the 2 existing wastewater-treatment plants and the Vistula River outlet. Several small streams also bring wastewater from surface runoff after heavy rains. This situation may be improved by systematic street cleaning, removing dog faeces from the pavements, and improving the transportation of municipal solid waste from the city. The system for local treatment of rain wastewater is not yet finished.

Drinking-water supply and sewer systems should be considered from several points of view. In addition to taking their structural and function into account, consideration should also be given to their history, how they were invented, constructed, modernized and developed over time, taking into account the processes of ageing. The sanitary infrastructure of a city can be seen as the largest machine constructed by human beings.

References and Notes


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Synopsis

The Debate on the Sewerage System in Copenhagen from the 1840s to the 1930s

Until 1856 the ramparts surrounding Copenhagen led, gradually, to overcrowding. At that time Copenhagen had about 150,000 inhabitants. A new constitution was revised in 1857 to increase municipal authority and local responsibility. These structural and political changes were one of the reason for the construction of a water supply system in 1856-1858, and a sewerage system in 1857-1860. But, why did Copenhagen choose a centralized pipe solution? What were the underlying political and scientific factors?

This study offers a brief description of the emergence of the sewerage system in Copenhagen, its historical and social aspects, and the impact that the available engineering knowledge had on the decisions. A sewerage system uses “invisible”, underground and often “taken for granted” technology. My purpose is to examine the historical development of the sewerage system and water closets in Copenhagen as outcomes of a complex process developed in a specific social and cultural context. The study focuses on the ideas, concepts, and arguments presented by different participants in this process rather than on the technology applied (1, 2). The pe-

Figure 1. A. The sewer outlets in Copenhagen in 1883. B. The sewer outlets in Copenhagen in 1960. Source: Copenhagen Water, Sewerage Department. Map: A. Jaakola/Urban Facts, City of Helsinki.
period being studied here is characterized by the rapid expansion of the city, the creation of a new social and political order, and the development of new technologies and scientific theories (3–8). The study is based on archival material, newspapers, and the publications of physicians and engineers in local scientific periodicals.

**THE FIRST DEBATE ON SANITATION AND SEWERS**

Beginning in the last decades of the 18th century, urban life was seen as unhealthy in the health education literature written by doctors in various countries. In contrast, the simple, unspoiled life in the countryside became the model for a healthy life (9). This was the case also in Denmark. According to a study published in 1845 a child born in the countryside, on the island of Fyn, was likely to live 15 years longer than a child born in Copenhagen (10).

The use of precarious sanitary technology was one reason for the unhygienic living conditions in the cities. In the 1840s, Copenhagen had approx. 46,450 m² of gutters. Most of them were open, and wastewater was led into the nearest canal or directly into the harbor. Human waste was collected in cesspools in backyards, and twice a year night men were hired to remove the excrement to locations outside the city, where it was sold to peasants as fertilizer.

Measures were taken to improve this situation. The focus was first on preventive measures, such as establishing a special sanitary police. From the 1840s on, applications of new technology were also suggested, and adopting municipal sewerage became a matter for Copenhagen and its newly elected city council. Sanitary technology and means for sanitation were explicitly suggested as possible comprehensive solutions for Copenhagen. A civil engineer by the name of F.C. Kabell, who had travelled extensively in Europe and visited Hamburg, Paris, and London, outlined the problems of large cities and the technologies that were available to deal with them. In his report to the newly established city council he described the situation in Copenhagen and London in the following terms:

> If we turn our eyes for a moment from the beautiful facades of the houses (...) we will find that the brick pavement in damp weather is covered with filth, and that (...) dust will attack the lungs in the most uncomfortable and most unhealthy way. (...) London has under its fashionable streets an extended sewerage system covering the entire city and connected to that a well-calculated water supply plant. As a unit, this system supplies clean water and disposes of dirty water, thus removing by invisible means that which often causes pain to nose and eyes (11).

London had an underground sewerage system connected to water closets to flush the human waste away with running water. This fast and “invisible” system impressed the Danish engineer as a revolutionary technical solution. According to Kabell, it was not only a healthy and aesthetic measure, but also a modern, civilized and comfortable system that even smaller towns should install.

In 1847, the Danish physician Emil Hornemann submitted a statement entitled *Addressing several gaps in the public hygiene in Copenhagen through sanitary concerns*. Hornemann emphasized the all-encompassing nature of the needed hygienic reforms.

> As a counterweight, hygiene attempts to use our, if I may say so, cultured knowledge on sanitary advice concerning public and private life, and thus it is civilisation itself that remedies the evil it has done. Therefore, the importance of hygiene and health is sufficiently accepted in all the countries where civilisation has made its greatest advances (10).

