ATLANTIS PRESS

Advances in Social Science, Education and Humanities Research, volume 393

The Fifth Technological Order: Prospects for the Development and Modernization of the Russian Agro-Industrial Sector (TFTS 2019)

Issues of Drinking Water Supply and Possible Solutions on the Example of Gorkovsky District in Omsk Region

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***Abstract*— The article considers issues related to the problems of providing drinking quality water to populations of rural settlements of the Omsk region. For a significant number of the population in Omsk region water does not meet the established standards for quality and is not provided in the required quantity. Existing water supply systems in the region were built mainly in 1960-1970. In this regard, the main problems are associated with the deterioration of water supply networks and structures, including damaged groundwater intake structures. One of the features of Omsk region water resources is the significant pollution of both surface and underground water sources. The geological and hydrogeological state of underground water resources is analyzed on the example of one small settlement – the Gorkovsky district in Omsk region. Recommendations on bringing the underground drinking water quality up to the standards, the liquidation tamping of wells and the construction of Source water protection for underground water intake are given.**

Keywords—water supply, hydrogeological conditions, water quality, water treatment, liquidation tamping of wells, Source water protection.

I. Introduction

The issues of providing the population with adequate quality drinking water in sufficient quantities and the environmental safety of water use are relevant both for most countries of the world and for the Omsk region [1-3].

The condition of water objects Omsk Region, which are sources of drinking water supply, and the water management complex as a whole, is of crucial importance for the socio-economic development of the Region.

Currently, drinking water that is provided for a significant number of the Omsk region population does not meet the established standards for quality and is not supplied in the required quantity. In addition to the regional center, centralized water supply systems cover only about 50% of housing. Even in those settlements where such systems exist, they work with frequent interruptions, which reduce the quality of the water. The existing water supply systems in the region, including group water supply systems, were built mainly in 1960-1970; therefore, the main issues are related to the deterioration of water supply networks and structures.

The urgency of these issues is caused not only by technical problems of obsolete equipment and general technical backwardness, but, above all, by legal, organizational and economic problems [3].

II. Literature review

One of the features of Omsk region water resources is the significant pollution of both surface and underground water sources. At the same time, the main rivers – Irtysh and Om, belong to the category of “polluted” and “dirty”. The main pollutants of the river basin Irtysh are oil products, phenols, compounds of nitrogen, copper, manganese, organic substances. In addition, the Om river is characterized by an excess of threshold limit value for iron by 7 times, for manganese – up to 20 times. Exceeding the threshold limit value for chemical and microbial contamination is observed in 23 out of 32 districts of the region.

The effluent bulk is not subjected to treatment and disinfection when discharged into water objectives. Livestock farms, tank farms, natural dumps, horticultural associations are located along the river banks. The main sources of groundwater pollution are: littering of territories with anthropogenic wastes, agricultural fertilizers, lack of sewage.

According to the plans of the regional government in 2010-2012, to solve the problem of providing water to municipalities, a general water supply scheme for the Omsk region was developed. One of the ways to solve this problem was the construction of the Gorkovsky group water supply system, combining several districts with water intake in the Irtysh river.

Depending on the geographical location, the qualitative component of groundwater is different. So, in the southern part of the region the water is alkaline, in the middle – with increased salinity. In some areas, such as the Tyukalinsky district, water is not suitable for drinking and imported water is delivered to these areas. Until 2014, the Pure Water Program was implemented in the Omsk Region: local water treatment plants were built, delivery vehicles were purchased, and more than 150 drinking water distribution points were created. The program was closed due to funding problems.

Basically, only in those areas that can receive water from Irtysh river (southwestern part of the region) the population has the opportunity to use high-quality drinking water.

Today, the problem with existing wells is urgent, they are silty and not to be cleaned, which is why water quantity is reduced. In addition, on the territory of Omsk Region, the issue of real accounting and the need to eliminate abandoned water wells has remained one of the most relevant for several years, since such wells are a potential source of groundwater pollution. In accordance with the Russian Federation legislation, the subsurface user is responsible for the liquidation of wells that are not to be used [4].

