that much of the range of historical insights remains unused.

Case and background

In presenting my arguments, I will consider why and how the infiltration[3] of rainwater came to be used in Germany throughout the 1980s and 1990s. Here it is important to focus on how rainwater is conceptually incorporated into the urban, or more precisely, the *anthropogenic water cycle*. At first I will use the expression 'infiltration of rainwater' as it was initially an open question how this could be done. There were proposals for central facilities, run by water works, to solve one of their major problems, the recharging of aquifers. Others considered facilities for sewage disposal. Semi-central or even localized solutions were an option and some proposed giving the responsibility for rainwater disposal to property owners. Of course, pre-treatment would be advisable in the case of potential pollutants. Retrospectively, it seems as if a variety of options and combinations were then possible. The direction of development was neither fixed, nor was it the outcome of intrinsic technical constraints. As will be shown below, there were a number of attempts—indeed, the decisions on the type of approach and application were made only indirectly and at a relatively late stage of the development process.[4] I will use 'rainwater infiltration' to designate the design primarily used today: a localized mode of sewage disposal under the responsibility of the property owner.

This transformation is remarkable in that, since the period of initial development of modern urban water infrastructures (around 1870–1900) and throughout the spread of systematic water supply and sanitation systems, the question of the destination of rainwater had apparently been answered: On the one hand, groundwater became the principal source of water supply; the use of rainwater was marginalized. On the other hand, rainwater run-off was increasingly discharged together with other qualities of used water; rainwater subsequently became labelled as waste water. From the perspective of the sociology of technology, closure was reached on this matter by the end of this period.[5]

Approaches such as optimized discharge (e.g. taking control of sewer overflows), infiltration of rainwater into the ground or even the re-use of rainwater provided a broad spectrum of options for a new way to handle rainwater. It is of strategic importance for my analysis to consider the second option (infiltration of rainwater). As the provision of both water supply and sewage disposal would have had vital need to develop and promote this option, its history draws attention to boundaries and their power in a period of transformation.

Focus and outline

The underlying assumption is that the urban water cycle is a 'hydraulic machine' (Kluge 2000). The terms *anthropogenic water cycle* and *hydraulic machine* will be used synonymously with *urban water cycle*. If a particular term is chosen, this will be to emphasise either the fact that the urban water cycle is a man-made construction (and can only be changed by human activity) or to stress the contradiction between the perceived need to conceptualize the urban water cycle as a unitary machine and the actual facts. The urban water cycle needs to be looked at as a whole (water supply and sewage disposal) in order to understand its characteristics, which derive from a co-evolutionary development process, and to identify possible options for optimization.

Related to the anthropogenic nature of the urban water cycle is, firstly, the hypothesis that different groups of actors and even different sub-disciplines of engineering (with their characteristic perception, attitudes and ways of interaction etc.) are involved in the design of the hydraulic machine and shape its characteristics. Further, as the question of rainwater seems to be 'firmly linked' to the responsibilities of sewage disposal, a second hypothesis arises: existing boundaries, separating, for instance, various groups of actors, fields of engineering and bodies of knowledge, have influenced the acceptance of the idea of using the infiltration of rainwater. Moreover, they have even shaped the design of rainwater infiltration as a new 'technology'—whereas its adoption involved much more than just a technological choice.

The following case study will briefly describe four niches, representing specific projects, with differing actor groups and driving forces. 'Niche' in this regard refers to the local setting as well as the different kinds of actor groups that are involved. Following this, as a summary, I will discuss why and how the infiltration of rainwater became established as an innovation in sewage removal practice but not for water supply. The suggested interpretation builds on concepts of the sociology of technology (socio-technical configuration, technological niche and niche cumulation). In conclusion, I will consider how these insights—and consequently interdisciplinary teamwork—are of importance for engineers.

Reinventing the infiltration of rainwater —a German perspective

The following four niches have been chosen to give an overview of the various intentions that motivated different groups of actors to promote the idea of using the infiltration of rainwater and, in addition, to map different attempts to translate this into socio-technical solutions—into 'configurations that work'. One could of course also differentiate the situations in a different way, drawing attention to additional niches.[6] However, in consideration of the actor groups that proved to be relevant during the development process, and the 'functionalities' that were (and still are) attributed to the design of rainwater infiltration in use today, four different niche types can be seen as most influential in the German case. From a water supply perspective, I will discuss the project in West Berlin; from a sewage disposal perspective, both urban (e.g. Krefeld) and rural settings (e.g. Jesteburg near Hamburg); and, as an example that combines some aspects of both these perspectives, projects in the context of the ecological building movement (e.g. Hamburg-Allermöhe cf. Figure 2, below).

