From Transport to Water Protection

Urban drainage is in transition from functioning simply as a transport system to becoming an important element of water protection; however, this transition has been only partially successful since certain properties of today's sewage system represent inherent weaknesses. The cleaning efficiency of the sewage system as a whole, for example, is limited due to significant dilution with grey water and leaky sewage pipes. It is with this background that science is looking for ways to optimize existing structures and develop alternative approaches bringing sustainable urban drainage to a higher level.

The urban drainage system is one of the major public works achievements in Switzerland of the last 100 years (Tab. 1 and Fig. 1) [1, 2]. Over 95% of the Swiss population is served by 40 000 km of sewage pipes and countless other structures related to sewage removal. With 18 billion ton kilometers, the urban drainage system is one of the largest and most efficient transport systems in the country. For comparison: the entire volume of goods transported by rail and on roads in 1997 amounted to 26.6 ton kilometers. In a single year, Switzerland's 964 sewage treatment plants process two billion tons of sewage, producing 209 000 tons of sewage sludge [3], 250 000 tons of carbon, 20 000 tons of nitrogen, and 4000 tons of phosphorus.

Disposal at the Push of a Button has its Price

Far more important than the obvious performance numbers are the hidden benefits of these treatment plants:

- Public health: The ability to dispose of feces and used water efficiently and in nearly unlimited quantities has practically eliminated water-borne diseases in Switzerland. If there is a rare outbreak, it usually can be attributed to a problem in either the sewage system or the wastewater treatment plant. For example in 1998, the drinking water supply of the community of La Neuveville was contaminated due to a defective pumping plant. Sewage leaked into the ground water, which in this case was the community's source of drinking water.
- Protection of infrastructure: Efficient drainage of rain water from urban areas reduces the number of floods and associated damage.
- Water protection: Thanks to the increased number of wastewater treatment plants, general water quality has improved dramatically over the last 40 years. It has become the exception that public beaches are closed due to concerns over water quality.
- Comfort: Last, but not least, urban drainage offers in its prevalent form a level of comfort that was unthinkable not too long ago. There is hardly any other service that is as simple and comfortable to use. All kinds of liquid waste disappear within seconds simply by pressing a lever or button. As far as the consumer is concerned, the wastewater system requires virtually no maintenance, and unpleasant odors are a thing of the past.

Such an accomplishment has, of course, its price. The replacement cost of the entire urban drainage system in Switzerland is approximately 60 billion CHF [4, 5]. This corresponds to roughly 15% of the esti-

5000–3000 B.C.	Pipes and open half-pipes made of fired clay for drainage of villages in the Euphrates valley
2500–1500 B.C.	Bathrooms, toilets and street sewers in the Indus civilization
2000 B.C.	Pipes for water supply, rain water storage and wastewater facilities in the palace of Knossos
300 B.C.	Expansion of the sewer system in Rome
1591	Proposals for sewage treatment in London
1660	Water closets (WC) in England und France
After 1760	Drain fields for waste water
1830	Severe cholera epidemic in London
1840–1850	Construction of the sewer system in London
1848	First modern sewer system in Hamburg
1873	Sewer system in Berlin
1884	Typhoid epidemic in Zurich
1888	Fisheries legislation in Switzerland with regulations on water protection
1892	Biological wastewater treatment in England
1895	First settling basin in Germany
Around 1908	First biological investigation of water pollution by waste water
1916	First mechanical-biological treatment plant in Switzerland (St. Gallen)
1971	Water Protection Law in Switzerland
1975	Regulations on wastewater discharge in Switzerland enacted

Tab. 1: Development of wastewater technology [after 1].