The causes of such problems are:

• lack of information due to frequent reorganization and bankruptcy of agricultural producers;

• the termination of a number of settlements and a reduction in the number of cattle with the elimination of livestock farms and summer pastures in the territory of which wells were drilled;

• lack of true information on the condition and use of a significant part of the wells and reported data on unlicensed wells.

Water supply problems in the Serebryanoye village, Gorkovksy district, Omsk Region are no exception. In accordance with the explanatory note of the administration of Serebryansky rural settlement dated 08/09/2017, the organization of the village water supply system is in critical condition, there is not enough water for the population.

Serebryanoye village belongs to the group of medium-sized rural settlements with the number of inhabitants within 200-1000 people. Currently, the village is supplied with water through the operation of wells located on the lands of Serebryanoye village according to the Water Supply and Sanitation Scheme [5]. Ownerless wells are an object that creates a potential danger to the aquifer and the population of the rural settlement (district). Therefore, to ensure safety in order to prevent the threat of the entry of hazardous substances into groundwater, which may result in harm to human health and the environment, measures are required to transfer them to municipal ownership.

Thus, the administration of the Gorkovsky district of the Omsk region, and in particular, the administration of the Serebryansky rural settlement, is responsible for identifying abandoned, ownerless, emergency wells, as well as their elimination if necessary.

The aim of this work is to study geological and hydrogeological information and the quality of groundwater in the study area, to develop proposals for the water treatment of groundwater before supplying it to the population. As well as the development of projects for liquidation tamping of ownerless wells and creating a Source water protection of existing wells.

III. MATERIALS AND METHODS

The Omsk Region is geologically located on the territory of the West Siberian Plate. It is part of the Ural-Siberian young platform, which formed in the post-Hercynian time on the spot of Proterozoic-Paleozoic fold formations that were part of the Ural-Mongolian fold belt. In modern tectonic terms, it is located at the junction of the two largest structural elements of the earth's crust: the southern part of the West Siberian Plate and the northern parts of the Central Kazakhstan orogeny. The main tectonic elements of the territory are the Caledonian (Prikazakhstanskaya, Salym structural-formation zones), Hercynian (Central-West-Siberian structural-formation zones) orogenic fold systmes and the Early Triassic rift system. The beginning of the neotectonic phase is considered (by many researchers) when there was a retreat the Neogene Zhuravsk Lake-Sea. The territory is characterized by a stable tectonic regime.

The presence of neotectonic uplifts is evidenced by the rejuvenation of river basins, expressed in the straightening of channels, the intensive development of a ravine-gully network, the location of oxbow lake above the river bed, wide drainage of swamp massifs, drainage of lake basins, development of suffusion-subsidence processes. There are no hard primary rocks deposits in the region. The deepest borehole revealed Triassic deposits at a depth of 4573 m. In the stratigraphic column in the geological map of the Omsk Region, the oldest formations are the Proterozoic formations identified by similar deposits of neighboring regions. In the geological structure of the territory, a folded foundation is clearly distinguished, composed of rocks of the Paleozoic and Pre-Paleozoic age, and a platform cover with gently sloping deposits of the Mesozoic and Cenozoic [6].

In accordance with the scheme of geomorphological zoning of the territory of the Omsk region, this territory belongs to the V region – the West Baraba plain, which within the Omsk region occupies the southern and central parts of the right bank of the river Irtysh. This is a Neogene lacustrine-alluvial denudation-accumulative plain with an abundance of marshes in the north and lakes in the south.

According to the hydrogeological zoning scheme, the territory of the Omsk region is located in the southern part of the West Siberian complex artesian basin (first-order hydrogeological structure (fIV)), within the second-order hydrogeological structure — the Irtysh-Ob artesian basin (aIV-A) [7]. In hydrogeological terms, in the thickness of the artesian basin, there are 2 different hydrogeological levels that are different in terms of the formation of hydrogeological levels, separated by powerful (up to 400–700 m) regional water storage of the Cretaceous-Paleogene age — upper and lower.

