

# Water Integrated Scheduling of Metallurgical Enterprises

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**Abstract** — The article deals with water-integrated scheduling of metallurgical, mining and processing enterprises on the areas of water shortage of the Southern Urals and the Volga region. The key factor of these regions development as well as their water-consuming metallurgical field is water resources which are not uniform on this area. The comparison of water supplies allowed drawing a conclusion that Orenburg region is the most water-deficit region of all the nearby ones. It is shown that most metallurgical enterprises are near the big rivers. The interrelation has been determined between the density of the enterprises and a number of water resources. Water consumption and other parameters of some enterprises have been calculated. It has been determined that it is necessary to create a water reservoir in the Orenburg region for the development of the metallurgical field during a low-water season.

**Keywords** — metallurgical enterprises; natural resources; water resources; water-deficit region.

## I. INTRODUCTION

Extracting and primary processing of the natural resources nowadays cannot guarantee sustainable development of the region and the whole country. Development of the metallurgical industry, efficiency increase and conversion processing of the natural resources greatly depend on natural conditions and exactly water resources and their amount. Natural resources are extracted mostly on water-deficit areas, despite a big number of mineral resources it is necessary to transport raw materials for processing to the regions with better water supply [11, 12]. Most of the metallurgical enterprises are water-consuming [5]. Limited water resources are the main constraining factor of mining industry development and reason to avoid extractive models of economy.

The Orenburg region is the richest in natural resources, but limited in water resources. In similar environmental conditions are the Ural and Volga Federal Districts. In the Orenburg region

nowadays more than 80 different types of solid, liquid and gaseous natural resources are being extracted. There are ores and other minerals, great oil and gas reserves. Non-ferrous and ferrous metallurgies, mining and gas and oil industries, gas conversion, mechanic engineering are developed in the region [6]. On the whole the areas of the Volga Region and the Ural are the raw material base, oil and gas supplies and metallurgical centers of the country.

## II. PECULIARITIES OF WATER STORAGE FORMATION AND METALLURGICAL ENTERPRISE SCHEDULING

The distribution of the metallurgical enterprises in the Orenburg and Samar regions and in the Republic of Bashkortostan has been studied in order to determine the regularities of their location and influencing factors on the development of the metallurgical complex and the economy of the region.

The data on the type and location of the metallurgical enterprises by A. P. Karpinsky All-Russian Institute of Geological Research and the Orenburg Geological Survey and others have been used.

With the computer-aided system GIS – “Nature management” developed at the Bureau of Engineering Ecology of the Orenburg Research Center Ural Branch of the Russian Academy of Sciences a map of the metallurgical enterprises for the studied area has been created (figure 1). The geological database which is used to analyze the peculiarities of the metallurgical enterprises location includes the information on the inhabited areas, mineral resources and rivers, water reserves, lakes and other water objects.

