Main factors of water supply systems industrialization in Russia

E Ketova\textsuperscript{1,*} and J Nizhegorodtseva\textsuperscript{1}

\textsuperscript{1}Novosibirsk State University of Architecture and Civil Engineering, 630099, Novosibirsk, Russia

E-mail: *Jn051191@mail.ru

Abstract. Generalization of historical engineering solutions to the issue for cities’ water supply reveals the main industrialization factors and important historical periods in the development of water supply systems. Water sources are one of the determining factors in the emergence and development of new settlements. The history of water supply in Russian cities begins with the founding of the first settlements. The evolution of settlements, the emergence of trade and economic ties, industrial production, the development of transport infrastructure have significantly influenced the emergence of new technological solutions in the field of water supply. Nowadays centralized water supply became the property of most rural settlements. Modern city’s water supply is a very complex, technically highly equipped system.

1. Introduction

The presence of water sources is one of the determining factors in the emergence and development of new settlements. Water supply systems are subject of continuous change and development. The long and rich story of success regarding water distribution systems (WDS) reach back to the third millennium before Christ. [4] First artefacts from pressurized pipes have been excavated roughly 1400 BC at the island of Crete. [5] Over time so called “rules of thumb” have been detached by mathematical approaches in the field of water supply. Since ancient times to date, big advancements have been achieved in the field of mathematical approaches, hydraulic modelling, optimization and last but not least monitoring. Measurement devices in general undergo a continuous change and development. The devices became more sophisticated with new achievements during the computer and telecommunication age. [6].

The late Middle Ages brought about technical innovations in machinery and the use of flowing water as a prime mover. It was mainly in Central Europe that the rediscovery, renewal, and improvement of ancient water-raising methods took place in the late Middle Ages, thus enabling urban consumption from adjacent rivers. The roughly 300 years covered by this study represent a formative phase in the history of water supply systems, from the first large-scale European urban water raising device, built in Lübeck around 1300, to the construction of the London Bridge Waterworks in the 1580s. Historians have generally viewed the London project as one that revolutionized attitudes toward water supply, transforming water into a commodity and water supply into a business. [7]

The history of water supply in Russian cities begins with the founding of the first settlements. The evolution of settlements, the emergence of trade and economic ties, industrial production, the development of transport infrastructure have significantly influenced the emergence of new technological solutions in the field of water supply.
Nowadays centralized water supply became the property of most rural settlements. Modern city’s water supply is a very complex, technically highly equipped system.

2. Materials and methods
The following scientific works served as the fundamental basis for the study:

The idea of the historical development of water supply and sanitation in Russia are given in the monographs of A.F. Poryadina, Yu.V. Voronova, N.I. Falkovsky, V.N. Dobrovolsky, S.V. Khramenkov. In the writings of V.V. Jubo, A.E. Belana, V.A. Fisher, V.V. Balygina, A.A. Surin, V.A. Drozdova, S.N. Aronov, devoted to the problems of technological processes in the water supply system, various devices and their operating principle are described.

The goal of the study was identifying the main factors of the water supply systems industrialization in Russia.

In accordance with the goal, the following tasks were set:

- explore the prerequisites for the emergence of water supply systems in Russian cities;
- identify the historical periods of the water supply systems formation in Russian cities;
- determine the factors of water supply systems industrialization in Russian cities.
- The research approaches were:
  - search, study and systematization of scientific, statistical, literary and journalistic sources, regulatory documents, photographic and design and graphic materials;
  - study of domestic and foreign design and construction practices in the field of water supply.

3. Results
At the beginning of the XVII century, the most part of the Russian Empire population lived in the countryside. Urban population did not exceed 5%. Therefore, there was still no need to create a centralized water supply. The population was provided with water due to the climatic factor. For example, water needs were met at the expense of the Moscow River and its significant catchment area in densely populated Moscow.

The influence of the climatic factors was well noticed in the first historical period - the Pre-Petrine period, when the main sources of water supply were springs, wells, rivers, ponds in Russia. Many Russian fortress cities, fortress monasteries were built on the same principles, in high places in order to defend the city and protect it from possible flooding near a water source. At the same time, it was necessary to create hiding places and secret exits to water sources in the fortress cities.

Figure 1. Water intake in a complex of defensive structures. 1 - water intake well; 2 - gallery passage; 3 - fortress wall.

