Brief survey of water supply and sanitation with special reference to East European Countries

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Abstract

Purpose of the study: This article is a brief history of development of water sanitation systems in European countries. One of the aims is educating people about importance of water treatment in today's world.

Methodology: Bellow article briefly discuss some history of drinking water supply and municipal wastewater sanitation, *i.e*., construction of historical water engineering system like water wells, first flush toilets, indoor plumbing and simple pressurized showers, sewage farms and irrigation, in China, ancient Greece, Roman Empire, Asia minor, India, by Mayans in America and in Australia.

Main Findings: By the 1840s the luxury of indoor plumbing, which mixes human waste with water and flushes it away, eliminated the need for cesspools. As Britain was the first country to industrialize, it was also the first to experience the consequences of major urbanization and outbreaks of diseases like typhoid and cholera from contaminated water and was the first to construct a modern sewerage system. Most cities in the Western world added more expensive systems for sewage treatment in the early 20th century, after scientists at the University of Manchester Ardern and Lockett discovered the sewage treatment process of activated sludge in 1912.

Implications of the study: More than 100 years have been passed since the activated sludge process was explored, since the time when the mankind started to realize how important is the water sanitation in diseases prevention. However, the water treatment technology is permanently improving and enriched with new innovative solutions, the basic principle from the year 1912 *i.e*., activated sludge process remains as the main process of all conventional wastewater treatment plants.

BRIEFLY FROM THE PREHISTORIC TIME TO THE 19TH CENTURY

The main human settlements could initially develop only where fresh surface water was occurring, such as near rivers or natural springs. Furthermore, the size of the human settlements depended greately on the available nearby water body. Archaeological evidence and old Chinese documents reveal that the prehistoric and ancient Chinese had the ability and skills to dig deep water wells for drinking water as early as 6000 to 7000 years ago (Angelakis, 2015).

The ancient Greek civilization of Crete was the first civilization to use underground clay pipes for sanitation and water supply. Their capital had a well-organized water system to bring in clean water, to remove wastewater and storm sewage canals to overflow when there was heavy rain. It was also one of the first uses of a flush toilet, dating back to the 18th century BC. The Ancient Greeks of Athens and Asia Minor also used an indoor plumbing system, used for pressurized showers. The Mayans were the third earliest civilization to have employed a system of indoor plumbing using pressurized water (Borea *et al*, 2019).

In ancient Rome, the Cloaca Maxima, considered a marvel of engineering, was discharged into the Tiber. Public latrines were built over the Cloaca Maxima. The Roman Empire had indoor plumbing, meaning a system of aqueducts and pipes that terminated in homes and at public wells and fountains for people to use (Fig.1.). Rome and other nations used lead pipes; while commonly thought to be the cause of lead poisoning in the Roman Empire, the combination of running water which did not stay in contact with the pipe for long and the deposition of precipitation scale actually mitigated the risk from lead pipes (Cipolla, 2019).

There is little record of other sanitation systems (apart from sanitation in ancient Rome) in most of Europe until the Middle of the nineteenth century. Unsanitary conditions and overcrowding were widespread throughout Europe and Asia during the Middle Ages. This resulted in pandemics which killed tens of millions of people. Very high infant and child mortality prevailed in Europe throughout medieval times, due partly to deficiencies in sanitation (Angelakis, 2015) (Chant, 2005).

Figure 1: Ancient Rome factual approximation.

Sewage farms (i.e. wastewater application to the land for disposal and agricultural use) were operated in Silesia in 1531, in Scotland in 1650, in Paris in 1868, in Berlin in 1876 and in different parts of the USA since 1871, where wastewater was used for beneficial crop production. In the 16th and 18th centuries in many rapidly growing countries/cities of Europe (e.g. Germany, France) and the United States, "sewage farms" were increasingly seen as a solution for the disposal of large volumes of the wastewater, some of which are still in operation today. Irrigation with sewage and other wastewater effluents has a long history also in China and India; while also a large "sewage farm" was established in Australia in 1897 (Chant, 2005).

SEWER SYSTEMS IN COURSE OF CIVILIZATION DEVELOPMENT

A significant development was the construction of a network of sewers to collect wastewater. Sewerage (or sewage system) is the infrastructure that conveys sewage or surface runoff (stormwater, meltwater, rainwater) using sewers. It encompasses components such as receiving drains, manholes, pumping stations, storm overflows, and screening chambers of the combined sewer or sanitary sewer. Sewerage ends at the entry to a sewage treatment plant or at the point of discharge into the environment. It is the system of pipes, chambers, manholes, etc. that conveys the sewage or storm water.