Infiltration as a solution for sewerage problems in urban settlements

River pollution due to sewer overflows, especially from combined sewer systems, was causing concern in Germany by the mid-1960s and became a crucial problem during the 1970s. Two factors made matters even worse: i) the area serviced was still to be extended (newly urbanized areas); ii) runoff quantities in existing settlements were still increasing due to further sealing of the surface. Since the capacity of sewers is limited, critical levels were soon reached. Thus, the questions of rising importance for cities were how to maintain and preserve existing sewer systems and how to run them in an environmentally-friendly way.

Cities like Krefeld and Mönchengladbach occasionally used rainwater infiltration. To some degree, they were able to make use of past experience, as infiltration was considered common practice in this area (EdG 1983, 11). The issue of rainwater infiltration had reached the national agenda as early as 1973. For the first time the infiltration of rainwater was discussed, among other topics, at that year's meeting of municipal civil servants. The matter under consideration was whether official permission would be required for the infiltration of even minor quantities (EdG 1973, 28 ff.)—a legal procedure which had been introduced as the conventional approach was being optimised.

In the years that followed, the disposal of rainwater was regularly an issue at such meetings (1977, 1979, 1981, 1983), an obvious indication that there was both the need and the will to find alternative solutions. In the late 1970s, a proposal for a central infiltration basin, with pre-treatment, for a specific land-use area (around 40 hectares) was put forward and implemented in Krefeld (EdG 1981, 10). Due to a lack of design criteria for such a design, a research project was set up and carried out with financial support from the Federal Ministry of Research and Technology (BMFT).

The infiltration of rainwater was seen as a potential measure to reduce the amount of waste water in newly urbanized areas, as well as to reduce peak flow, by disconnecting run-off rainwater in existing settlements from sewer systems. But it remained an unregulated approach throughout the 1970s and 1980s. Its implementation depended strongly on the judgement of local authorities and their approach to urban planning and to the management of sewerage systems.

As municipalities represent the main actors of this niche, it could have been expected that central infiltration facilities would be the approach of choice, since they would be compatible with the organization of conventional urban water infrastructures and with ease of control and maintenance. Economic factors were clearly a major driving force, with the object of reducing the cost of urban water infrastructures.

Rainwater—a resource for municipal water supply?

In the mid 1970s, the BMFT encouraged the municipal water supply sector to undertake further research, in order to prepare itself for future demand. As a consequence, a call for project proposals was published by the DVGW—the German Technical and Scientific Association for Gas and Water.

With regard to the increasing problem of groundwater depletion, for instance, the Berlin Water Works, among others, applied for funds to investigate and develop focused groundwater recharge, using purified river water and / or treated waste water. However, only the Berlin Water Works additionally applied for a project with a greater scope, intended to reutilize run-off rainwater for infiltration purposes. They even raised the question of whether rainwater collected from roofs could be used more economically for focused groundwater recharge (DVGW 1976, 37). In addition to the exceptional political and spatial circumstances in Berlin at that time, with restricted access to groundwater stocks, it was significant that questions of water supply and sewage disposal in Berlin were, in contrast to common practice, under the control of a single authority.

Although this far-reaching approach was included in the compilation of project proposals, which the DVGW forwarded to the BMFT (DVGW 1976), and although this proposal passed the selection process, the results of the research were rarely mentioned. No hint of the outcome of this particular project can be found, neither in the regular reports on the latest research results, nor in the proceedings of the annual seminars (so-called 'status seminars') held in conjunction with the research initiative.[7]

The ambitious goals initially formulated had already been scaled back at an early stage. This was justified by the priority of basic research, to provide a solid foundation for further investigations. The scope of the project was finally restricted to run-off rainwater from pavement areas only. Beyond the fairly positive conclusion that the pavement materials in use at that time already allowed an unexpectedly high infiltration rate, the suggestions focused exclusively, albeit broadly, on design-related improvements to pavement areas, especially regarding bed and slope (cf. Kowalewski et al. 1984, 127 ff.).

