The use of hydropower potential of the rivers of Moscow basin

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The use of hydropower potential of the rivers of Moscow basin

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Abstract. The purpose of this article is to study the changes in the ways of using the energy potential of the rivers of the Moscow River basin in the XVIII-XX centuries. Analysis of the data of the General Survey suggests that in XVIII century the energy of flowing water was used for several kinds of mills: gristmills, saw mills and fulling mills. Energy of flowing water was applied for oil mills and blacksmith hammers. Analysis of literary data shows that the number of mills reduced at the end of XIX century. Only mills built on large rivers continued to work. At the turn of the 19th and 20th centuries small hydroelectric power stations were built instead of mill dams, and the modern hydropower facilities in Moscow basin are small stations of local meaning only. As a result, the maps showing the location of different kinds of mills in the Moscow river basin in XVIII century were composed for the first time. These maps are unique for this territory.

1. Introduction
Moscow basin occupies 17640 km² and unites 912 rivers. The largest left tributaries are rivers Inoch, Iskona, Ruza, Istra, Skhodnya, Pehorka, Gzhelka and Nerskaya; the largest right tributaries are rivers Setun, Pakhra, Ostra, Severka and Kolomenka. In ancient time hydrographic network of the Moscow River fulfilled many important functions. Due to the fact that timber harvesting, charcoal harvesting, billet resin were made in forests of Moscow Province, the Moscow River and its large tributaries above the town served forest rivers [1, 2] and below the town for shipping.

One of the most important resources of Moscow basin rivers is their hydropower potential. In spite the fact that Moscow river and rivers of Moscow basin are not major rivers and do not flow in the highlands, their waters were always used as an energy source.

2. Materials and methods
Different kinds of sources served the base of this work. In the XVIII century these sources were economic notes created during a general survey in the second part of the XVIII century. They are kept in the Russian State Military Historical Archive (Moscow). These notes concern 7 counties of Moscow province: Volokolamsky, Dmitrovsky, Klinsky, Kolomensky, Mozhaisky and Ruzsky [1] within the boundaries of the regional reform in 1775 [3, 4]. The materials of economic notes contain a lot of detailed information, for example, the amount of tax levied on the mill and other objects, which may serve as an indirect indicator for example of the power of the mill. Information obtained from these resources was supplemented with data from economic notes for Moscow province compiled as of 1800 [2].
The economic notes that were written in the second part of the XVIII century gave a fairly complete picture of all kinds of mills in the Moscow River basin. One of the attempts to summarize the data on the mills in the Moscow River’s basin contained in the economic notes was made by surveyor F.A. Okhtensky who had a task to create the general plan of Moscow city. In May 1775 Okhtensky composed a description manuscript of Moscow city and Moscow province. According to Okhtensky, on the rivers of Moscow county there were 223 mills: 12 mills made wheat flour, one made pearl barley and 3 mills didn’t work [5].

The research made by Okhtensky has become one of the many works that were written in the end of the XVIII century, based on Economy notes and contained data about sights and economy of Moscow province. But only in his research there was information about the number of water mills. Now these data allow us to know about the scale of economic use of the energy resource of the rivers in the Moscow county. Unfortunately, it is very difficult to determine the location and the exact number of mills situated in the Moscow river basin on the lists made by Okhtensky. The reason is that Moscow county includes the river basins of Klyasma and Lopasnya. It is possible that such description manuscripts and lists were written for other counties of Moscow province, but they have not been published yet. For example, the work of Okhtensky was prepared for publishing, but in the XVIII century it didn’t come out. It was published only in 1997 in the collection prepared by S.S. Ilizarov [6].

So the work of Okhtensky is of great interest, but it doesn’t give a complete picture of the mills in the basin of the Moscow River. That is why the economic notes are the main resource about these data for the XVIII century.

The information about the river use in the XIX-XX centuries and nowadays is taken from books, articles and some old maps. These data are not complete because in the XIX and XX centuries there were not such large-scale studies as in the XVIII century; so information is scattered. But it is not a secret that mills played a large role in economic life, not only in Russia, but also in European countries in the XIX and XX centuries [7]. The analysis of these data allows changes in economic use of the rivers of Moscow river basin.

