Engineering problems of water supply and sewerage at Moscow city example

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The theme of my presentation is devoted to engineering and ecological issues of water supply and sewerage of major conglomerations taking Moscow city as an example.

To proceed further let me first speak about some technical terms.

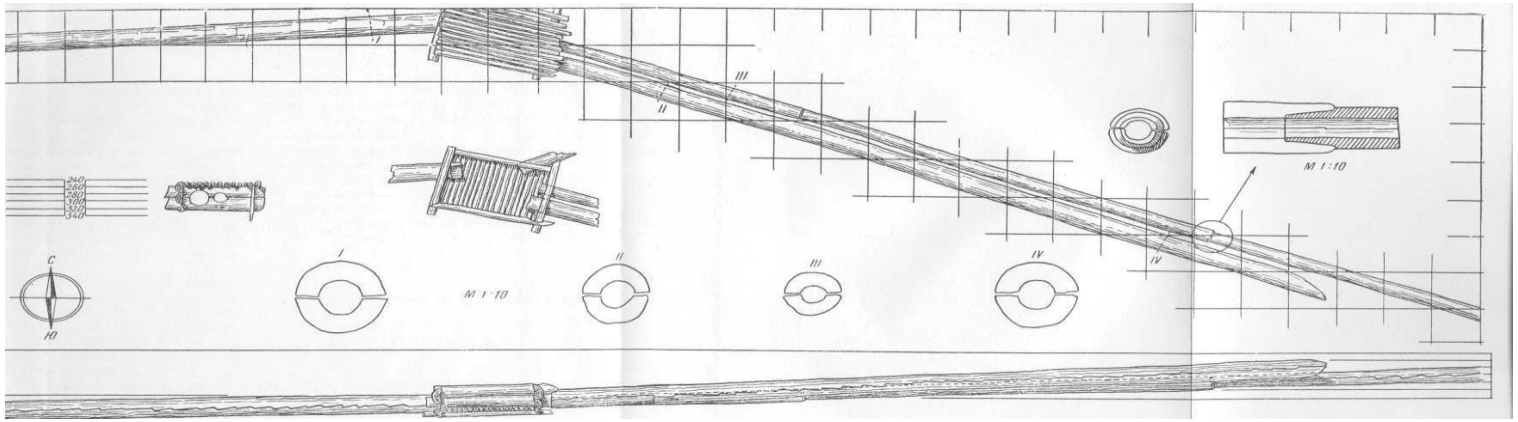
Water supply line is a network of inline (pipe lines) and stationary facilities (water intake stations, water treatment, pump stations, etc) which enable to provide the customer with water.

Sewerage is a network of wastewater pipelines both pressure and gravity type including other facilities (sewerage pump stations, purifying and disinfection stations) which enable to transport domestic sewage and utilize it.

Now let me refer to history.

Channeling

The first drainage facilities in Russia appeared in Novgorod in the XI century. It was a well spread town system. The facilities had various shape and design but were inevitably made of wood. The framework consisted of two halves of a log each hollowed out and connected together.



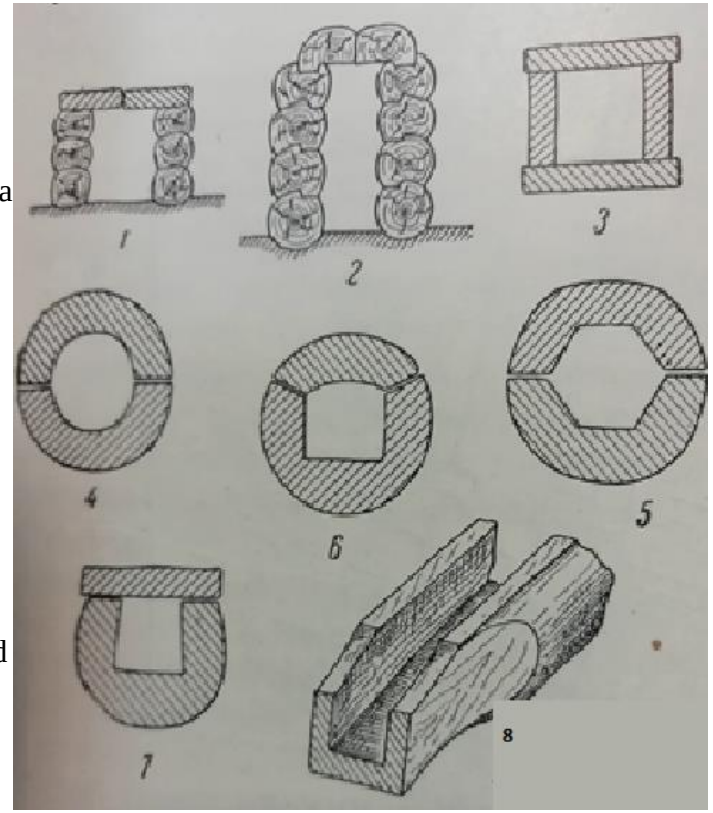
The system consisted of the following parts: 1) catchments (barrels) under buildings which were also used during fires; 2) outlet pipes with incline from the catchments; 3) main water pipeline with the connected outlet pipes from several constructions ending by the river bed.