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Borovsk is known city from the XIII century. Borovsky Pafnutiev Monastery was built 3 km from the city in 1444. The monastery was built contrary to the custom of setting up fortresses on the high banks of the rivers, on a flat plot, at the mouth of the Iterema River, which flows into the Protva River. One of the monastery's towers, Tainitskaya, like others, was named so because the defenders of the fortress could get to the source of water supply through ponds during a siege, those ponds that served for fish farming and water supply. In addition, the hiding places served to protect the fortified city from such a natural factor as fire, because the main building of the city was wooden one. Therefore, craftsmen, making fire pumps (pumps) in the form of copper water pipes, or wooden pumps from drilled pipes worked in Moscow from the XVII century. [12]

Moscow water pipes out of lead were dated by the 15th century. Stone water pipe was created in the Trinity-Sergius Monastery in the XVI century, where water flowed into the monastery pipes. Then, in one of the Solovetsky Monastery wells, water was supplied by gravity from a dug up Holy Lake through underground pipe, then it was lifted using a hand pump (pump) and distributed through gutters to neighboring rooms - to the kitchen and to the brewery. There was a large water economy in the Solovetsky Monastery. For example, in 1566 there were three grain mills and one mill (crush) percussion for grinding solid materials. [10].

The technological factor influenced both, the construction of a water supply system in the Trinity-Sergius Monastery and a pressure water supply system in the Moscow Kremlin in 1631 - 1633. The corner south-western tower of the Kremlin (Sviblova) was equipped with a cache for taking water from the Moscow River and supplying it to the Kremlin. Later in the 1630s, the Kremlin’s Sviblov Tower was renamed Vozvodvoznaya, as the water was lifted using “water platoon”, a water-lifting machine that operated from a horse drive. A pressure tank lined with lead was arranged on the tower, which helped water flowed through lead pipes into the control tank that was called the Vodovzvodnaya Tent, on another tower. Then, water was sent to the palaces of Sytny, Kormovoi, Khlebny, Konyushenny and Poteshny through lead pipes laid in the ground, as well as to the services and gardens of the Kremlin. On the network there were pressure tanks and reservoirs - “water supply lari”. [1]

Pre-Petrine period, as the first historical one, was characteristic of the Russian kingdom by slow technological development. But as a result of the social factor influence, several schools with a curriculum including knowledge in mechanics, physics, chemistry and hydraulics already appeared in Moscow in the 16th century. The first dam in the Russian Empire was built on the Volkhov River with a mill in the XVI century. This indicated that the sources began to be used not only for the city’s water supply and water communications, but also for the generation of water energy, which was used by all industrial enterprises at the beginning of the 17th century. [8]

Petrine period, the second historical period was the end of the XVII - XVIII centuries, characterized by the development of many areas and reforms. This affected the development of water supply systems in cities: the creation of fountain complexes and the first centralized water supply. Deep economic transformations were realized thanks to social transformations and the creation of an absolutist Russian state. The influence of the social factor manifested itself since 1697, when Peter I sent gifted young people to study in Western Europe and planned to create secular state schools of various directions in Moscow, St. Petersburg, Voronezh, Tavrov, Arkhangelsk, Kronstadt, Astrakhan, Reveli, Kazan, Sestrorets in the future. In 1725, the St. Petersburg Academy of Sciences was opened and famous professors from Europe began to come and work in the Russian Empire.

In the same historical period, the political and economic factor appeared, when the Russian State began to purchase and bring European equipment to implement the plans of the Tsar by the decree of Peter I. So in 1709, Peter I issued an order on the creation of a water complex in the Summer Garden of St. Petersburg. Severi steam-atmospheric machine brought from England was used to supply water to 60 fountains, which pumped 120 cubic meters of water per hour from a depth of 8.7 m and was capable of lifting it along the discharge line to an additional height of 3.3 m.

Construction of a unique water complex in Peterhof was begun by decree of the Tsar in 1715. The main source of water supply was the “Shinkarsky” twenty-kilometer canal with a lock, which supplied
water from the sources. The Peterhof fountains began to operate on August 9, 1721. The Samson fountain remains the most famous ones. They were created at the direction of Anna Pavlovna in honor of the Poltava Battle. In total there are 76 fountains in Peterhof, representing a complex hydraulic system, which were constructed many by well-known European and Russian engineers. [13]

Major reforms took place under the leadership of Peter I in 1721 (in particular, the first regular army was created and the convocations of the Zemsky Cathedral stopped), as well as, the transformation of the kingdom into an empire. During this period, a palace was built in Tsarskoye Selo against the backdrop of the political factor. In 1748 construction work was underway on the first Tsarskoye Selo water pipeline, and in 1773 construction of the third Tsatsky water pipeline began under the direction of General V.F. Bauer. The total length of the water supply network was 15 km with two aqueducts construction.