Hygiene became a specific discipline in medicine, influencing its practices and knowledge, and hygiene became the most important means to prevent epidemics, both in private and in public life. As disease might break out in poor hygienic conditions where faeces, rot and wastewater were present, measures were needed to eliminate those conditions by removing all soil and preventing the occurrence of a “miasma”, the development of noxious vapors that spread disease (12).

In England, a civil servant by the name of E. Chadwick had published a report in 1842 entitled *On an Inquiry into the Sanitary Condition of the Labouring Population of Great Britain*, in which he outlined the need to improve public health in England. This publication became a landmark on account of its description of how filth in the air, soil, water, and surroundings was a major factor in the spread of disease. Public health was not just invented as a simple response to an obvious urban problem, but also as an important social and cultural issue, and this explains why the problem was a public, not an individual concern (13). Chadwick called both for sanitary and technical reforms. Together with J. Roe, who was a civil engineer, Chadwick conducted an experiment on the diameter of sewer pipes that resulted in the development of the “arterial-venous system” for drainage. Instead of rough spongy bricks, they used glazed clay pipes in order to maintain the stable water flow that was necessary for the proper transportation of human waste from water closets without causing clogging (13).

A competition for the best solution

In 1847, a committee was appointed to select new water supply, sewerage, and gas systems in Copenhagen. It was decided in 1849 to arrange an international competition involving all 3 infrastructures. In 1851, the committee received 18 proposals. The first prize for the sewerage system was shared by a Danish engineer.
named Lindberg and by Marillier, a French engineer. Marillier’s plan included underground sewers and water closets, and both plans foresaw that the sea would serve as the recipient, not the canals or the harbor.

During the next 2 years the municipality of Copenhagen and its civil servants prepared more precise plans. Local physicians and engineers went to England to study the water supply and sanitation installations and to obtain additional expertise from English engineers. A Danish physician commented on the visionary English sewer system in the following terms:

The assets of the pipes and sewer system are obvious. Earlier the night soil was allowed to lie for weeks or months in the cesspools where it rotted and fermented, thereby polluting the air in courtyards and houses. (...) according to the pipe system all of it will be led instantly and swiftly outside the city boundary (14).

Nevertheless, in Copenhagen the idea of a municipal sewer system was not generally accepted. One of the opponents was the mayor of the city. He pointed out the high costs of sewerage system for taxpayers and the violations of the property rights of property owners if sewers were to be laid. In addition, valuable fertilizer would be lost if it were flushed via pipes into the sea, and the sewers would freeze in winter because such a system was not suited to the Danish climate (15). Others argued that the new plans were too visionary and that Copenhagen should wait to see how well the new network systems were functioning in other European cities.

A cholera epidemic hit Copenhagen in 1853, and more than 4000 people died. However, this catastrophe was not enough to convince all the powerful politicians of the advantages of a new network system. Consequently, Copenhagen did not get its visionary sewerage system, which would have been one of the most modern in the world at that time. Instead the city got a new water pipe system in 1856, and an 'incomplete' sewerage system, as the engineers and physicians referred to it, came into use in 1860.

'Incomplete' referred to the fact that might men handled the solid human waste and that a separate sewer system was used to remove stormwater and wastewater from the households. As it was forbidden to dispose of human excrement by means of a sewer system, the installation of water closets was also forbidden. The sewer outlets were located at the nearest canal or in the harbor. The old cesspools were replaced by buckets, and the waste continued to serve as fertilizer in agriculture around the city.

**THE SECOND SANITATION DEBATE IN THE 1880s**

The physicians and the engineers had never accepted this 'incomplete' sewerage solution, which they regarded as a technically inferior and politically improvised solution. With the establishment of 'teknisk hygieje' in 1865 as a new discipline at the Polytechnic Institute, a new profession was created and a new generation of technical experts thus became acquainted with the ongoing sanitary reforms. In 1868, hygiene became a discipline in the Department of Medicine at the University of Copenhagen. As these disciplines and institutions were established, the advocates for sewers obtained more expertise, and more discussions took place. On the initiative of E. Hornemann, the two new professions, that of hygienist and that of sanitary engineer, initiated a kind of network in 1878 by cooperating in a new society named Foreningen for Sundhedsplejen i Danmark (Association of Public Health in Denmark) (16). The introduction of water closets was a common topic in its meetings:

Yes, indeed I would vote for water closets (...) but I would know that I voted not for reasons of natural science, but because I would find it more pleasant that I had it flushed away (17). The further away the excrements are taken, the better. There is no need to prove this, as it is obvious and self-evident (...) If the whole medical profession stands up and declares: “This is the only possible and only reasonable system”, then all economic difficulties could be overcome. There is no doubt about this (17).