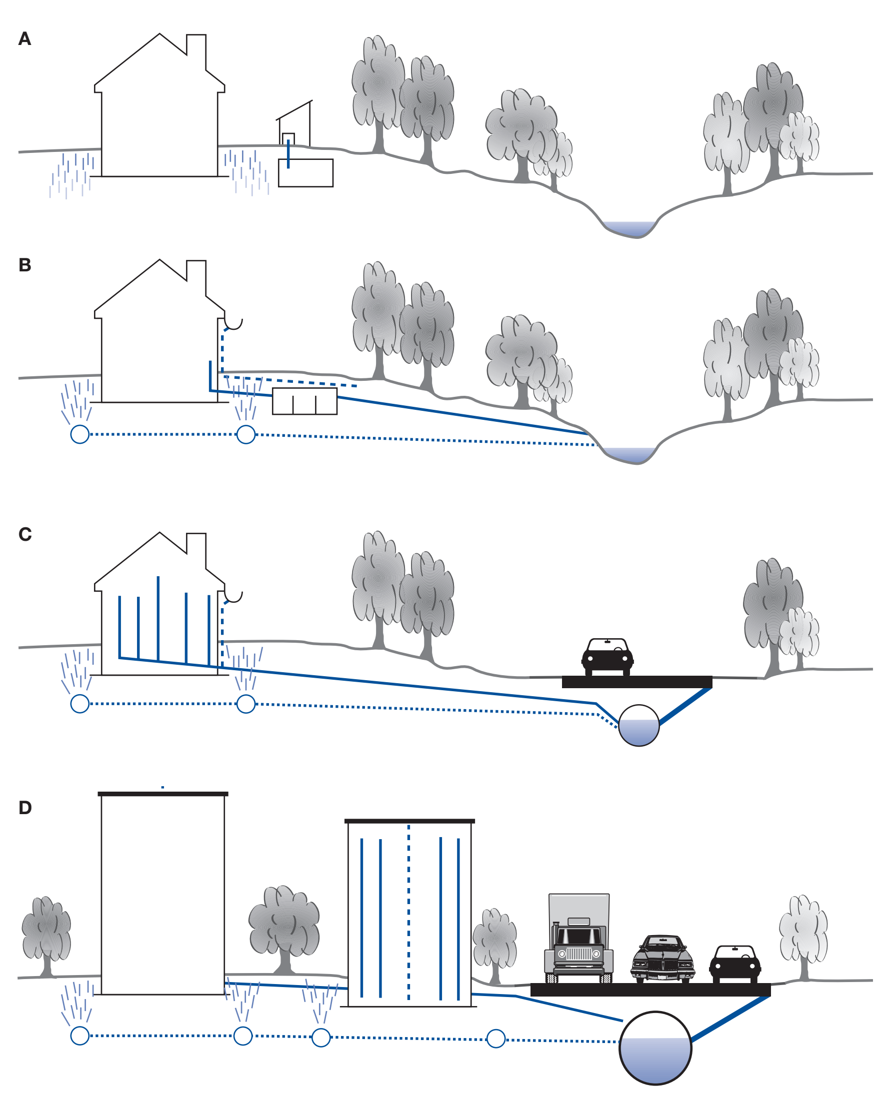

Fig. 1: Historic development of urban drainage [adopted from 1].
A: The cistern or pit system.
B: The pit system had to be abandoned after central water supply systems, bath tubs and flushing toilets were introduced. In addition to waste water, drainage water (in order to improve conditions in basements) was soon discharged into streams as well.
C: The volume of waste water increases with the living standard. Some streams were transformed into sewers.
D: Even today, growing cities require capacity increases in the urban drainage systems.

mated value of all civil engineering structures in Switzerland. The sewage system represents approximately 80 % of this value; the wastewater treatment plants comprise the balance. The total operational cost of urban drainage, including annual depreciation, interest on financing and actual operation, amounts to approximately 3 billion CHF. This amount represents a considerable 2.6 % of the total income of the public sector.

This large and valuable infrastructure must remain organized and managed efficiently. The consumer expects uninterrupted service and a high level of quality at low costs. Compared to the value of the infrastructure, the organization of the urban drainage system has several shortcomings. Necessary organizational and planning processes are often inadequate or non-existent, important information for new investments is incomplete, and planning and control instruments (e.g., clear performance standards, periodic evaluations) are rarely in place. We must provide managerial personnel of wastewater treatment plants with simple and practical tools to evaluate and optimize organization and planning (see article by S. Binggeli, p. 32).