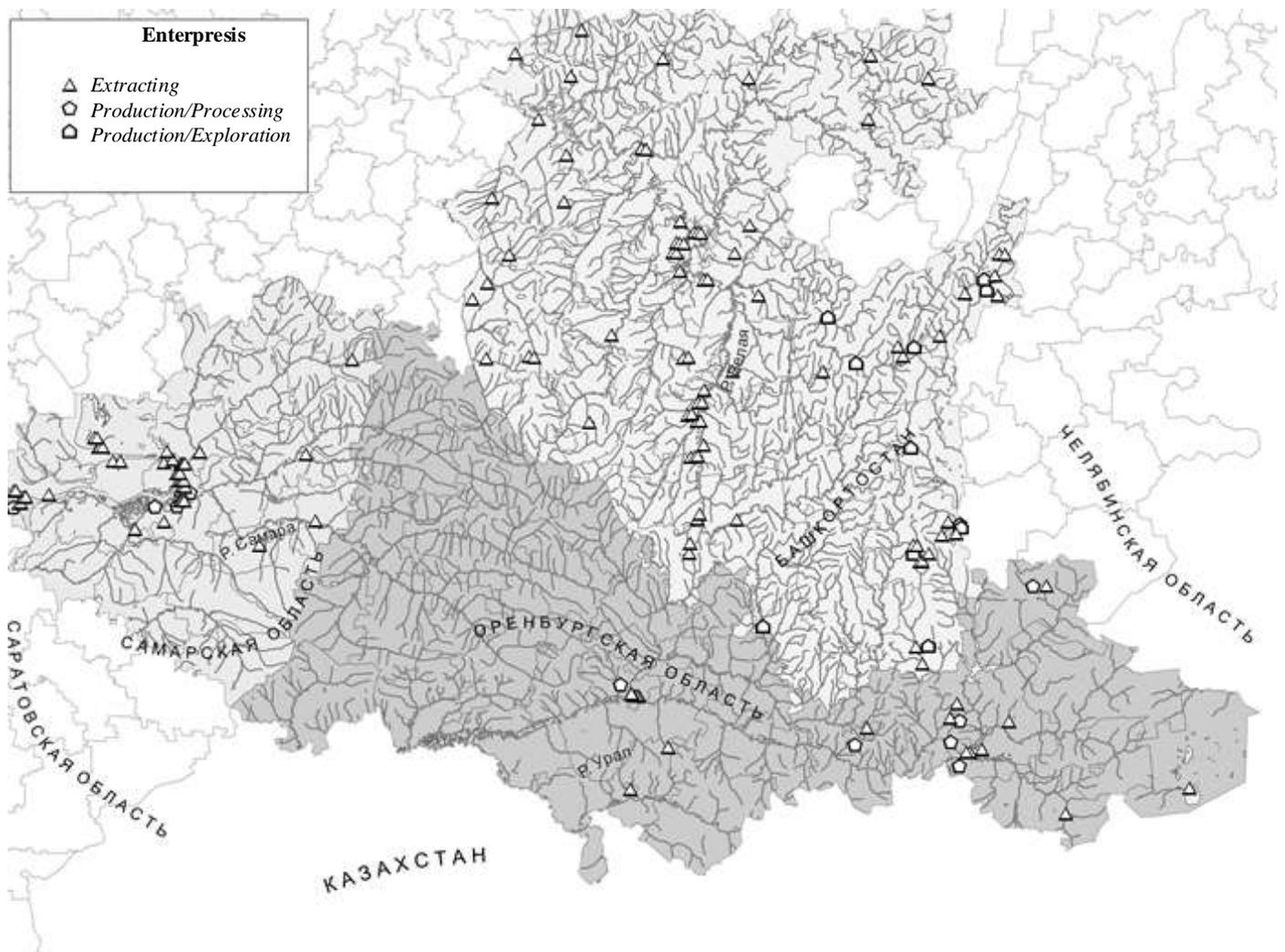


Fig. 1. Metallurgical enterprises scheduling in the Orenburg, Samara Region and Bashkortostan

The key factor of the Southern Ural and the Volga region development as well as their water-consuming metallurgical field is water resources which are not uniform on this area. The comparison of water supply in Bashkortostan, the Orenburg and Samara Region is in table 1

The analysis of the data in table 1 shows that the Orenburg Region has 30 % less of precipitations and consequently of water resources. The whole river flow in the region on average is 13.6km<sup>3</sup>/year, which is 2.5 times less than in the Bashkortostan Republic and 18 times less than in Samara Region.

These regions have greater difference in water supply during the low-water season, which is conditioned by the differences in the natural river flow distribution between the high water and the low-water flows, as well as its regulation by water storage in reservoirs. In Orenburg Region the most part of the water flow (about 80%) is in spring floods, only 5% of which is accumulated in reservoirs and ponds.

As the result water resources in low-water season, which is 11 months a year, decrease by 3 times and are only 6.35 km<sup>3</sup>. If more than 50% of the river Volga flow is regulated in reservoirs

the water resources in the Samar Region will increase up to 305 km<sup>3</sup> averages per year and 161.8 km<sup>3</sup> in low-water season, which is correspondingly in 18 and 25 times greater than the water supply in the Orenburg Region. Less difference is in total water supply between the Orenburg Region and Bashkortostan, correspondingly by 2.3 and 2.7 times.

Multiple exceeding in water supply of neighboring regions to the Samara region and the Republic of Bashkortostan thanks to the outside water flow and its accumulating created there more favorable conditions comparing with the Orenburg Region for population and economical activity. As the result, the population density in the Orenburg Region is only 16.4 people/km<sup>2</sup>, which is by 1.7 times less than in the Republic of Bashkortostan and by 3.7 times less than in the Samara Region.