In some cities, like Rome and Istanbul (Constantinople), ancient sewer systems networked, continue to function today as collection systems for those cities that modernized sewer systems. Instead of flowing to a river or the sea, the pipes have been re-routed to some sewer treatment facilities. Basic sewer systems were used for waste removal in ancient Mesopotamia, where vertical shafts carried the waste away into cesspools. Similar systems existed in the Indus Valley civilization in India and in Ancient Crete (Greece) (Borea *et al*, 2019; Chmielewská, 2022).

In the Middle Ages the sewer systems built by the Romans fell into disuse and waste was collected into cesspools that were periodically emptied by workers known as 'rakers' who would often sell it as fertilizer to farmers outside the city. The tremendous growth of cities in Europe and North America during the Industrial Revolution quickly led to crowding, which acted as a constant source for the outbreak of disease. As cities grew in the 19th century concerns were raised about public health.As part of a trend of municipal sanitation programs in the late 19th and 20th centuries, many cities constructed extensive gravity sewer systems to help control outbreaks of disease such as typhoid and cholera. Storm and sanitary sewers were necessarily developed along with the growth of cities. By the 1840s the luxury of indoor plumbing, which mixes human waste with water and flushes it away, eliminated the need for cesspools (Chmielewská, 2022).

From as early as 1535 there were efforts to stop polluting the River Thames in London. Beginning with an Act passed that year that was to prohibit the dumping of excrement into the river. Leading up to the Industrial Revolution the River Thames was identified as being thick and black due to sewage, and it was even said that the river "smells like death." As Britain was the first country to industrialize, it was also the first to experience the disastrous consequences of major urbanization and was the first to construct a modern sewerage system to mitigate the resultant unsanitary conditions. During the early 19th century, the River Thames was effectively an open sewer, leading to frequent outbreaks of cholera epidemics. Proposals to modernize the sewerage system had been made during 1856 but were neglected due to lack of funds. However, after the *Great Stink* of 1858, Parliament realized the urgency of the problem and resolved to create a modern sewerage system (Chmielewská, 2004).

Joseph Bazalgette, a civil engineer and Chief Engineer of the Metropolitan Board of Works, was given responsibility for the work. He designed an extensive underground sewerage system that diverted waste to the Thames Estuary, downstream of the main center of population. Six main interceptor sewers, totaling almost 160 km in length, were constructed, some incorporating stretches of London's 'lost' rivers. Three of these sewers were north of the river, the southernmost, low-level one being incorporated in the Thames Embankment. The Embankment also allowed new roads, new public gardens, and the Circle Line of the London Underground. The intercepting sewers, constructed between 1859 and 1865, were fed by 720 km of main sewers that, in turn, conveyed the contents of some 21000 km of smaller local sewers. With only minor modifications, Bazalgette's engineering achievement remains the basis for sewerage design up into the present day (Commair, 2009).

In 1802, Napoleon built the Ourcq canal which brought 70 000 cubic meters of water a day to Paris, while the Seine river received up to 100 000 cubic meters of wastewater per day. The Paris cholera epidemic of 1832 sharpened the public awareness of the necessity for some sort of drainage system to deal with sewage and wastewater in a better and healthier way. Between 1865 and 1920 Eugene Belgrand lead the development of a large scale system for water supply and wastewater management. Between these years approximately 600 kilometers of aqueducts were built to bring in potable spring water, which freed the poor quality water to be used for flushing streets and sewers. By 1894 laws were passed which made drainage mandatory. The treatment of Paris sewage was left to natural devices as 5000 hectares of land were used to spread the waste out to be naturally purified (Edward *et al.* 2021).

The first sewer systems in the United States were built in the late 1850s in Chicago and Brooklyn. Initially the gravity sewer systems discharged sewage directly to surface waters without treatment. Later, cities attempted to treat the sewage before discharge in order to prevent water pollution and waterborne diseases. During the half-century around 1900, these public health interventions succeeded in drastically reducing the incidence of water-borne diseases among the urban population, and were an important cause in the increases of life expectancy experienced at the time (Tchobanoglous *et al*. 2008).