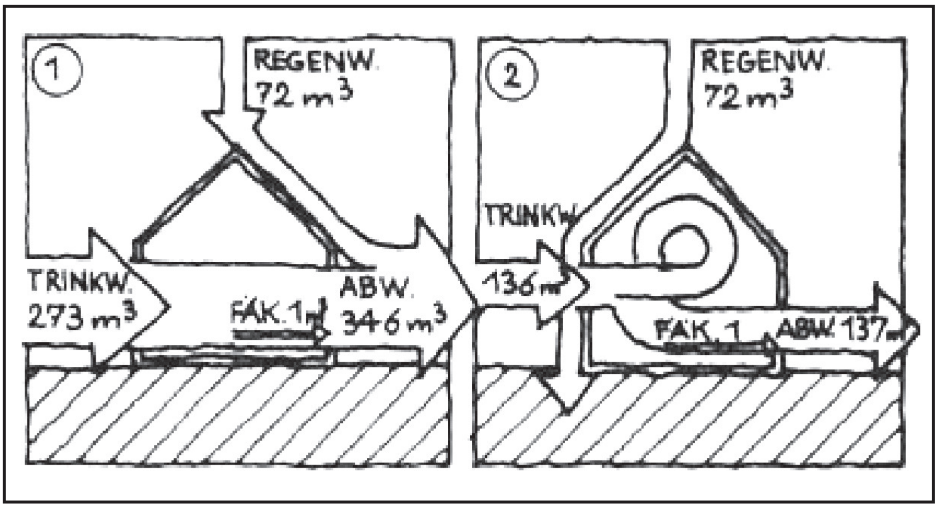
It seems as if the idea of re-utilizing rainwater for focused groundwater recharge did not find a wider audience among representatives of the municipal water supply sector. Although the Berlin Water Works, at that time the second largest water company in Germany, took the lead in the matter, the approach was not further developed by those responsible for water supply.

Rainwater and ecological building

New actor groups entered the debate surrounding urban water management, and thus also the debate about the destination of rainwater, at the end of the 1970s, when the ecological movement gained influence in West Germany and these ideas were promoted in real-world projects. A compilation of all sorts of ecologically sound ideas by Krusche et al. (1982) became a kind of source book for this movement.

This publication project[8] itself was able to make use of new institutions: it arose in the context of the International Building Exhibition Berlin (IBA Berlin), which paid special notice, among other topics, to urban ecology. In addition, it received financial support from the Federal Environment Agency (founded in 1974 to conduct and support research and to advise the federal government). Two out of 12 waste-water flowcharts included in Krusche et al. (1982) are shown in Figure 1.

Figure 1. Conceptual consideration of the urban water cycle—left: the conventional approach, right: one of eleven alternative approaches employing the infiltration of rainwater



Source: Krusche et al. (1982)

Widespread agitation from the grassroots and from architects was characteristic of early pilot projects in West Germany, e.g. Hamburg-Allermöhe or Berlin-Kreuzberg. However, the way responsibilities were allocated to solve these problems, as well as the regulations on which these responsibilities were based, were adapted according to the conventional approach to urban water management. These factors are social constructions, which would have to be suspended in order to make alternative approaches possible. Intensive negotiations between the different groups of actors were clearly necessary: on the one hand, to create a protected area for alternatives to develop, and on the other, to re-align their activities and responsibilities.

The proponents of applied urban ecology not only had to persuade municipalities and building authorities to provide building sites and planning permission, they also had to prove that their alternatives would provide suitable solutions for everyday use. This not only concerned the technical components, such as drains or pumps, but also (and this is the point I want to emphasize) involved the rules and habits of daily practice, the handling of different issues (such as financing, operation, or risk), and the interaction between different actor groups—in sum, they had to provide proof of a 'configuration that works'.

Property owners and users played a vital part in this new alliance, as they now had to handle issues for which they had traditionally not been responsible (such as operation and maintenance). This caused problems for municipalities, which provided the necessary opportunities (to promote themselves as ecological) but were still in doubt. Often they decided to install such infrastructures according to the conventional approach, as redundant facilities. On the other hand, architects and prospective users tried to influence planners in order to integrate alternative solutions (such as multi-use of open ground as a lawn, a playground and an infiltration zone).