In the XVIII century water supply needs increased many times, due to the influence of socio-demographic factor. At that time, the population of Moscow amounted to 400 thousand people in need of high-quality drinking water. [15]

In addition, the industrial progress began in the second historical period. The number of enterprises that required a large amount of water grew. If industrial enterprises used water wheels to create water energy at the beginning of the XVII century, then in the XVIII century they began to use ducers under the influence of a technological factor and the spread of steam power plants of Thomas Severi and Thomas Newcomen began.

![Figure 2](http://xn--80aqpk2ad9a.xn--p1ai/article/articlestsaritsyn/261-vodoprovod.html)

Figure 2 Photo 1894. The water pumping facility of Tsaritsyno was opened only 3 years ago. The initial terrain is clearly visible Source: http://xn--80aqpk2ad9a.xn--p1ai/article/articlestsaritsyn/261-vodoprovod.html.

In 1779, the question of the centralized water supply in Moscow arose and in 1780, General V.F. Bauer drafted a "Project on the conduct a water supply of the Moscow capital." After surveys, Mytishchi Keys were chosen as a water source near the village of Bolshoi Mytishchi. The water supply system was put into operation in 1804. Within Moscow, water was distributed through canals and cast-iron pipes, wells, pools, fountains. 7 thousand buckets of water were located where the water supply system operated in the cast-iron tank in the Sukharev Tower. Water flowed from the Sukharev Tower into the center of Moscow to Trubnaya Square and to Neglinka, where fountains for water analysis were built. [9]

Against the background of the technological factor influence, the social factor in the field of education in the Russian Empire appeared again. In 1782, mechanics, hydraulic engineering, hydraulics and foreign languages were introduced into the program in the existing education system, by decree of Empress Catherine II. Thus, the Russian Empire began to use scientific knowledge and advanced technologies, which were also applied in the field of the cities’ water supply.

Mid XIX century symbolizes the third historical period, when the first railway was set to operate from St. Petersburg station to Tsarskoye Selo under the great influence of the technological, political and economic factor, in 1837. It was a global technical breakthrough that opened up a lot of
opportunities for industrial production and regional development, as well as new directions for studying plumbing in the Russian Empire, since water supply to the railway transport required a lot of attention and training of engineering personnel. [11]

In the context of the railway construction globalization and urban development, a characteristic feature was the creation of Russian water congresses, which lasted until 1931, in the fourth historical period - the end of the 19th century and the beginning of the 20th century. The scientific and technical community made a great contribution to the initiation of the Russian plumbing, having united in a sectoral society. The design and construction fundamentals of water supply systems, principles of purification and drinking water disinfection, water intakes installation from underground and surface sources, organization of the water supply network operation, water supply of railway stations — all these questions were discussed at congress meetings, and the ways to solve them became the documents for the municipal water management in cities and other settlements of the country. At the same time, the construction of a centralized water supply network was not feasible mainly due to the influence of economic and political factors for most cities at the beginning of XX century. At first, 1917 historical events influenced the development of water supply systems and the country as a whole after the civil war. [14]

But thanks to research by the plumbing community members, it was found out that the water factor was decisive. The frequent occurrence of cholera epidemics, typhoid fever, dysentery and high mortality, became the main criterion for the construction of centralized water supply systems in cities. Council of People's Commissars of the RSFSR in 1921 adopted a decree “On measures to improve water supply, sewage systems in the Republic" due to the difficult sanitary and epidemiological situation in the country. This decree intensified the activities of not only government agencies, but also a wide range of plumbing specialists. In 1922 - 1923 many water pipelines in Russia were undergone restoration work. Due to this, in 1922 the number of water supply network increased 1.4 times in comparison with previous years, for example, at the Tomsk water supply system.

During this period, the factor of industrialization, affecting the rapid growth of cities, expanded the scale and changed the development nature of urban water supply systems. A feature of the water supply development was a comprehensive solution to the problems of water supply for the population, as well as the needs of industrial and municipal enterprises and transport. During this period, the interaction of the technological, social, economic, political factor opened up a sufficient number of opportunities for improving and industrializing water supply systems not only in central Russia, but also in its regions, taking into account the natural and climatic factor of each region.

It should also be noted that the design of new water supply systems was carried out in conjunction with the development of new cities’ master plans. The emergence of centralized water supply in cities has become an integral part of urban infrastructure and a city-forming factor during this period.

The beginning of the Great Patriotic War symbolized the beginning of a new fifth historical period, 1940 - 1960.