WATER SUPPLY AND SANITATION IN MEDIEVAL PRESSBURG (BRATISLAVA)

Figure 2: The first digged well on the Sihoť Island for Pressburg (upper left), Water Works at the Sihoť (upper right), Inventor of drinking water pumping to the castle of Pressburg Wolfgang von Kempelen (lower left) and Company which constructed the first 4.1 km of sewerage for the city of Pressburg (lower right).

During the 16th century Pressburg (Bratislava) inhabitants used many wells, such as on the streets Hlavné námestie, Zámocká, Kapitulská, Michalská brána and the others (Figure 2). Drinking water was supplied also from surrounded Malé Karpaty mountains using for transportation firstly stone and wooden and later on copper pipes and troughs. Around the year 1760 there was digged some well on the Danube river embankment which supplied with drinking water and horse drive the castle reservoir. Construction of the first objects of the city plumbing was started on the August 25, 1884 by C. Corte Company which managed Bernard Salbach. Since the February 1886 started the operation of the first city plumbing for 50 000 inhabitants with the capacity of 1059 m^3/d (20 liter/d/inhabitant) using the steam pump.

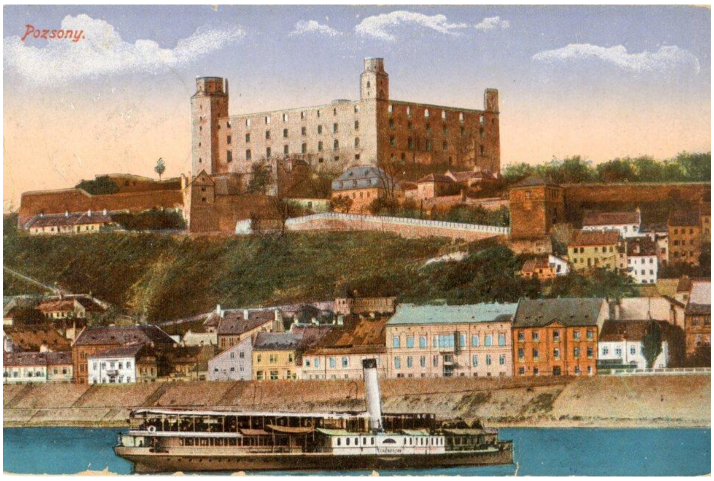

Figure 3: Prešporok (Bratislava), Pressburg, Pozsony in the middle-age time.

The first water pumping station was constructed on the left bank of the Danube River in Karlova Ves in 1886. Together with the well on the island of Sihoť and the water reservoir near Bratislava Castle, the pumping station forms the base of the waterworks for Bratislava. Drinking water was supplied from underground sources on the island of Sihoť. These sources have been rich in naturally filtered water from the Danube. Water was supplied from the water well on Sihoť to the main pumping station in Karlova Ves via a 1.7 km pipeline. From there, water was distributed by steam pumps to the entire city and then into the main water reservoir near Bratislava Castle (www.vodarenskemuzeum.sk).

Designed and engineered by Bernhard Salbach and Zdenko Ritter von Wessely, Bratislava's waterworks use a pressure-gravity system and were the first of their kind in Slovakia. The island's first water well from 1886 is surrounded by a high bank and lined with granite to protect it from floods (Figure 2). In the past, 3000 m^3 of water could be pumped from this well. The first pumping station with electric pumps was built on the island in 1912. Leading from here is a 100 meter concrete tunnel with water pipes, located beneath the arm of the Danube river. The Karloveské rameno is one of the few free-flowing arms of the Danube along the entire section of the Danube flowing through Slovakia. Its total length is 4800 m and it flows around the island of Sihoť, one of the most important sources of drinking water in Bratislava.

The original vegetation of the floodplain forest and natural willow-poplar forests which complement it are preserved in the surroundings of the Karloveské rameno. It is the home of many rare plant and animal species. The first 4.1 km long sewerage system was constructed in Pressburg (old Bratislava) during the years 1897 – 1900 by Pittel & Brausenwetter Company (Figure 2 and 3) (Henze *et al*, 2008)

BIOLOGICAL TREATMENT

It was not until the late 19th century that it became possible to treat the sewage by biologically decomposing the organic components through the use of microorganisms and removing the pollutants. Land treatment was also steadily becoming less feasible, as cities grew and the volume of sewage produced could no longer be absorbed by the farmland on the outskirts. Most cities in the Western world added more expensive systems for sewage treatment in the early 20th century, after scientists at the University of Manchester discovered the sewage treatment process of activated sludge in 1912. The activated sludge process was discovered in 1913 in the United Kingdom by two engineers, Edward Ardern and W.T. Lockett, who were conducting research for the Manchester Corporation Rivers Department (Khan, 2020; Khopkar, 2004; Lienert, 2007; Manahan, 1994; Metcalf, 2014).