Demand: Sustainable Urban Drainage

Urban drainage is a system that has evolved over time. The original focus, to quickly and efficiently remove waste water from urban areas, has gradually shifted towards the protection of water resources and, more generally, the sustainable development of society. We are realizing, however, that the original purpose of the sewage system does not agree – may even conflict – with these new emphases.

Rain water: Because of capacity issues, combined sewage systems (i.e., sewage systems that have to transport both sewage and rain water), have so-called combined sewer overflow tanks. They initiate when the sewage system is approaching its capacity limit during rain events; rain water containing some proportion of raw sewage is released directly into surface waters. Typically, 5–20 % of the sewage by-passes sewage treatment plants, significantly reducing the overall efficiency of urban drainage systems. Additional structures that temporarily store the mixed water, or possibly even treat it, can relieve the treatment plants and surface waters to some degree. Such structures must be designed for large volumes of water, but are not used during dry weather or during low intensity rain events (i.e., >97 % of the time), and so are relatively expensive. The project STORM (see article by V. Krejci, p. 21) is developing a practical and transparent process for planning new technical solutions for rainwater drainage and treatment and includes consideration of local characteristics of streams and lakes, potential uncertainties, types of contamination, and a broad spectrum of potential remedial actions and their cost efficiencies.

Infiltration: An alternative to channeled drainage of rain water is infiltration into the soil. It has been shown repeatedly over the last few years, however, that rain water is not necessarily free of pollution. This is particularly true for rain water running off roofs or roads. This source of contamination can be considerable and poses an entirely new technical challenge, since this type of contamination is very different from that of domestic waste water. Crucial parameters of concern include the mass fluxes involved, the dynamics of the pollutants, and the capacities of barrier systems that protect surface water, ground water and the soil (see article by M. Boller, p. 25).

Invisible infrastructure: The infrastructure is largely hidden underground and is difficult to access and inspect. Only massive leaks are immediately detectable. With current methods, small to moderate defects require an enormous effort before they can be detected, and then they are usually found as individual leakage points. Urban sewage systems have a relatively long theoretical life span, but are subject to continuous stress due to traffic and soil movement. In combination with natural fatigue of the pipe materials, damages arise that allow exfiltration of sewage and/or infiltration of ground water. New measuring techniques are aimed at quantifying these processes, thereby enabling us to more efficiently plan remediation or reconstruction of defective sections of the sewage system (see article by J. Rieckermann, p. 29).

Dilution and mixing: The principle of the hydraulic sewer system is based on waste being transported by a large volume of water. The resulting dilution of the pollutants and the mixing of different types of waste water make the cleanup more difficult and limits the efficiency of the wastewater treatment plant. This, in turn also increases the risk that undesirable compounds are not completely removed and reach surface waters with the wastewater effluent. From the point of view of water protection, the hydraulic sewer system is a relatively poor system.

Micropollutants: Because of improvements in analytical chemistry, increasing numbers of pharmaceutical chemicals are readily detected in surface waters. These compounds are dangerous because they can accumulate in organisms, e.g., in fatty tissues, and/or because they can have effects at extremely low concentrations, as is the case for hormonally-active compounds. One of the ingredients of the birth control pill, 17α-ethinylestradiol, has measurable effects on fish at concentrations below 1 ng/l [6]. The

Photographs: Entsorgung + Recycling Zurich

Underground in Zurich.

risks associated with such contaminants are extremely difficult to assess. Based on the cautionary principle, however, it ist possible to take first measures now. In his article on page 7, H.R. Siegrist discusses the current state of knowledge and discusses various measures that deal with the problem at both the source and in wastewater treatment.

Conservative infrastructure: Urban drainage is a rather inflexible system. Innumerable elements of different age and lifespan must function as a whole. In order to make the best use of our considerable investments, we are more or less forced to continuously replace and maintain individual elements [7]; therefore, it appears to be unlikely, that in the short- to mid-term, decentralized (small-scale) systems can become successfully established, regardless of whether or not it would be beneficial from an environmental or economic point of view.