3. The usage of hydropower potential of the Moscow river basin in the XVIII-XXI centuries

According to materials of the general survey [1, 2], about 472 gristmills were built on Moscow river and its tributaries – in the period of 1760-1800; however 5 of them were out of work. Gristmills were almost evenly distributed about Moscow river basin. The exclusion is the territory of Meshcherskaya lowland with rivers running there: Gzhelka, Nerskaya and other right tributaries of Moscow River because this territory differs by flat terrain inconvenient for dam construction.

The majority of flour mills (385) are noted as gristmills. 44 chaff mills produced rye flour and 41 grist (mills) - wheat flour. One grist mill on the Samynka river was reconstructed for the chaff mill and one more on the Ozerna river was used for threshing rye. It is remarkable that the majority of chaff mills and almost all grist mills were built in the nearest suburbs of Moscow (on the Kimka river, Khodyanka river, Gorodenka river, in the basins of the Skhodnya, Setun, Pekhorka, Yauza rivers and on the Desna river (left tributary of the river Pakhra).

The majority of gristmills functioned all year long except the time of spring flood. The mills, which worked temporarily (during spring flood and other floods), were built in the upper reaches of the river and on the streams less than 10 kilometers long. There were 84 such mills. Gristmills in the basin of the Moscow river were “plantar” (water was running under mill’s wheel moving it) or “bulk” (water was falling down at the mill’s wheel turning it). The type of the mill’s construction was mentioned very seldom in the general survey; however the period of active work was indicated always.

An average number of sets (grain processing and flour making machinery) were two on water mills of the Moscow river basin, the minimal number was one. Record breakers by the number of sets were Bykovka mill in Pekhorka basin, which had 18 sets, and the mill near Nikolskoe (Strelkovo) village with 12 sets on the Pakhra river. Not all sets were functioning at the same time on mills. Sometimes there were data that a mill, which had several sets (two or three, as a rule), was working with “change”
using one set. So we can conclude that historical notes about the number of sets at mills may not reflect the efficiency of the use of hydropower potential of rivers.

Probably we could get a more exact picture of the efficiency of the use of hydropower potential of rivers in the XVIII century analyzing notes about tax amounts, paid to the treasury or to landowners. However if the mill was small and used for personal needs of the owner only (landowner or state peasant), they were exempted from tax. Just built mills were free of tax for five years. As a result, economic notes contained not all data about incomes from mills.

The data about tax amounts were represented in the earlier version of economic notes, which united seven counties of Moscow province only. Even based on these incomplete notes we can conclude that gristmills of Moscow province situated at Yauza, Pekhorka and Pakhra rivers were the most profitable. For example, the mill near Taynitskoe village brought 400 rubles per year to treasury. The landowner got 500 rubles per year from the mill Bykovka near Ostrovtsy village and tax amount from all mills in Pekhorka basin gave about 1800 rubles per year to landowners. So rented out gristmills generated great income for landowners and treasury. Judging by the sums of money, the mills near Moscow worked constantly and made the most of the entire river water unlike mills situated farther from the capital.

Besides gristmills there were 18 saw mills in the basin of the Moscow river. Almost all of them were situated in the upper reaches of the river, at the Ruza and Istra rivers – on the territories where there were a lot of forests. On average they had 2 saw frames and 4 saw frames maximum. Tax amounts from saw mills were paid rarely. The maximal sum of the money sent to treasury was about 20 rubles per year; landowners got about 40 rubles.

Nine of twenty fulling mills were built in the basin of the Pakhra river. Average 4 mortar stupa (shoe mill frame) were installed at each of them; the latter were designed for the production of woolen cloth.

**Figure 1.** Mills in the basin of the Moscow river in the end of the 18th century
The maximal known number of stupa was 19. Landowners got 400 rubles per year from rent of some fulling mills.

Three oil mills were situated at rivers of Moscow river basin, one of them did not function; one paper factory worked. One copper sheet plant in the village Green Sloboda operated at the lower mill at the mouth of the river Pakhra. The plant produced forging copper with a hammer, which moved with the help of running water. The same plant functioned in Bedrino village (the basin of the Pekhorka river) [2, pt.1, sh. 40-1].