Sewerage systems for rural areas

Whereas water supply and sewage disposal had been developed for urban areas (urban technologies), the provision of sewerage for less-populated or rural areas remained an unsolved issue in the 1970s. Long distances and lower population density decreased the cost-benefit ratio and made high loans and subsidies necessary. In contrast, lower building density offered opportunities for more space-intensive technological solutions. In consideration of these circumstances, those engineers who were open to alternatives increasingly turned their interest to rural areas.

Of course the political will of the community was a prerequisite. However, in this situation a decision would have been needed that went against an approach that had proved its reliability and was closely connected to the achievements of hygiene and regional development, and in favour of an alternative that seemed to fit in the spatial context and might be less expensive. Jesteburg, a rural community in Lower Saxony, provides an example. Here, in cooperation with an engineering consultant, a rather unconventional drainage system has been implemented, one which employs ditches and dedicated infiltration zones for rainwater disposal.

It appears to be important in this context that Friedhelm Sieker, who later became one of the leading advocates of this approach among engineers, was involved in this project. He set up one of his first research projects on infiltration processes in Jesteburg. The issue to be clarified concerned the hydraulic conductivity of soil. In 1982, a small series of measurements was started; in the following year this was extended to a one-year project aimed at determining design criteria that could also be applied in other regions of Lower Saxony. The focus here was clearly on rural areas.[9] To a great extent, Sieker was able to confirm the assumptions used by the planners; and these results made him revise his initially sceptical view of the approach.

Together with local councils, engineers have pushed alternative solutions for rural areas. Questions of acceptance and responsibility remain crucial: How can homeowners be persuaded to make use of infiltration facilities on their own ground, as well as at their own expense? How can lay people be persuaded to care about technical issues?

Summary and interpretation

To summarize these insights into the history of the infiltration of rainwater, I will return to the questions I raised initially. The interpretation I suggest departs from more generally understood concepts of technological change. From there I will go on to focus on why and how rainwater infiltration became established as an innovation in sewage disposal but not for water supply.

Both water supply and sewage disposal faced crucial problems during the 1970s/1980s. And, to use the insights of Burian et al., both had to respond. Both approaches to the urban water cycle should have had significant reasons to rethink the destination of rainwater: in water supply, because of groundwater depletion and growing ecological concerns among the public; in sewage disposal because of the need to optimize existing sewer systems and to extend their service.

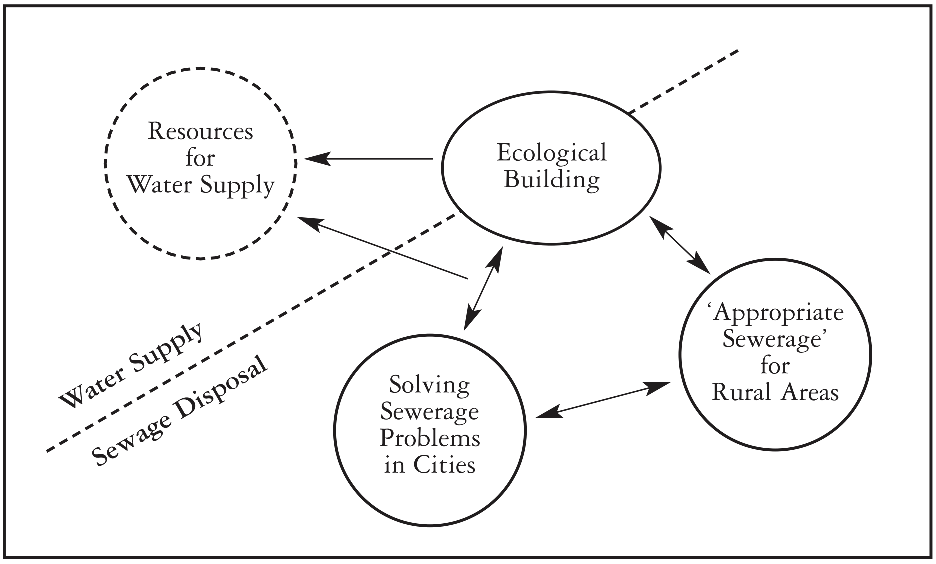
Concepts like 'technology push' or 'market demand' provide useful indications, but cannot fully capture the processes of innovation in rainwater infiltration from the 1970s until its success in the mid-1990s (1990: worksheet on rainwater infiltration, 1st ed., published by ATV;[10] 1996 changes to the Water Resources Act). Market demand, for example, could be regarded as a driving force within the first niche described above (focussing on the situation in cities). However, the approach of using central infiltration facilities (Krefeld), for instance, did not spread further; it was not even considered as an option in the first (1990) or second edition (2002) of the ATV worksheet.