Preliminary results from a German research project on "Integrated Microsystems for Supply" show, however, that the inert structure of urban water management is being confronted by factors that could create new dynamic forces leading to change (see article by D. Rothenberger, p. 11). Short-range shifts in population densities from urban centers to suburbs, for example, are already having a severe impact on investment needs and technical concepts. Other examples include water conservation efforts and budgetary constraints that cause investments to be postponed in many locations. The synergism of all of these factors might favor small-scale solutions in certain selected regions or consumer and/or application niches.

In Demand: Innovative Concepts in Urban Drainage

As illustrated in Figure 2, the first generation sewage system is currently being replaced in many areas of Switzerland. In light of the serious disadvantages and high cost of the urban drainage system as a whole, it is beneficial to consider devising fundamentally new concepts that can be integrated into the current system, but which offer new options for the future.

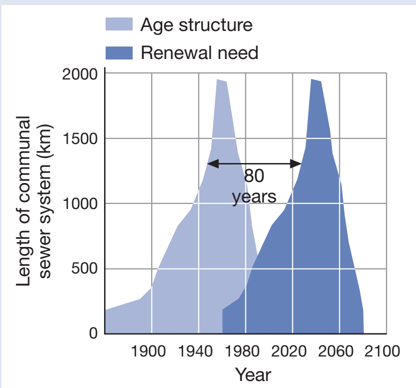

Fig. 2: Age structure of the sewer system in Canton Berne [4].

Maintenance work in the sewer system by employees of "Entsorgung + Recycling Zurich".

EAWAG is intensively pursuing such an alternative concept in the research project NOVAQUATIS, dealing with the separate collection and treatment of urine. Urine accounts for less than 0.5% of the total volume of waste water, but contains over 85% of the nitrogen compounds, 50% of the phosphorus and a large fraction of the hormones and pharmaceuticals in the waste, thus contributing substantially to the overall load in wastewater treatment plants [8]. It is interesting to note that this technology is very flexible and is easily integrated into the existing infrastructure and has benefits even in combined sewer systems. It has been shown that partial collection and storage of urine can help to "even out" peak loads in wastewater treatment plants [9].

EAWAG is not only concerned with the technical realization of this innovative concept, but with gauging public acceptance of such a "novelty". The success of any innovative technology in the real world depends on a number of factors. In today's world of urban drainage, technical decisions are made largely without any input from the public. Far-reaching changes of the current system, such as changes at the source, however, require the involvement of all affected parties at the earliest possible stage. For this reason, the NOVAQUATIS project has conducted several acceptance studies (see article by J. Lienert, p. 14). Results thus far indicate that the introduction of separate urine collection would not be met by any substantial resistance, provided certain conditions are satisfied. Obviously, wastewater experts still play a key role in successfully implementing new concepts and making them practical in everyday life.

Another indication that our urban drainage system is not sustainable in the long term are the difficulties we are facing when attempting to introduce hydraulic sewer systems in developing or underdeveloped countries:

- integration into a comprehensive system of waste disposal is not feasible,
- high resource consumption (water, sewer system),
- lack of flexibility in the case of major population movements or growth,
- need for highly centralized organization,
- high costs.

Based on the Bellagio principles, which were formulated in 2000, EAWAG has developed a new concept for the practical application of integrated waste disposal in developing countries which puts the household at the center of the entire planning process (see article by A. Morel, p. 18). This "household-centred" approach is of interest also in Switzerland because it demonstrates, with a modern understanding of the issues, how the entire waste disposal concept can be rebuilt from the ground up and how the system can be operated with less capital investment and resource consumption. If we succeed in learning from such approaches and are able to integrate them into our existing structures, we will be able to operate our urban drainage systems sustainably and at a high level for a long time to come.

Max Maurer, chemical and process engineer, working in the area of wastewater treatment and sustainable urban water management in the department "Environmental Engineering" at EAWAG.

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