The complex analysis of environmental conditions, water supply, population density distribution, and economical parameters in these areas proves that water supply in a strategic policy influences significantly their life. Water supply increase is a key factor of their fast socio-cultural and economic development.

**TABLE I. ENVIRONMENTAL, SOCIAL AND ECONOMICAL PARAMETERS IN ORENBURG, SAMARA REGIONS AND THE BASHKORTOSTAN REPUBLIC**

Parameters	Regions		
	Orenburg Region	Samara Region	Bashkortostan
Area, thousands km <sup>2</sup>	124	54	144
Precipitation, mm	300-450	450-500	400-500
Water resources:			
Total river flow, km <sup>3</sup> /year	13.6	245.6	35
Low-water, km <sup>3</sup> /year	2.7	102.4	12
Water reservoirs+lakes, km <sup>3</sup>	4.9	59.4	5.1
River flow+water reservoirs+lakes, km <sup>3</sup>	17.2	305.0	40.1
Low-water flow+water reservoirs+lakes, km <sup>3</sup>	6.35	161.8	17.1
Water recourses, m <sup>3</sup> /capita, day and night	23	259	27.0
low-water flow +water reservoirs+lakes, m <sup>3</sup> /capita, day and night	9.4	138	11.5
Water resources, thousands m <sup>3</sup> /km <sup>2</sup>	139	5650	278
low-water+water reservoirs+lakes, thousands m <sup>3</sup> /km <sup>2</sup>	51	3000	119
Population, mln people.	2.03	3.22	4.07
Density of population, people/km <sup>2</sup>	16.4	60	28.5

Natural waters in the Orenburg Region, being a nature system component influence greatly its economic and social development. Its economy modernization due to the water resources deficit follows the route of water-non-consuming enterprises. Water supply influences greatly the metallurgical industry.

Table 2 gives total amounts of water resources and metallurgical enterprises in the Orenburg and Samara regions and in the Republic of Bashkortostan.

Data analysis in fig. 1 and table 2 shows that there are 86 metallurgical enterprises in the Bashkortostan Republic and their density is 0.6 units per thousand km<sup>2</sup>.

There are 51 metallurgical enterprises in the Samara region and their density is 0.89 units per thousand km<sup>2</sup>.

In the Orenburg region, which is a little less than the Republic of Bashkortostan there are 23 metallurgical enterprises, and their density is 0.18 units per thousand km<sup>2</sup>, including 6 mining and processing ones – Orenburg gas processing enterprise (Orenburg), PJSC Orsk Quarry management, Orsk), PJSC Gaisky GOK (Gai), CJSC South Ural Gold-mining company (Kvarkeno), LLC Ural Steel (Novotroitsk), LLC Ural Mining and Metallurgical Company (Mednogorsk) [3].

According to the map (fig. 1) nearly all the metallurgical enterprises are along the big river beds – the Volga in Samara region, the Belaya in Bashkortostan and the Ural in the Orenburg region. Consequently, water supply directly influences the number and density of the mining and processing enterprises.

**TABLE II. CONSOLIDATED FIGURES OF WATER RESOURCES AND METALLURGICAL ENTERPRISES IN ORENBURG AND SAMARA REGIONS AND THE BASHKORTOSTAN REPUBLIC**

Parameters	the Orenburg region	the Samara region	the Republic of Bashkortostan
Region area, thousands km <sup>2</sup>	124	53.6	143
Number of mining enterprises	22	47	86
Density of enterprises per thousand km <sup>2</sup>	0.18	0.89	0.6
Water resources, km <sup>3</sup> , (table 1)	17.2	305	40.1
Average distance from enterprises to water source, km	3	1.3	1.7
Number of enterprises using hydrocarbon raw material, %	5	40	1
Number of enterprises on non-metallic feed, %	41	49	80
Number of enterprises extracting non-ferrous and precious metals, %	45	-	15
Number of enterprises extracting ferrous metals, %	9	-	4
Number of occurrences in fuel, metal and non-metal raw materials	478	391	1072
Mineral deposit density, per thousand km <sup>2</sup>	3.85	7.29	7.50