The technique of hydraulic drainage facilities invented in the XI century proved to be so sophisticated and efficient that they remained functional without any significant changes for eight centuries.

The underground channels for wastewater disposal were dug in Kiev and Moscow in the XIV century. It is known that in 1367 the sewage pipe was laid down from the centre of Moscow Kremlin to the Moskva river.

The first home toilet with flowing-cleansing drainage appeared in St. Petersburg in 1710 under the decree of Peter the Great.

The construction of centralized sewage in towns started to develop due to rapid growth of water consumption, sanitation price rise, heavy pollution of the major residential centers and epidemics. The authorities of resort towns were the first to initiate the construction of sewage and take measures for improvement of town environment. At the beginning of the XX century only 12 out of 1063 towns in Russia had the sewage systems. Even in Moscow it was functioning only in the center of town.



Only in 1892 the Municipal Duma approved the project of the separate canalization of the capital city.

The project envisaged the construction of sewage with the separate drainage system. It had to get only household and factories' sewage while the atmospheric water after filtration was to be dumped into the water bodies. The implementation of the projects started in 1893.

Twenty three (23) Russian towns had the sewage systems by the year 1917 which made only 3 per cent of the total number of towns.

The modern Moscow sewage is a complicated system of engineering facilities.

Historically the sewage system of Moscow has a separate functioning as it was mentioned above. It receives only domestic, municipal and industrial waste water. The surface waste water is diverted into the independent drainage system. All household and industrial waste waters received by of the Moscow canalization through network of pipelines, channels and collectors with diameter from 125 mm upto 4,5 m undergo the full purification cycle at the purification facilities with the total project capacity of 5,4 million cubic meters per day. The total length of the city sewage network comprises more than 8812 kilometers.

The city water disposal is carried out at the purification facilities of three stations.

The way of waste water to the town purification facilities is rather long. At the first stage waste water from residential areas and industrial enterprises flows through internal and yard pipelines into the sewage system.

In the majority cases it flows by the gravity due to compliance with the required slope and depth of pipes laying. In the areas where it cannot be fulfilled because the limited depth of pipe laying or other conditions of urban construction the pump stations are installed for providing further pressured flow of the waste water.

The Moscow sewage system includes 8,7 thousand kilometers of pipelines, 156 pump stations which ensure every day disposal of about 3,3 million cubic meters of waste water. All household and industrial waste waters received by the municipal canalization undergo the full purification cycle.

The main challenges of the water drainage of Moscow city:

- Quality increase of waste water purification by introduction of the best available technologies of biogenic elements' removal and ultraviolet disinfection;
- Provision of ecologically safe utilization of waste water residue;
- Prevention of specific sewage odor spread;
- Introduction of energy efficient equipment into sewage system.

One of the perspective trends in alternative energy development is an extraction of thermal energy from waste water with the help of thermal pumps.

The practice has shown that pipeline systems are the most functionally significant in the sewage system but also the very vulnerable from the reliability point of view. As usual the issue of network deterioration is quite acute.

Annually upto 200 kilometers of free flow sewage pipelines and upto 50 kilometers of pressured pipelines reach 100 per cent of deterioration.

In conditions of dense city construction the most efficient economical solution is the usage of trenchless method of pipeline restoration which covers about 80 per cent of the total reconstruction volumes.

Nowadays the following is used:

- Application of concrete-sand coating on the inside surface of pipes;
- Broach of seamless polymer sleeves;
- Broach of polyethylene pipes into existing pipeline;
- Close method of laying of high-strength cast pipes.