The upper hydrogeological level with a thickness of 300-350 m is composed of sand-silt and clay deposits of the Oligocene-Quaternary age (the first hydrogeological complex) and, according to the general scheme of hydrogeological zoning, is located within the Irtysh basin of the underground water runoff of the second order, where groundwater is drained by the Irtysh and its tributaries. The hydrographic network exerts the most draining effect on the upper part of the hydrogeological complex, which includes non-pressure and low-pressure waters of Neogene-Quaternary sediments; as a result, it belongs to the hydrogeological zone of intense water exchange.

Groundwater of the lower hydrogeological level, confined to the sandy-clayey rocks of the Triassic-Upper Cretaceous, is distinguished by a large thickness of the host rocks, high salinity and temperature, significant pressure and are in problematic, and in some places stagnant water exchange. There is a trace of reservoir hydrochemical zoning from the nourish areas in the marginal parts of the basin to its center.

At the same time, areas of fresh and slightly saline groundwater are allocated only in the very upper part of the complex, in close proximity to the nourishing area.

Greatest interest for domestic water supply makes the groundwater in the Oligocene-Quaternary sediments of the first hydrogeological complex of the upper hydrogeological level.

According to the conditions of formation, distribution, interconnection and hydrodynamic characteristics, in the context of the upper hydrogeological level, there are 2 main operating complexes:

• Mid-Upper Miocene – Holocene

• Lower Oligocene - Middle Miocene.

In the context of the lower hydrogeological level in the south of the region, the main exploited aquifer is the Aptsenomansky (Pokur Formation) complex.

IV. Results

Underground waters of aquifers of the Lower Miocene sediments of the Abrosimov and Upper Oligocene sediments of the Zhurav Formation with a weighted average water mineralization of 1.0-3.0 g / l are the most interesting in this case.

In accordance with the hydrogeological conclusion [8], the main aquifers and their hydrogeological characteristics that are typical for an area of the water supply facility, are presented in table 1.

One of the main problems in organizing the water supply system in the village is the lack of reliable information about the operation modes of water intakes.

TABLE I. BASIC AQUIFERS IN SEREBRYANOE VILLAGE, GORKOVSKY DISTRICT OF OMSK REGION

Geological age of an aquifer	**The average depth of the sole, m**	**Intervals of occurrence of aquifers, m**	**Aquifer summary**			
			well flow rates, m^3 / hour	**lowering level, m**	**Static levels, m**	**groundwater salinity, g / dm^3**
N_1tv	44	39.5-43.3	0.6	6.5	25.5	0.6
N_1ab	107	92-104	6	30	30	1.2
P_3tr	143	120-147	3.5-5	37.50	25-35	1.0-2.5
P_3nm	275	147-171	2.3-4	27-42	20-36	1.0-2.0

In 2017, engineering surveys (geodetic, geological, environmental) were carried out on the territory of the planned water intake. According to Territorial Geological Information Fund in the Serebryanoe village 22 wells were drilled, six of them are listed as active.

There are 5 water intakes in the village. Centralized water supply to the village is carried out from two wells (Water Intake No. 2, No. 3) and non-centralized from one well (Water Intake No. 4). Out of the seven wells, four are to be liquidated. The depth of the wells is 106-150 meters. In wells, electric submersible pumps of the ETV and Grundfos brands are installed. Pump control is carried out in manual mode. Wells have been in operation for over 30 years (Table 2).

TABLE II. CHARACTERISTICS OF UNDERGROUND WATER INTAKE IN SEREBRYANOE VILLAGE

Indicator	**No. of the water intake**						
	1		2	3	4		5
Amount of wells	2		1	1	2		1
Year of drilling	1986	1977	?	1990	1979	2017	1990
Depth, m	150	150	137	138	106	107	150
Source water protection	no	no	no	no	no	no	No data
Subsoil license	no	no	no	no	no	no	No data
Water quality (Mineralization, g/l)	No data		No data («bad»)	No data («good»)	(«good») 1.2		No data
Water intake status	Abandoned		Rarely active	Active	з Abandoned	Active	Property of agricultural cooperative “Irtysh”

Serebryanoe village of Gorkovsky district in Omsk region is home to about 1000 people (2017). On the territory of the village are located: a school, a kindergarten, shops, a bank, a culture house, hotel complexes, and rest houses. The village has numerous agricultural organizations.