In addition, a discussion restricted to technological and market factors would neglect the differences between the various groups of actors which took part in the debate and thus influenced the transformation process. As the inhomogeneous setting (consisting of different niches) indicates, a variety of stakeholders, with different perceptions of the problems and different approaches to their resolution, were involved in the construction of rainwater infiltration as a new technological solution. The example of the re-emerging debate about the destination of rainwater suggests that even within engineering different fields can be identified which were, and still are, engaged in (re-)designing the hydraulic machine.

Figure 2 provides a schematic overview: at least three niches (solid line) can be seen as precursors that led to a successful innovation. The arrows indicate the assumption that the developments within these niches interacted and that each of these niches contributed in a particular way to the success of rainwater infiltration as a widely accepted technology.

Firstly I will approach the question 'why'—why an innovation in sewage disposal but not in water supply? Simply asking the question in that way invites some reflection on the often hidden continuities. In both fields, the approach to the infiltration of rainwater contradicts the conventional approach.

Figure 2. Development niches of rainwater infiltration



The issue of rainwater is not just 'firmly linked' to the responsibilities of sewage disposal, as stated above. Rainwater disposal can be traced back in time as a long-established issue of sanitation. Traditionally, rainwater has been a matter of sewerage as it had been thought and taught that all water within urban areas had to be drained off.[11] Engineers responsible for water supply adapted to this 'division of labour' when they turned their attention to groundwater. In order to recharge the groundwater body, central infiltration facilities using treated river water and also, since the 1970s, purified waste water, became their technological solution of choice.

Nevertheless, the suggestion of making use of rainwater for water supply purposes—as proposed by the Berlin Water Works—was no novelty of the mid-1970s. The idea of re-utilizing rainwater for focused groundwater recharge had already appeared some decades earlier. Christian Mezger, a surveyor who investigated the relationship between infiltration and groundwater during the first quarter of the 20th century, linked his insights to the growing demand for water. His wealth of publications[12] was noticed but remained without consequence. Later, the same happened to information about an infiltration project in the United States. Only a short notice is to be found (n. A. 1961) even in the leading German scientific journal (‘*Das Gas- und Wasserfach*’). The direction of development in the water supply sector becomes evident in the topics which have been discussed within DVGW, where a working group on water abstraction and groundwater recharge was founded as early as 1953. A search for any indication of this approach is, however, of no avail.[13]

All these references are evidence of the different projects that were not taken up, let alone developed further. The neglect of this idea in water supply considerations supports the hypothesis of a dividing line between these and sewage disposal. Additionally, the references given here point indirectly to the consequences both for practice and for research and development. Not only did the chosen approach take form (‘materialized’) in urban water and sewage systems (causing path dependencies), the way to handle rainwater run-off had also been institutionalized in social constructs such as legal requirements, organizational or institutional structures and professional competencies.[14]

The water supply sector insisted on the traditional organization of urban water management, distinguished by separate approaches to water supply and sewage disposal. As soon as it became necessary to tap river or waste water, water supply engineers could refer to the water quality standards that sewage disposal had to meet. In fact, a re-use of rainwater would not only have meant the diversion of a water flow, it would also have necessitated a renegotiation and reorganization of the way to handle rainwater run-off.

From a sewage disposal perspective, water infiltration had been a topic of discussion very early on.[15] Although it was sidelined by the conventional approach, the existence of different niches (as they developed in the 1970s/1980s) as well as their cumulation gives an indication of ‘how’ rainwater infiltration—as a localized mode of sewage disposal under the responsibility of the property owner—was established as an innovation during the 1990s.

On the micro level,[16] not only have technological approaches been developed, in each niche different groups of actors have been able to actively develop a new role, to acquire the requisite knowledge, and to develop their relationship with each other. A cumulation took place, as the different groups of actors referred to other niches and experiences. The need to successfully link the characteristics of this new solution to the weaknesses of the existing approach (reverse salient) as well as to changes on a macro level (e.g. the growing importance of economic factors, or increased environmental concern) was as important as achieving a consensus on technological matters (Knie & Hård 1993, 238).