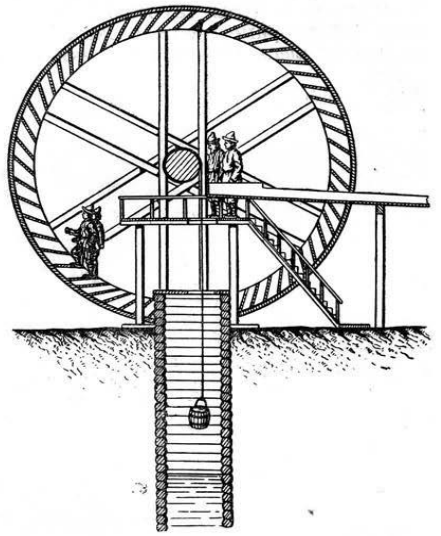
Water supply

The first gravity water supply appeared in Russia in the XI century, and the water flowed in wooden pipes.

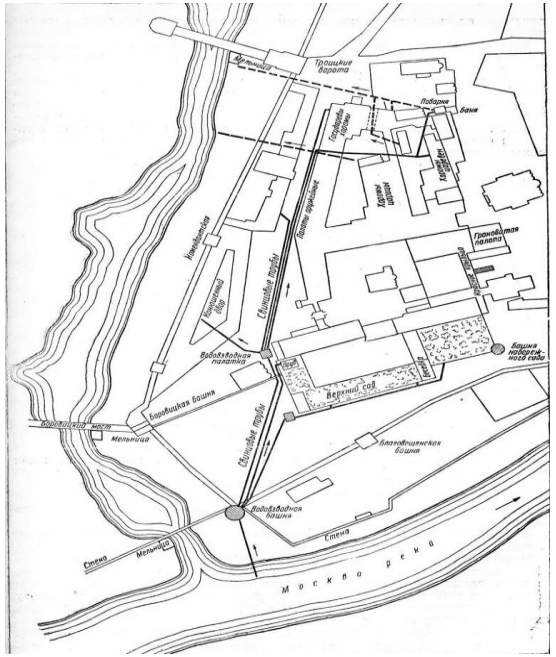
At the end of the XV century a powerful water supply system was erected in Moscow Kremlin using the underground water which was flowing over the stone channel and cast pipes laid in the underground tunnels.

The length of some of the channels was about 1,5 – 2,0 kilometers which means that was a water supply network.

The development of industry, trade and town growth resulted in a new rise of hydro-technical construction. For industrial purposes in the majority of cases the technical water supply with dams, water reservoirs and other facilities were made. To deliver water upwards the projects of the XVII century used piston pumps, water and tread wheels, in rare cases winch and slug inlet.



step-by-step wheel



Scheme of water supply and Sewerage in the Kremlin

In the XVII century the gravity water supply for household and drinking purposes was widely spread. They transported water over channels and pipes – stone and wooden.

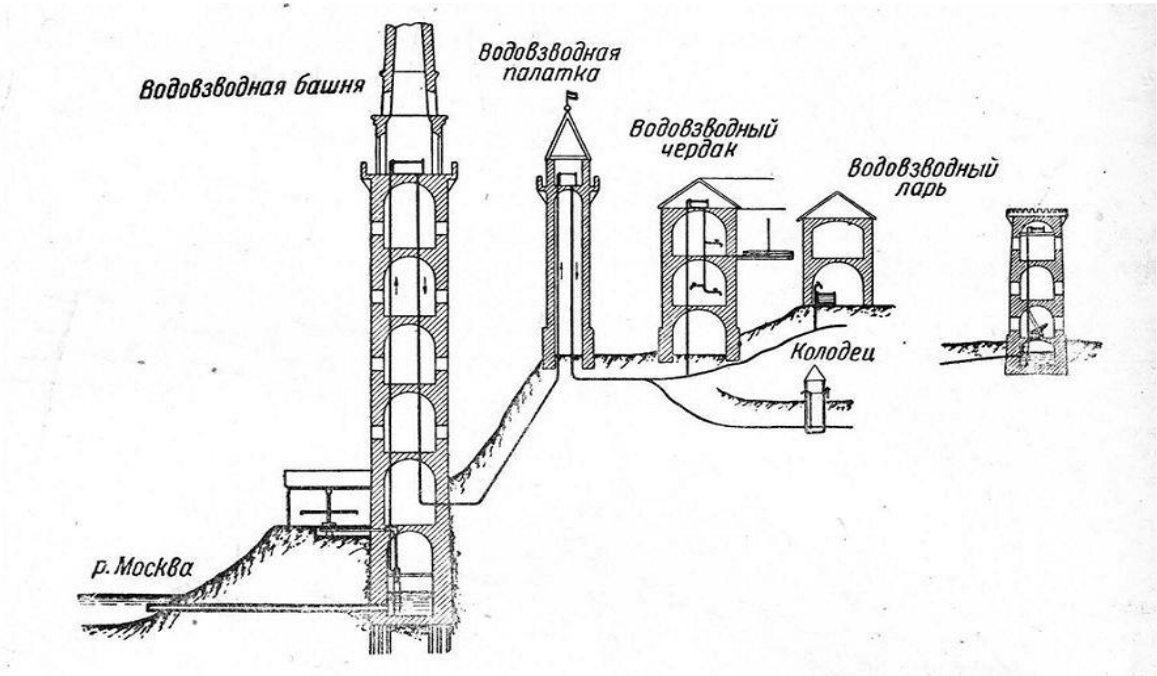
For the first time the pressure water supply with water pumps and mechanical drive appeared in Moscow Kremlin in the XVII century.