According to reports, we made an attempt to make a model of the work of existing and planned water intakes. The percentage of rural residents' intake by hours of the day has been established. Given the required maximum daily water consumption, the existing water intakes do not provide the water demand for the residents of Serebryanoe village. During the construction of a new well, the water supply will be at 53.4%, which will slightly improve the situation. In addition, the village's water supply system lacks storage tanks and second-lift stations, which makes it impossible to extinguish fires from the water supply network. In this regard, in the future, it is necessary to perform the calculation of the water supply system taking into account all consumers, including firefighting costs and provide for the following:

- wells construction, in an amount satisfying the demand of water,
- laying of new intra-settlement water supply networks,

- arrangement of clean water tanks and water towers,
- installation of a water treatment plant for the entire water volume.

According to a survey of water sources in Serebryanoe we have established the following:

- There is no reliable information on water withdrawals.
- There is no control over the quality and quantity of water taken from wells.
- There are no equipped water withdrawals at all water intakes.
- There are no Source water protection of the first level.
- There are no subsoil licenses and information about the organization that operates at the water supply system facilities.
- Water from wells does not correspond to drinking quality; there is no water treatment station.
- Three out of six wells are abandoned and cannot be used as a source of water supply.
- Decentralized Water Intake No. 4 is in an unsanitary state (the parapets are open, cattle herds are grazing on the water intake site).
- Water intake wells No. 1 and No. 4 are in disrepair and are subject to mandatory liquidation tamponing.
- Due to lack of information, the possibility of equipping all wells on one aquifer is not ruled out.
- The main sources of pollution through open parapets: wastewater, foreign objects (including household waste, carcasses of small animals, etc.).

These wells are dangerous from the point of view of the penetration of any kind of pollutants through them, and this creates a threat to the normal implementation of economic or other activities and the subsoil state.

A. *Well liquidation tamponing*

The paper proposes measures to eliminate two water wells: wells No. 42-679 and wells n/n-2018 drilled in 2018. Well n/n-2018 has visible signs of a violation of the construction technology (there is no annular casing cementation) and is drilled on the projected water intake with obvious violations of subsoil legislation.

Since the wells are located at a very close distance of no more than 2 m from each other, the hydrogeological section for them will be the same. The sanitary condition of the well is extremely low. There are no pavilions above the wells. Wells are freely accessible. Well parapets are open.

These wells are environmentally hazardous facilities.

The lifespan of well No. 42-679 is 40 years, which significantly exceeds the standard. There are no data on repairs or specific reasons for the failure of the well. Well No. 42-679 can be attributed to category IV – wells that are liquidated for technological, environmental and other reasons [9].

The capacity of well No. 42-679 decreased by 100%. A decrease in performance indicates a malfunctioning filter. One of the main reasons for reducing the flow rate of wells is the clogging of the filters and filter zones of the aquifer, which causes an increase in hydraulic resistance and a decrease in the flow of water into the wells.

Another reason for the decline in well capacity is the ingress of foreign objects into the well during improper operation.

The choice of the method of well liquidation was made in accordance with the Rules for the liquidation tamponing of boreholes for various purposes, backfilling of mine workings and abandoned wells to prevent pollution and depletion of groundwater. (1968) [10].

The considered wells are liquidated by the method provided in section 10 [10], and also taking into account other information on the liquidated water intake (Table 3).

TABLE III. PLAN OF ACTION FOR LIQUIDATION TAMPING OF WELLS

Grounds (rule section) [10]	**Scope of action**	
	№42-679	***№n/n-2018***
	Preparatory work	
s.31a		Filter column removal
s.10	Drilling	
	Water rinsing	
s.10	Reagent well treatment	
s.34	Solid setting of clay-cement or sand-cement mortar	
	Installation of a cement pedestal around the wellhead with a sign	
s.37	Reporting documentation drafting	
Estimated cost of well liquidation, thousand rubles	2 208.82	1095.079
1 linear meter, thousand rubles	9.458	10.044

Estimated documentation is made in the software package “Smeta.RU”.