While the various attempts to implement the idea of rainwater infiltration differed with respect to their technological components, a consensus was reached (closure); it seems that each niche contributed to the success of rainwater infiltration in a certain dimension. To illustrate this point, I will restrict myself to the most obvious examples related to this case study.

Urban area: representatives of large cities put the issue on the national agenda and put pressure on the dominant approach. This, among other factors, contributed to raising public awareness. Subsequently, other cities also considered the infiltration of rainwater; a working group was set up within the ATV. Their arguments were based on current concerns, e.g. economic considerations and environmental concerns, which secured public attention.

Rural area: rural communities were the last areas to gain the advantage of sewer systems. As engineers began to focus on these areas, they had other motives in addition to the development of suitable solutions. In fact, they found rural areas much less controversial than urban ones. Of course, water quality was an issue here too. But less polluted rainwater and generally lower stress from anthropogenic impacts allowed them to focus on hydraulic matters first, so that they were able to demonstrate that infiltration was a reliable option for rainwater disposal. Facilities for pretreatment could, where necessary, be added on later—an approach (add-on technologies) already widely used in environmental engineering. Apart from such technological matters, rural areas provided the opportunity to find and test possible methods of co-operation with property owners.

Ecological building: the spread of acceptance can be connected to a rising awareness of environmental issues. This might lead to the expectation that rainwater infiltration would be a sure-fire success. But how could it be proved that this alternative was a feasible and acceptable solution? These projects provide a role model for property owners and users, showing them how these new responsibilities can be handled. For instance, some of the attitudes of ecologists will certainly have been taken up by other people, as the ideas of urban ecology spread further.

What is more, there are evident attempts to extend this approach to water supply. Traditionally, water supply engineers fear diffuse infiltration, a potential threat to groundwater quality; advocates of the new approach have made productive use of this concern. Friedhelm Sieker, for instance, claims that even quality comparable to drinking water should be achievable (Sieker 1998).

As cooperation with property owners was achieved, even though they were lay people, and attention was paid to the requirements and concerns of water supply engineers, a way was found to establish a 'configuration that works', which could serve the needs of the different settings. At the same time the success of this innovation, among others, contributed to a change in the image of sewage disposal. Today, rainwater infiltration is regularly cited to emphasise contributions to sustainable development; sewage disposal is recognised as a form of environmental engineering.

Conclusions

The hydraulic machine does not only work because of the functionality and reliability of its technical parts, such as drains or pumps. It also builds on user practices and hygienic standards; recently concessions, if only small ones, are even being made to our 'natural' environment. Those building blocks, however, are constructed by society and institutionalized in the focus of the different groups of actors, as well as in the rules that guide their daily routines. A perception of the hydraulic machine as a socio-technical configuration takes account of this context and would offer engineers a more 'reflexive perspective'.[17]

The history of technology reveals a wealth of information and experience, which can serve as a starting point for the study of the settings, linkages and dependencies which make up socio-technical configurations, and their development over time. Such knowledge will not tell us (engineers) precisely how current or future projects will change existing configurations, but it provides insights into what reactions can be expected, how reactions are, or might be interlinked (in respect of co-evolution), and which approaches might be promising. History not only makes available information about previous successful, or unsuccessful, technical solutions to particular problems. It also provides insights into why certain directions of development were adopted and not others.

Boundaries define certain groups of actors, fields of engineering, or bodies of knowledge, and secure their identity, but they also separate them from others. Such boundaries are socially constructed. Since they provide the context of decision-making processes (who is involved?), they have influenced, and still influence, the design of technology: they co-construct socio-technical systems. Studies of the context of technological development processes make available information about which actors, as stakeholders, have taken part in the construction process: the urban water cycle is not only constructed by engineers. Such studies also provide engineers with the opportunity to learn more about their own involvement in the complex dynamics of socio-technical development. Engineers are not only concerned with technical issues. They also take part in the social construction of the context. Furthermore, such studies offer a rich foundation for reflection about disciplinary characteristics, in terms of perceptions, attitudes and interactions.