During this period, water supply of cities was divided into two groups. The first group included cities in the war zone and the second group of cities located in the rear, where industrial enterprises and production personnel were evacuated. These were mainly Siberian cities. In the first group of cities, there was a demand for the ability of water supply systems to extinguish fires, which influenced the industrialization of water supply systems. In the second group of cities, the influence of the technological factor required maximum system capabilities for the smooth operation of industrial enterprises. At the same time, the water factor required great attention from the population, since it was necessary to prevent outbreaks of mass infectious diseases by any means.

During the post-war restoration of destroyed water supply systems, an appeared social factor required the development of engineering solutions and projects for the restoration of water supply systems. Only the Giprokommunvodokanal developed projects for 16 cities.

The recovery period and the period of gradual recovery gave way to a new sixth historical period - the middle of the 20th and the beginning of the 21st centuries; it was the intensive development of water supply systems.
 installation works (in comparable prices), billion rubles.

Commissioning of fixed assets, capital investments and the volume of construction and installation works (in comparable prices), billion rubles.

| Country   | Area, million km² | Population, million people | Density population, people per km² | Extended railway station, thousand km | Coal Mining, million tons | Production of cast iron, million tons | Steel production, million tons | Products of machine building, million rubles, population kg, rub. | Spindle in cotton paper industry, thousand pcs | External turnover trade, million rubles |
|-----------|-------------------|-----------------------------|-------------------------------------|---------------------------------------|---------------------------|--------------------------------------|-------------------------------|---------------------------------------------------|---------------------------------|-------------------------------------|
| USA       | 9.84              | 22.0                        | 0.42                                | 2.10                                  | 21.3                      | 4.5                                  | 31.8                          | 329.0                             | 5.0                             | 135.05                             |
| Germany   | 4.96              | 169                         | 0.29                                | 2.00                                  | 1.00                      | 0.39                                | 2.25                          | 35.90                             | 4.0                             | 32.0                               |
| Russia    | 1.22              | 152                         | 0.28                                | 1.14                                  | 0.20                      | 0.39                                | 1.30                          | 17.6                              | 0.25                            | 1.30                               |
| Italy     | 0.91              | 128                         | 0.29                                | 1.12                                  | 0.25                      | 0.25                                | 1.85                          | 7.7                               | 0.30                            | 1.30                               |
| Japan     | 3.56              | 142                         | 0.29                                | 1.12                                  | 0.25                      | 0.25                                | 1.85                          | 3.96                             | 0.30                            | 1.30                               |

**Table 1.** Russia rating among other capitalist countries in 1913 y.

* Without individual housing construction.

The social factor played an important role in the intensive development of water supply systems, smoothly flowing into the new historical period. The presence of a design and research base in the...
water sector allowed us to begin deep analytical and experimental work to assess the condition, technology and further development of water supply and sanitation systems.

Since the 1950s, more than ten thousands of kilometers of urban water and sewer pipelines were built. This was ensured, in the second place, due to the influence of the economic factor, which manifested itself in the investment in ferrous metallurgy and subsequently interacted with the technological factor and the development of pipe production from metal, reinforced concrete and asbestos cement. During this period both, these factors and the socio-demographic factor had the main influence. Fast-growing cities required much more capacity for water supply systems, while increasing demands on the quality and quantity of water. Currently, the Government of the Russian Federation was developing long-term programs to improve the technological process of water supply. A lot of researches were being done on water quality, and fire-fighting technologies were being developed separately.

- historical periods of water supply systems industrialization in Russian cities were identified;
- factors, affecting the water supply systems industrialization in Russian cities were studied.

4. Discussion
As the study’s result, the main factors of water supply systems industrialization were formulated and historical periods were identified.

In the first historical period - the Pre-Peter the Great period, the main influence was exerted by the social factor, which allowed the construction of the first gravity water supply system, in combination with the technological one.

In the second historical period - the end of the XVII and the XVIII centuries - The Petrine period, it was worth noting the influence of the political and economic factor, which consequences opened up for Russia interaction with European experience in the design and construction of water supply systems in European cities.

It should be noted that the first and second periods can be considered as preparatory for the further industrialization of water supply systems

The middle of the 19th century is the third historical period characterized by a technological breakthrough, primarily the construction of the railway and the further development of its structure, as well as the expansion of industrial production in the Russian Empire Cities.

The end of the 19th and the beginning of the 20th centuries is the fourth historical period again influenced by the social factor in interaction with the water factor, since the quality of drinking water becomes a priority.

In the fifth historical period - 1940 - 1960, the technological factor was especially manifested in connection with the Great Responsible War, which required large-scale globalization of industrial production and uninterrupted operation of the water supply system.

In the sixth historical period, the middle of the 20th and the beginning of the 21st centuries, the economic and socio-demographic factor mainly affected the industrialization of water supply systems. There was an increase in funding in many utilities and the development of Russia as a whole.

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