B. *Water treatment*

There are no water treatment facilities on the territory of Serebryanskoe. The quality of water does not meet the requirements of Sanitary Regulations and Standards 2.1.4.1074-01 [11]. There is no centralized sanitation in the village.

Groundwater withdrawal is planned from the aquifer confined to the sediments of the Abrosimov Formation.

According to the testing of wells equipped for the aquifer of the Lower Oligocene (Abrosimov Formation) in areas adjacent to the projected well, opening of slightly brackish or brackish waters with mineralization (by dry residue) of 1.0-2.0 g / dm3, sulfate-bicarbonate-magnesium sodium type with the content of individual components on the example of well No. 42-679 (Table 4).

TABLE IV. QUALITATIVE INDICATORS OF UNDERGROUND WATER FROM WELL NO. 42-679

Indicator	**Unit of measurement**	**Indicator**	**Sanitary Regulations and Standards 2.1.4.1074-01**
Organoleptic indicators			
Turbidity		1,5	≤1,5
Color	grade	10	≤20
Smell at 20 and 60 ^{0}C	point	1	≤2
Flavour		Fresh	≤2
Microbiological indicators			
Total microbial quantity at 37 ^{0}C		N.s.	≤50
Common coliform bacteria		N.s.	Absence
Thermo-tolerant coliform bacteria		N.s.	Absence
Chemical indicators			
pH		7.8	6-9
Total hardness	mg / dm^3	**10.4**	7
Total mineralization	mg-eq/dm^3	**1240**	≤1000
Permanganate oxidizability	mgO2/l	N.s.	5
Iron	mg / dm^3	**0.5**	0.3
Manganese	mg / dm^3	N.s.	0.1
Ammonia (nitrogen) (NH3,NH4)	mg / dm^3	0.8	2
Nitrate (NO3)	mg / dm^3	0.9	45
Nitrite (NO2)	mg / dm^3	0.001	3
Sulphate (SO4)	mg / dm^3	283	500
Phosphate(PO4)	mg / dm^3	N.s.	3.5
Fluoride (F)	mg / dm^3	N.s.	1.5
Chloride (Cl)	mg / dm^3	200	350
Radiation			
Total alpha and beta activity, radon (only in the well)		N.s.	
Determined additionally upon well completion			
Alkalinity (HCO3),	mg / dm^3	597	
Magnesium (Mg)	mg / dm^3	73	
Sodium (Na)	mg / dm^3	272	
Calcium (Ca)	mg / dm^3	88	

After drilling a well, it is necessary to conduct a complete study of water and before supplying water to the water supply network, conduct a phased water treatment to bring the water quality to the standards established by Sanitary Regulations and Standards 2.1.4.1074-01 “Drinking Water” and Hygiene Standards [11,12].

To assess the quality of water, the composition and quantity of substances in it are determined. The class of drinking groundwater is determined in accordance with regulatory documents. The waters from the considered source belong to the third class, as there are deviations in some indicators from the requirements of standards and norms [13].

The choice of the technological scheme for the preparation of water from the designed well was made taking into account the recommendations [14,15], where reliability and sanitary-epidemiological safety factors were taken into account. In the studied source, an excess in iron, mineralization, hardness, as well as reduced calcium content was found, therefore, water treatment is required in obligatory order.

According to existing data on water quality, it is possible to pre-design a water treatment station, which allows changing the studied indicators. Upon receipt of the actual full analysis of water from a drilled well, it will be possible to adjust design decisions on technology to improve water quality.

As a result of the studies presented in the previous chapter, the indicators (iron, hardness, solids) were preliminary identified; the content must be reduced in order to comply with the requirements for the quality of water intended for household and drinking purposes [11,12].

Based on the Classifier of natural water treatment, the technological scheme T12 [14.15] was selected, which consistently includes the following processes: biosorption with preliminary deep aeration (BS), coagulation (C), flocculation (Fl), filtering (F), permanganate injection potassium (KMnO4), filtration (F), electrodialysis (ED), sorption on granular activated carbon [GAC], stabilization [S], disinfection [Dis].