For several centuries the scheme of Moscow water supply system was improved by Russian craftsmen and became a complicated but rather rational network with water supply towers, storage reservoirs, widely spread network of pipes and street water pumping. It provided water for household and industrial purposes as well as palace gardens, ponds and fountains.

The water supply in the Russian empire in the XVIII century can be characterized by the wide network of palace water supply which provided water mostly for fountains. Those water supply systems were of gravity type in most cases. But sometimes the additional rise of water to fountains was done with the help of steam machines.

The Moscow water supply is the oldest engineering facility of the Russian capital. In 2019 it celebrates its 215th anniversary. The source for water supply served the underflow water of the Yauza river at the vicinity of the Bolshye Mytischy village. The construction work lasted 25 years and on October 28th, 1804 the commissioning of the water supply system took place. And Moscow started to get about 300 thousand buckets of clear water per day.

By the beginning of the XX century the Moscow water supply system reached the limits of its development.



In 1903 the Rublev water supply station was built. Its capacity was 6 thousand cubic meters of water per day. The water treatment was performed in accordance with so called “English” variant which included water precipitation and its further filtration on the slow sand filters with the speed 1 m per hour. In 1904 during the flood there was an attempt to use a coagulant – the special reagent for water purification. From the very beginning a science laboratory started its functioning there and that was the foundation of the national school of water analysis.

For many years the water from that station was one of the best in the world and second only to glacier water from Armenia. For over a century after its commissioning the station is sustainably working covering 25 per cent of city drinking water demand.

Scheme of Moscow water supply

Nowadays the supply of drinking water to the city is about 3 million cubic meters per day. After commissioning of a new unit 64 % of drinking water will be treated with the new technologies: ozonization, ozonosorbtion and membrane filtration.

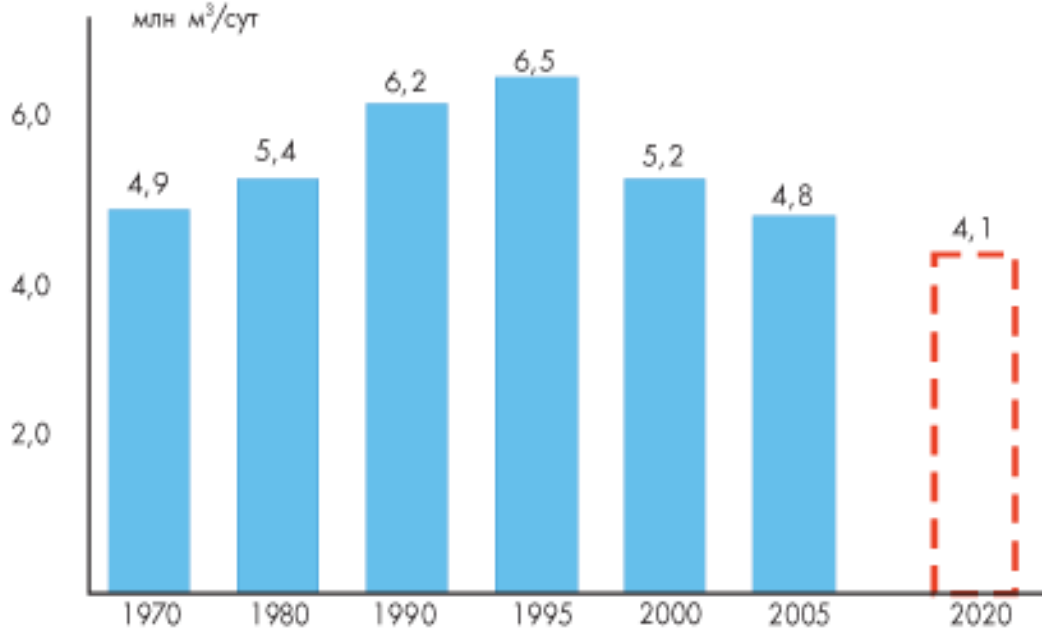
The centralized water supply of Moscow region is performed from the surface water sources which are Moskvoretsky-Yauza and Volzhsky water systems which include 15 water basins and water supply paths – the Moskva river with tributaries and the Moskva channel.
The 15 water basins of Moscow city water supply system have the useful volume of 2,3 billion cubic meters. The total water delivery comprises 11 million cubic meters per day which 2,5 – 3 times more than Moscow city water demand.