There are obviously several possible dimensions along which to extend the use of historical insights for engineers. To illustrate my point, I return to the urban water cycle and rainwater infiltration. One lesson would be the insight that the infiltration of rainwater could already have been implemented to a greater extent—in one way or another—some decades earlier. Different attempts to put this idea forward have, however, been ignored. Another lesson is that changes of urban water management involve changes to the context. On the one hand, this means that changes in context might provide a 'window of opportunity'. On the other hand, it points to the need, not only to construct and optimize technical solutions, but to (re-) design different parts of the socio-technical configurations at the same time. A third lesson refers to 'boundaries'. Certain approaches would have required a re-negotiation of the boundary between water supply and sewage disposal. Such boundaries themselves are a social construction, but—as this case study on the destination of rainwater suggests—they have had a significant influence on the direction of transformation processes.

Notes

1 This contribution has been made possible by the financial support from the Austrian Exchange Service (ÖAD) and the Institute for Advanced Studies on Science, Technology and Society (IAS-STS). The case study was presented this year at the 6th Annual IAS-STS Conference, Graz, 24–26 May 2007, as well as the 5th Conference of the International Water History Association 'Past and Futures of Water', Tampere, 13–17 June 2007.

2 Cf. Burian et al. (1999); Burian et al. (2000) as well as Burian, Edwards & McPherson (2005), at the latest International Conference on Urban Drainage.

3 I prefer to refer to infiltration / the infiltration of rainwater / rainwater infiltration; others use different terms such as percolation or seepage (cf. Moss 2000). The reason is that the technology not only makes use of a natural phenomenon, as applied today, it also contains knowledge of how to determine and manipulate hydraulic conductivity (compare for instance the first, very early, German patent on this topic [Mezger 1929b]).

4 Rainwater infiltration did not become immediately available as a ready-to-use solution, in spite of the impression given by Timothy Moss, when he analyzes the influences of a new technological solution on an existing technological system. When a working group within the German Association for Water, Wastewater and Waste decided to deal with localized solutions first, they still had central large-scale solutions on their agenda.

5 Closure is at the same time productive and counterproductive: it enables a choice to be made and allows engineers to focus on a more detailed (technical) level in order to optimize (e.g. Knie & Hård 1993, 238). Closure also leads to a certain path of development that requires special efforts when later changes become necessary. By then, other decisions have been based on this consensus, different rules and institutions depend or rely on it, etcetera. This contribution addresses the latter and rather problematic part of closure.

6 Another niche could be rainwater running off from roads outside cities.

7 For regular reports on the latest research (usually once a year), see the journal '*Das Gas- und Wasserfach*' between 1976 and 1987; for the proceedings of the annual status seminars, see the DVGW publication series '*Wasser*' vols. 101–105.

8 Cf. Krusche (1980); Krusche, Maria and Per Krusche (1981); Krusche, Per et al. (1982).

9 The development of this matter as a topic of research projects becomes clear in 'wawi-intern', for projects in Jesteburg cf. WAWI 12 (1 July 1982) and WAWI 18 (15 April 1983).

10 ATV is a predecessor organisation to DWA, the German Association for Water, Wastewater and Waste, and comparable to DVGW in the area of water supply.

11 The opinion of Max v. Pettenkofer (1818–1901) is noteworthy in this respect. In the middle of the 19th century, he insisted on ground drainage to prevent fluctuation of the water table. As this dogma had been rejected by the end of the century, the question of the destination of rainwater emerged again. Here engineers argued for retaining the option currently in use (cf. DVföG 1898).

12 Compare for instance: Mezger (1921); Mezger (1926) as well as Mezger (1929a).

13 The activities of the working group are summarized in the annual DVGW report, contained in the journal '*Das Gas- und Wasserfach*'.

14 The phenomenon of 'momentum' and its consequences was described in this context by, for instance, Thomas Hughes (cf. Hughes 1969). Later he referred to this concept in order to develop his approach for Large Technical Systems.

15 Cf. August Gärtner, a German hygienist, on the occasion of the 1897 annual meeting of the German Association of Public Hygiene (DVföG 1898, 57).

16 For the differentiation between different levels (micro – 'niche', meso – 'regime', and macro – 'landscape') cf. Geels (2005).

17 I share the distinction between 'traditional engineers' and 'reflexive engineers' with Peter Robbins (Robbins 2007). I would even claim that engineering education could (and should) make a contribution to achieve a higher degree of reflexivity. Increased interdisciplinary teamwork as well as STS studies would—in my opinion—make a difference.

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