In addition, proposals of modern manufacturers of water treatment plants were studied: scheme No. 1 – “ST-STORY” (Omsk) and scheme No. 2 – “Inmetekh” (Nizhny Novgorod) on the possible composition of the designed station.

In the process of analyzing proposals, a number of problems were identified that questions the use of their products:

1 – the proposals do not contain data on concentrations in wastewater after water treatment. This fact makes it impossible to calculate sewer devices, it is impossible to reliably calculate operating costs;

2 – incomplete analysis of water accepted for processing without a guarantee for the subsequent adjustment of design decisions. Obviously, with the data described in this paper, it is impossible to select a quality water treatment plant. In this regard, the addition of “unnecessary” equipment is possible, while there is no explanation for the use of this equipment;

3 – overpriced equipment in general.

Table 5 provides an analysis of the two proposed technological schemes in the context of a method of reducing undesirable underground water indicators, taking into account the initial indicators.

TABLE V. COMPARISON OF TECHNOLOGICAL SCHEMES

Indicator	**Scheme №1**	**Scheme №2**
Iron– 0.5mg/l	1) Coagulation 2) Filtration on a block of deferrization filters (filter material: EcoFerox-aluminosilicate sorbent) 3) Sorption on GAC	Na – cationization through a water softening complex. Softening complex (ion exchange resin)
Total hardness – 10.4 mg-eq/l	Reverse osmosis	
Solid residue– 1240 mg/l	Reverse osmosis	Reverse osmosis

Preference is given to technological scheme No. 1, since the experience of using these schemes has shown that scheme No. 2 has proved itself poorly during operation.

C. Source water protection

One of the most important water conservation measures for pollution preventing, clogging and depletion of an underground water body (aquifer) is the establishment of a special regime in the Source water protection of a water intake facility.

In accordance with Sanitary Regulations and Standards 2.1.4.1110-02 and methodological documents [16-18], it is necessary to create a Source water protection around the borehole intake in three zones in order to ensure the sanitary and epidemiological reliability of it.

The first zone of the Source water protection is designed to eliminate the possibility of accidental or deliberate pollution of the water source at the location of the water intake and water supply facilities.

The second and third zones of the Source water protection are designed to prevent microbial and chemical pollution. The survival time of pathogenic microbiota tm in an underground flow for a given climate zone does not exceed 200 days. During the time of reaching chemical pollution, the estimated well operation time is tx = 25 years or 9125 days. According to the calculation results, the ranges of the Source water protection from the wellhead were: Source water protection-I = 30m, Source water protection -II = 51m and Source water protection-III = 346m. Sanitary measures are regulated by Sanitary Regulations and Standards 2.1.4.1110-02 [18].

V. Conclusion

In the course of the work, the necessary geological and hydrogeological material, including stock information, was collected and analyzed.

Based on the studies, we have developed measures for the liquidation tamping of hazardous, ownerless wells for a specific designed water intake, which will partially solve the problem of negative impact on an underground water body in the Serebryanoe village.

An assessment of quality of water from an underground water body was made, which is a source of drinking water for the Serebryanoe village, Gorkovsky District, Omsk Region, and proposals for improvement of the quality of underground water for supplying the population in the required volume were developed. A modern factory-made installation for water treatment is proposed.

Based on the survey of the designed water intake site, a project for Source water protection of the designed well and water treatment station was developed.

The practical significance of the presented work lies in the possibility of real use of the developed proposals (projects):

- project of well liquidation tamping;

- project of a modular installation of water treatment for a well, which is necessary for obtaining water for household and drinking purposes in accordance with the requirements of Sanitary Regulations and Standards 2.1.4.1074-01 [10];

- project of a Source water protection for a water well, which is necessary not only to fulfill the requirements of the current legislation of the Russian Federation, but also, first of all, to protect underground sources from various types of pollution: anthropogenic, chemical, bacterial.

An estimated calculation of the costs of installing a water treatment plant was made; the construction cost of producing of 1 m3 of clean water was calculated; the payback period of the costs of installing the station and the cost of the liquidation tamping were calculated, which can serve as a rationale for planning the budget expenditures in the water supply system of the village. The calculations were made in order to include these financial costs in the federal project “Clean Water”.

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