The main facilities of Moscow water supply system:

- 9 hydraulic units
- 4 water treatment stations
- System of water supply and distribution:
  - Municipal pump stations (6 municipal pump stations are operated to insure the required pressure in the areas with different height of pipe laying and remoteness from stations).
  - Municipal regulatory units which have at their disposal not only pumps but also drinking water reservoirs which make it possible to smooth unevenness of water demand by the city. 11 regulatory units are operated on the territory of Moscow.

Moscow water supply system:

- 50 thousand sqm – the drainage area of water supply sources
- 11 million cubic meters per day – the guaranteed water delivery
- 4 water treatment stations with capacity 6,37 million cubic meters per day
- 4 stations of industrial water supply – 0,83 million cubic meters per day
- 3,0 million cubic meters per day – drinking water production
- 13 thousand kilometers – length of water supply network



Dynamics of water consumption of Moscow city from 1970 till 2005 and forecast for year 2020

The European norm of water consumption in the city is upto 180 – 200 liters for an individual per day. At the present moment a Muscovite uses about 347 liters per day.

Nowadays the capacity reserve comprises upto 20 % of the actual water consumption. According to calculations of Moswaterchannel (Mosvodokanal) there won't be an increase of water consumption until 2020 because at the present moment the consumer has enough reserve of drinking and technical water. And that reserve makes it possible to increase the total consumption from the sources. There is no water shortage in Moscow and in the nearest 15 – 20 years it is not expected.

The length of water supply networks comprises more than 13 000 kilometers, including:

Name	%
Water main	17,9
Street water supply network	59,8
Residential apartment and yard network	22,3
Total	100

The share of steel pipes comprises 57 %, cast iron pipes – 37 %, polyethylene pipes – 5 %, other materials – 1 %.

Disinfection is performed with sodium hypochlorite with the ammonia-containing reagent to insure sanitary condition of the extensive distribution system in spite of presence of the water ozonozation within the technological scheme. It is a typical practice not only in Moscow but in other largest cities of the world (Paris, London, Tokyo, etc) which also have the lengthy water supply systems. It is predetermined by the long effect of chlorine bactericidal properties. Ozone is a non-persistent agent which dissolves in water very quickly which explains its limited usage for final disinfection only in small towns and more wide usage on the intermediate stages of water purification.

In the conditions of dense municipal housing and traffic gems it is economically more efficient to use trenchless method of repair and restoration. Nowadays the most advanced methods are used in Moscow, including: application of concrete-sand coating on the inside surface of pipes, broach of seamless polymer sleeves, broach of polyethylene pipes into existing pipeline. For the pipelines of big diameter the method "pipe-in-pipe" has been developed. It makes possible to bring back in operation the communications which have lost their working capacity and increase their service life for minimum 50 years and throughput rate. And it is more vital for water supply networks to maintain the high quality of transported water, to minimize the number of breakdowns and unproductive water loss.

The problems which should be settled from engineering point of view

1. Design

- Optimal options of connection points for new buildings and facilities
- Material type (pipes) for a new laying
- Type of stop valve
- The depth of laying and in that connection method of laying (open or trenchless)
- Environmental component (the construction cost)

The main expenditure:

- Materials
- Equipment
- Machinery
- Labor cost
- Taxes

2. Construction

The principal issue is the selection of a professional construction company.

Selection criteria:

- Work experience of the company
- Staff qualification.

There are organizations in Russia which are entitled to license the engineering personnel and enter their data into the National register as well as specialized centers of certification of the working personnel (welders, fitters, etc.)

But that is not enough. A compulsory periodic certification of personnel needs to be introduced. More likely it should be private certificates confirming the qualification level.

3. Maintenance

- Issues of diagnosis of the existing networks and facilities
- Schedule of a minimum annual program of reconstruction of networks and facilities
- Budget planning for those projects
- Implementation of new technologies in reconstruction

4. Disposal of the old networks and equipment

- Maximum usage of old networks for application of pipe-in-pipe technology
- In case of inability to dismantle old networks are filled with concrete
- Demolition, utilization, replacement with new ones.