In 1912, Dr. Gilbert Fowler, a scientist at the University of Manchester, observed experiments being conducted at the Lawrence Experiment Station at Massachusetts involving the aeration of sewage in a bottle that had been coated with algae. Fowler's engineering colleagues, Ardern and Lockett, experimented on treating sewage in a draw-and-fill reactor, which produced a highly treated effluent. They aerated the wastewater continuously for about a month and were able to achieve a complete nitrification of the sample material. Believing that the sludge had been activated the process was named *activated sludge*. Not until much later was it realized that what had actually occurred was a means to concentrate biological organisms, decoupling the liquid retention time from the solids retention time.Their results were published in their seminal 1914 paper, and the first full-scale continuous-flow system was installed at Worcester two years later (Spuhler *et al*, 2020).

Figure 4: Sketch of secondary sewage treatment in activated sludge tank connected with secondary clarifier (activation – intensification of processes ongoing in nature)

Sewage treatment (or domestic wastewater treatment, municipal wastewater treatment) is a type of wastewater treatment which aims to remove contaminants from sewage to produce an effluent that is suitable for discharge to the surrounding environment or an intended reuse application, thereby preventing water pollution from raw sewage discharges. Sewage contains wastewater from households and businesses and possibly pre-treated industrial wastewater. There are a high number of sewage treatment processes to choose from. These can range from decentralized systems (including on-site treatment systems) to large centralized systems involving a network of pipes and pump stations (called sewerage) which convey the sewage to a treatment plant.

For cities that have a combined sewer, the sewers will also carry urban runoff (stormwater) to the sewage treatment plant. Sewage treatment often involves two main stages, called primary and secondary treatment, while advanced treatment also incorporates a tertiary treatment stage with polishing processes and nutrient removal (Fig.4). Secondary treatment can reduce organic matter (measured as biological oxygen demand) from sewage, using aerobic or anaerobic biological processes (Spuhler, 2020; Tahara, 2019; Tzanakakis, 2007).

With regards to biological treatment of sewage, the treatment objectives can include various degrees of the following: transform dissolved and particulate biodegradable components (especially organic matter) into acceptable end products, transform and remove nutrients (nitrogen and phosphorus), remove or inactivate pathogenic organisms, and remove specific trace organic constituents (micropollutants). The main processes of wastewater treatment and biodegradation of organic compounds, i.e. carbonization, nitrification and denitrification, could be described stechiometrically by the following chemical equations (Sperling, 2015):

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O$$

$$NH_4 + 1.83\,O_2 + 1.98HCO_3^- \longrightarrow 0.021\,C_5H_7NO_2 + 1.041\,H_2O + 0.98\,NO_3^- + 1.88\,H_2CO_3$$

$$C_6H_{12}O_6 + 4\,NO_3^- \longrightarrow 6\,CO_2 + 2\,N_2 + 6\,H_2O$$

where $C_6H_{12}O_6$ presents some model organic substance, $C_5H_7NO_2$ is composition of protein biomass for specific microorganisms growth with respect to its proportion of biogenic elements incl. water alkalinity.

Some types of sewage treatment produce sewage sludge which can be treated before safe disposal or reuse. Under certain circumstances, the treated sewage sludge might be termed "biosolids" and can be used as a fertilizer.

CONCLUSION

This short literature survey reports briefly the development of water engineering systems over the most advanced civilizations in history like China, ancient Greece, Roman Empire, Asia minor, India, Mayans Empire in America, Australia and the others. Water is of enormous importance and therefore it is necessary to clarify permanently its cardinal concern in our everyday life and health. One of the most abundant compounds, water covers about 75% of Earth's surface. Life depends on water for virtually every process. Life is believed to have originated in water and living organisms use aqueous solutions as mediums for carrying out biological processes. About 80% of the world's wastewater is currently still dumped back into the environment and thus this widespread problem of water pollution is endangering our health. Unfortunatelly, unsafe water kills even today more people each year than war and all other forms of violence combined.

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