Mills retained the main way of the use of hydropower potential of the rivers of Moscow basin till the end of the XIX century. The study of the map made by F.F. Shubert demonstrated that in comparison with the second half of the XVIII century the number of mills reduced in the middle of the XIX century; only the most cost-effective mills working most of the year remained till the end of the XIX century.

The era of the construction of small hydroelectric power plants has started since the end of the XIX century; the heyday of the era has come between 1920-1940 years. Many of hydroelectric power plants were created instead of old mill’s dams at the same place. The first such station in the basin of the Moscow river started working in 1893. It was built at the Pakhra river in Leninsky Gorky suburbs in Novlenskoye village. In the 1920s it was reconstructed according to GOELRO plan. Producing electric power for V.I. Lenin residence and several neighboring villages, it became the symbol of GOELRO plan. “Light bulb of Ilyich” had been associated with this hydroelectric power plant for a long time. In 1959 this plant stopped working but the dam at the Pakhra river exists nowadays functioning as a regulating water system.

In the 1920s one more dam with “electric mill” was built at the Zhuravenka river – tributary of the Bitza river between villages Bolotnikovoe and Zagorje. In 1948, Yakshinskaya HPP and Krasnogorsk HPP were built on the Ruza river; each of them had a power of 75 kilowatts [8]. In January 1953 the Ruza river was blocked by a dam of Gorbovskaya hydroelectric station near village Gorbovo. All these hydropower facilities appeared instead of reconstructed old mill’s dams.

During construction of Moscow Canal in 1932-1937 Skhodnya waterworks were at the Skhodnya river. Skhodnya hydroelectric power station with adjacent straightening of the Skhodnya river became its main construction. The main feature of this hydroelectric power station was a pipeline constructed of two wooden pipes 180 meters length and with a diameter of 5.4 meters. They serve for the flow of water to the turbines of the station from the pressure pool.

In 1935-1989 several reservoirs were constructed at Moscow river and its tributaries Istra, Ruza and Ozerna. The hydroelectric power station of small power was constructed at Istrinskoye, Mozhayskoye, Ruzskoye and Verkhneruzskoye waterworks of these reservoirs. After starting of Vazuza hydropower system at full capacity in 1997, the waterwork of Ruza reservoir was strengthened with an additional hydroelectric unit. All the above-mentioned hydroelectric power stations generate little electricity and service hydraulic structures only [9].

4. Conclusion
Summarizing we can conclude that at the second half of the XVIII century hydropower potential of the Moscow river was used effectively. To the greatest extent, the energy of the running water was used for gristmills in Moscow suburbs. This can be explained by the fact that Moscow was the place where the grain was delivered from southern provinces. The location of saw mills is evidently was close to territories covered with forests and that of fulling mills was determined by availability of labor and raw material (wool), which was delivered from other regions of Russia. All other enterprises, which used the energy of flowing water for driving mechanisms, were in large and rich landowners' possessions. Generally, at the second half of the XVIII century the use of the energy of flowing water promoted the development of processing and food industry and served as an important source of income.

In the XIX century the number of mills reduced significantly; only the most cost-effective mills working constantly remained. The era of mass building of mills was over. The end of the XIX century and the beginning of the XX century are characterized by replacing of mills by small hydroelectric power plants.
However, the economic value of these plants fell as a result of the development of electrical networks and the possibility of electricity supply from other areas. These hydroelectric power plants were closed. The plant in Bitsa was destroyed completely. Ruins of the dams of Yakshinskaya HPP and Krasnogorskk HPP remained as a historical landscape monument [10, 11]. HPP Gorbovskaya stopped functioning, but the dam has preserved till nowadays. All hydropower facilities in the basin of the Moscow river are small facilities of only local meaning.

It seems very interesting that in pre-industrial time in European countries the number and the ratio of different types of mills were the same as in Russia. So Mr. Louis C. Hunter says that the “pre-industrial water-mills, supplemented in some regions by others propelled by wind, are numbered by the thousands and possibly by the tens of thousands. By far the greater number are gristmills, engaged at appropriate seasons in the reduction of the farmer’s grain into meal, often ticking on unattended much of the time during the daytime hours. Much smaller numbers of water-mills are employed in the filling of hand-loomed cloth, the raising of water for irrigation, the crushing of olives, and, much less frequently, the carding of wool and sawing of lumber” [7].

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