The main amount of water in industry is consumed by metallurgical and oil-gas processing enterprises [1]. The biggest Russian integrated company PJSC Magnitogorsk Iron and Steel Company consumes on average 3.2 km<sup>3</sup> of water per year. According to the data of the enterprise [9] there is a recalculated cooling water system, thanks to which water consumption of clean feed water from the sources is about 0.1 km<sup>3</sup> per year or 3% of the total water consumption of the enterprise. Annual flow of the Ural in the area of Magnitogorsk in 2007-2012 changed from 0.16 to 0.75 km<sup>3</sup>. Due to its low-water level and flowing inequality during seasons there is Magnitogorsk water reservoir for the metallurgical enterprise and other enterprises within the city boundaries 0.19 km<sup>3</sup>, and for its refilling – the Upper Ural one in volume 0.6 km<sup>3</sup>.

The biggest enterprise in the Orenburg region LLC “Gasprom Orenburg” consuming on average about 5 mln m<sup>3</sup> per year [9], takes from the Ural 0.16 m<sup>3</sup>/s of water that is about 0.2 % of its average annual flow and in a low-water season it is more 1 %.

The density of all developed occurrences in Orenburg region is 2 times less than in neighboring regions; the density of mining and processing enterprises is 5 times less than in Samara region and 3.3 times less than in the Republic of Bashkortostan. The development of mining and processing industry in the Orenburg region is limited by the low-water flow (table 1), which meets the needs in water of the economy and 2 million people in the basing of the Ural.

The annual average flow of the Ural off Russia is 8 km<sup>3</sup> of water per year, 80% of which is changing greatly in spring flow in different years. To compare the run off of the Volga is on

average about 250 km<sup>3</sup> per year, the Belaya on the territory of Bashkortostan when flowing into the Kama is 30.6 km<sup>3</sup> per year. It is possible to overcome water resources limitation in the Ural by accumulating the flood flow in water reservoirs.

According to the calculations the average distance from the metallurgical enterprises in the regions to the nearest water source is not greater than 8 km, about 28% of all enterprises are near the river (fig. 2). In the Samara region more than 70% of enterprises are at the distance less than 1.5 km from the water source, in Bashkiria - less than 2 km, in the Orenburg region 70% of the enterprises are at the distance of less than 3.5 km from the water sources (fig. 2). Thus, with water sources decrease and increase in river sparseness, the distance from enterprises to water sources increases.

Non-metallic feed enterprises are also along the rivers. In the Bashkortostan Republic along the Belaya to Ufa there are 30 enterprises on its development. More often they are two kilometers from the river. To the West of the Republic the enterprises are also grouped on the banks of the biggest rivers and close to the cities and villages which is cost effective. In the Republic of Bashkortostan there are many water reservoirs and ponds at small rivers which allow effective application of water resources.

In the Samara region the processing enterprises are along the Volga near Samara, Novokuibyshevsk, Tolyatti and Sazan'. Two big water reservoirs in the region allow improving the low-water share and enable running of the water-consuming enterprises (fig. 2). To the North of Samara oil and construction materials are extracted. Small enterprises on argil extraction as well as sand and gravel mix are to the west of the region along the small rivers. Water resources are necessary for the primary processing before sending the resources to the consumer.

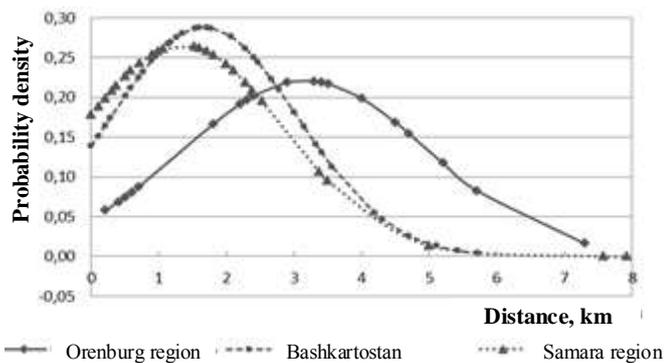


Fig. 2. Curve of a frequency distribution from an enterprise to the nearest water reservoir.