It was, perhaps, to be expected that a few wealthy people illegally installed their own water closets. As a result, the harbor and the canals received wastes and started to stink. Even though the miasma theory had been scientifically challenged by the modern science of bacteriology, the stench raised a debate. Nevertheless, bacteriology gave the physicians new arguments in their fight against the bucket system, because the possible human contact with the excrements was regarded as a major hygienic problem:
There is sufficient evidence that human excrements could contain living, infectious germs and also that the danger of infection from excrements is at its highest when it is fresh and that it decreases as the disease germs are decomposed (18).

It seemed that a fast, pleasant and aesthetically acceptable solution was preferred. The side effects existed, but they were not seriously taken into account. The engineers emphasized that the sea had the capacity to purify itself naturally and that hence wastewater could be pumped into the Baltic Sea via the Sound of Oresund. Sewerage and water closets became linked with the idea of a modern, healthy society.

The technical solution presented in Copenhagen in 1897 was a 'tout-à-l’égout' that allowed the installation of water closets that would make it possible to flush human waste with running water via sewers into the sea. In 1897–1901, a few long collectors were installed along the harbor and canals, and pumps directed the wastewater without purification via outlet pipes into the Sound off the Amager beach. This was the 'complete' system that was adopted from the plans of the 1850s. The 'inner' city environment was the area to be kept clean and safe, and although the spectre of pollution 'outside' was in fact raised during the debate, it was seen as a problem that could be solved by technical means.

**THE START OF THE SEA POLLUTION DEBATE IN THE 1930s**

The negative effects of the 'complete system' became gradually visible, but not as rapidly as one might think. It seems that only a few complaints were expressed in 1900–1930. According to B. Jensen's study on the history of environmental reporting in Danish newspapers, the first intense and organized protests against pollution came from the area north of Copenhagen along the coast of the Sound. In 1930, local council representatives called a meeting during which the city of Copenhagen was blamed for pumping daily "370 000 tonnes of waste, for example from water closets, into the Sound", which then drifted towards their coastline. They demanded that Copenhagen treat its wastewater (19).

In 1931, Copenhagen appointed a committee to find a solution to the Sound question. The conclusion was that longer outlets and mechanical wastewater-treatment plants, including a biological purification plant in the southern part of the city, would be enough (5). The municipal sewer department pointed out that as Copenhagen had the advantage of being located near the Sound "the disadvantages of directing the sewage into the sea are considerably less than those resulting from handling the sewage on the ground". They also argued that Copenhagen already had a purification plant in the western part of the city and that Copenhagen should not be regarded as the only sinner: the municipalities up north were discharging loads of sewage into the sea (5).

Bathing places near Copenhagen, in Kalvehøj and Helgoland, began to suffer from increased wastewater discharges. The city decided to build a wastewater-treatment plant to protect Kalvehøj, which could not be cleansed naturally by the sea. To improve the situation in Helgoland, chlorine was added to the treated sewage during the bathing season. However, the municipality had to close down the baths in 1932 because of bacterial pollution.

Pollution discussions continued on account of the poor hygienic conditions and the danger to the public health. Plans had been made to solve the problems by extending the outlets and by making finer filters to remove solid wastes from the wastewater. The soluble organic substances were not regarded as a problem. Rather it was argued that the organic substances served as food for small animals and that organic substances dissolved in seawater served as nutrients for vegetation. Sewage was thought to have a positive effect on marine flora and fauna (5).

**CONCLUSIONS**

The present-day practice of urban engineering and especially the sewerage technology of Copenhagen are connected to the 19th century idea of solving public health, aesthetic, and social problems by technological means. A centralized sewerage system was seen at that time as a solution that would instantly, swiftly and completely remove unsafe and smellsy wastewater outside the city boundary. When new disciplines such as "public health" and "recreational engineering" were established, they made important contributions to the discussion of the development of urban infrastructure and sewerage technology applications. The common idea of a complete system, which solves all sanitary problems by discharging wastes into the open sea, out of sight, was applied. However, this solution itself became gradually a major source of coastal pollution. The system was developed further technically, but its principles still remain in use. Nowadays, these systems are often discussed and questioned from the environmental point of view as being the product of a "pipe bound" mentality. The change of the 'complete' system will demand not only finding new technical solutions but also readjustment of a lot of concepts associated with health, aesthetic, and modern civilized life.

**References and Notes**


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