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Original Research Article

WATER QUALITY ASSESSMENT AFTER MODERNIZATION OF THE TECHNOLOGICAL SYSTEM IN THE WATER TREATMENT PLANT IN DRZENIN (POLAND)

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Abstract

The article assesses the physical and chemical parameters of drinking water before and after the modernization of the technological system of water treatment station in Drzenin, Poland. The extension and modernization of the existing installation was necessary due to the poor technical condition of the devices, increasing demand for water in recent years and the periodic exceeding of the permissible values of water quality indicators.
Analysis of physical and chemical properties of drinking water after the modernization of the system showed the effectiveness of the water purification processes used and the correct selection of the technological line. The obtained water quality parameters were in accordance with the Regulation of the Minister of Health on the quality of water intended for human consumption (Journal of Laws of 2017, item 2294).

Keywords: groundwater and treated water, water quality, modernization of the water treatment station

1. INTRODUCTION

Water supply for people and industry determines the level of development of the country. The task of the water supply company is the collection, treatment and

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supply of water to recipients in the necessary quantity, with the required pressure and quality.

According to data from the Central Statistical Office of Poland, water consumption in households from the water supply network in 2018 was 1.3 km^3 and increased by 4.7% compared to last year. Groundwater abstraction for the needs of the national economy and population is also growing - it was higher by 96.4 hm^3 compared to the previous year and amounted to 1772.6 hm^3 [3]. It is caused by the expansion of the water supply infrastructure and greater public access to the water supply network. Water treatment plants must cover the user's increased demand for water while providing water of adequate quality.

The increasing requirements for the physico-chemical and bacteriological composition of water are the result of learning about the threats to human health caused by the presence of substances of natural and anthropogenic origin in the water and a possible epidemiological threat [6, 7].

Water quality is determined by national regulations, i.e. the Regulation of the Minister of Health of 07.12.2017. on the quality of water intended for human consumption (Journal of Laws of 2017, item 2294).

Groundwater is an important source of drinking water. Groundwater usage values are much higher than surface waters due to the more favourable chemical and microbiological characteristics. In this context the positive factor is lack of pathogenic bacteria and viruses as well as toxic pollution. Groundwater at the same time has favourable and stable physicochemical properties. A vast majority of groundwater requires iron and manganese removal. Therefore, these processes play a key role in water treatment technology [5, 14].

The main reason for setting the parametric value of iron at a low level in legal regulations - 200 μg/l (0.2 mg/l) [12] is an adverse effect of higher iron concentrations on the technical condition of the water supply system and on the organoleptic indicators of water - colour, turbidity, as well as the metallic taste of water, raising consumer concerns [4, 10, 11].

The presence of iron and manganese bacteria in water supply system causes change in water quality (smell) and bacterial growth in pipes.In the case of the occurrence of iron (II) and manganese (II) ions at the consumer’s point, iron and manganese are oxidized and precipitated under suitable conditions (e.g. in washing machines, boilers). Higher concentrations of iron and manganese in water cause technological problems, failure of water supply systems operation, water quality deterioration and, in water with slightly higher concentrations of oxygen, they form undesirable incrustations that result in the reduction of pipe flow cross-section. In practice, this means the necessity of treating water from most underground water intakes used for the needs of residents and ensuring that iron does not penetrate the water during its treatment and distribution [1, 2].

Iron and manganese occur in dissolved forms as single ions (Fe^{2+}, Mn^{2+}) or in undissolved higher forms mainly as $Fe(OH)_3$ or $Mn(OH)_4$, respectively. They can also be present in colloid form (bound to humic substances). The form of their occurrence depends on oxygen concentration, solubility of Fe and Mn compounds in water, pH value, redox potential, hydrolysis, the presence of complex-forming inorganic and organic substances, water temperature, and water composition (e.g. CO_2 content) [1].

Despite many years of research, the problem of effective iron and manganese removal from groundwater is still present. New, effective and economically justified methods of removing these contaminants from water are sought.

Studies show that the use of appropriate filtration masses allows to reduce the size of the treatment station and achieve a measurable economic effect in the form of minimizing investment and operating costs [8, 9, 13].

The main purpose of this study was to determine the effectiveness of iron, manganese and ammonium ions removal in the Water Treatment Plant in Drzenin (Poland) before and after modernization. The effectiveness of water treatment was evaluated based on the removal degree of the individual physicochemical and organoleptic parameter of water quality.