In the Orenburg region the ore deposits are in the east of the region where enterprises function on their grounds in the nearest big regional centers where it is economically practical to locate the economic activity. Metallurgic raw material processing enterprises are in big cities on the river Ural – Orenburg, Orsk, Novotroitsk, Mednogorsk and Gay [4].

Precious metals extracting and processing mostly gravitates to the occurrences than to the water resources comparing with

the Republic of Bashkortostan and the Samara Region and are located further from the water resources (fig. 2). In the east of the Orenburg Region the gold fields are developed (Kirov, Aidynrlinskoie) near Kvarkeno 160 km from the Iriklikskoye water reservoir on the Suunduk, the left-bank inflow of the Ural.

Oil-and-gas recovery prevails in the west of the region. The primary separation of the oil and petroliferous blends is done at the deposits. They are dehydrated, desalinated, degassed, desolidized [7]. Water separated from the oil and purified is injected into the productive strata [8]. Gas treating needs constructing a special facility for complex treating (CGTI) close to the gas occurrence. They purify and dry the gas in special absorbing columns. Bringing extracted oil and gas to the necessary consumer properties and further deep processing needs a lot of water and done at the enterprises close to the water sources [2].

Hydrocarbon raw material extracting and processing ratio in the studied regions is in table 3. Oil processing industry is water consuming. The processing of 1 t of oil depending on the technology requires from 0.5 to 15 m<sup>3</sup> of water [10]. Gas processing industry requires on average 20 times less water.

The amount of water resources in the regions influences significantly the amount and oil and gas conversion ratio, and regions differentiation. Enterprises-converters of the hydrocarbon are mostly near the cities close to water sources.

In the water deficit Orenburg region there is the largest gas-processing plant in the country, with the rated capacity 45 billion m<sup>3</sup> of gas, which processes the gas extracted from the Orenburg occurrence and close to the Karachaganaksk occurrence of the Kazakhstan.

The extracted oil conversion needs a lot of water and is fulfilled by 34 %; the rest is transported to the regions with greater water supply – the Samara region, and the Republic of Bashkortostan.

TABLE III. COMPARATIVE DATA ON EXTRACTING AND CONVERSION OF THE HYDROCARBON RAW SOURCES IN REGIONS PER YEAR

Region	Natural and accompanying gas			Oil and gas condensate		
	extracted, billion m <sup>3</sup>	converted, billion m <sup>3</sup>	processing share in the region, %	extracted, billion tons, t	converted, billion t	processing share in the region, %
the Orenburg region	20.4	19.66	96.4	22.7	7.8	34
the Samara region	0.64	0.67	104.7	15.6	22.2	141.5
the Republic of Bashkortostan	0.56	0.46	88 %	15.7	19	121

The data on hydrocarbon raw sources extracting and conversion in the Orenburg, Samara regions and the Bashkortostan Republic per year are in table 3.

In the Samara region and the Republic of Bashkortostan oil conversion and accompanying gases conversion (AGC) prevails different to the Orenburg region, which specializes on gas and gas condensate conversion.

In the Samara region the biggest oil converting enterprises are in the cities on the Volga (Samara, Novokuibyshevsk, Syzran'). The enterprises converting AGC are in the East of the region where the high hydrated raw materials are extracted near the Bolshoi Kinel' and the Neftegorsk water reservoir.

In the Bashkortostan Republic the biggest oil extracting and converting enterprise is PJSC AOC Bashneft". The enterprise consists of several small companies on oil extracting and conversion with the total 24.1 billion tons of oil per year. They make an industrial complex on the Belaya river to the north of Ufa. There are some oil and gas enterprises on the Belaya in Salavat and Sterlitamak.

### III. CONCLUSION

1. In the Southern Urals and in the neighboring part of the Volga region water resources are a strategic component of the society and economy. The low-water periods have a negative impact on people's life-quality and the social and economy development of the region.

2. Metallurgical enterprises location is determined by geological conditions, the deposits development and the conversion rate are determined by the water resources presence. Extracting and raw material processing is water consuming industry. The oil and metallurgical ones need greater water sources and gas one needs less water sources.

Most metallurgical enterprises are on big rivers. Their density is closely related to the total amount of water resources and the river flow.

3. It is necessary to increase the amount of water resources in the Orenburg region during the low-water periods with the construction of water reservoirs in order to develop the metallurgical industry in the region.

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