2. METHODOLOGY OF RESEARCH

2.1. Object of research

The subject of research was raw and drinking water in a municipal water intake plant located in the town of Drzenin in the municipality of Gryfino in the Zachodniopomorskie province. The water treatment plant was designed for Q_h max = 33.0 m^3/h and built in 1977. It supplies water to over 1,300 inhabitants from Drzenin and Gardno as well as the industrial zone created in Gardno.

In the area of the water intake there is a Quaternary aquifer built by three aquifers: sub-clay, middle and upper inter-clay. The first usable aquifer is associated with the upper inter-clay aquifer, which in the so-called Zastoisko Wełtyńskie and on the slope of the Odra valley loses the clay insulation layer and becomes exposed to adverse anthropogenic factors. This aquifer is of fundamental importance for the water supply of the surrounding towns.

The water intake consists of two deep water wells drilled at depths 52.0 and 53.0 m below ground level. The geological profiles of deep water wells contain two sandy layers and two levels of sandy clays. The first layer from the ground surface is the one of sandy loams, 12.0 m thick, followed by a layer of fine-grained sands - up to a depth of 27.0 m. Then a second layer of sandy loams - up to a depth of 34.0 m, built of fine-grained and medium-grained sands with a floor depth of 49.5 and 48.0 under ground level - aquifer.

2.2. Modernization of the technological system

Prior to the modernization of the station, raw water from deep wells was pumped by pipeline from DN100 steel pipes to 2 pressure filters with a diameter of 1700 mm (with a total filtration area of F=4.54 m²) filled with quartz deposits, operated for over 30 years. Each filter was preceded by a water-air mixer with a diameter of 600 mm and a height of 700 mm, mounted on the raw water discharge pipeline before the filter. Treated water was collected in a retention tank with a capacity of V=300.0 m³. A compressor unit with a capacity of only 25.0 m³/h was used to aerate the water and to flush the filter bed. Filters were checked for contamination by measuring the pressure upstream and downstream of the filters. The filter rinsing process was started manually by an employee of the station who decided about the frequency and length of the process. The filter beds were flushed once a week. All technological pipelines were made of black steel pipes with welded and flanged connections, the technical condition of which was evidence of advanced corrosion.

Table 1. Production of treated water at water treatment plant "Drzenin" in 2013-2018

Month	***Year***					
	2013	***2014***	***2015***	***2016***	***2017***	***2018***
January	*2,794*	*2,481*	*3,581*	*4,424*	*4,017*	*6,433*
February	*2,390*	*2,475*	*3,103*	*2,888*	*9,698*	*6,620*
March	*2,909*	*2,661*	*3,737*	*4,566*	*8,389*	*9,647*
April	*3,544*	*2,946*	*3,622*	*4,865*	*5,865*	*5,307*
May	*3,872*	*2,927*	***5,152***	*6,062*	*7,709*	*9,280*
June	*3,584*	*3,330*	*2,601*	*7,646*	*8,557*	*8,134*
July	***4,231***	***4,260***	***4,436***	*5,579*	*8,997*	*9,253*
August	*3,160*	***4,044***	***5,205***	*6,261*	*7,128*	*9,447*
September	*3,069*	*3,488*	*3,468*	*9,011*	*5,493*	*6,045*
October	*2,648*	*3,284*	*3,513*	*6,764*	*6,670*	*6,117*
November	*2,409*	*3,116*	*3,644*	*6,556*	*5,474*	*5,356*
December	*2,578*	*3,149*	*3,808*	*5,562*	*5,290*	*4,826*
Total [m³/year]	***37,188***	***38,161***	***45,870***	***70,184***	***83,287***	***86,465***
Q_d = TOTAL / 365days [m³/day]	***101.9***	***104.6***	***125.7***	***192.3***	***228.2***	***236.9***

By 2016, increased water consumption was recorded mainly in the summer months: June-August, which was due to the prevailing weather conditions and the use of larger amounts of water for watering gardens. Since 2016, a significant increase in water demand has been observed throughout the year, which was caused by the creation and development of enterprises in the Gardno industrial zone. Table 1 presents the amount of treated water supplied to recipients by the treatment plant in 2013-2018.

Due to the growing demand for water in the area supplied by the water treatment station, periodic exceeding of permissible values of water quality indicators and poor technical condition, it was necessary to modernize the technological system. The modernization included the extension of the technological system of the groundwater treatment plant to the capacity $Q_{h\ max} = 45.0\ m^3/h$, consisting of two independently working sections. Each section consists of two filters and a water-air mixer (Fig. 1). There are plans to expand the system by another section, which will increase the plant's efficiency to $Q_{h\ max} = 65.0\ m^3/h$.

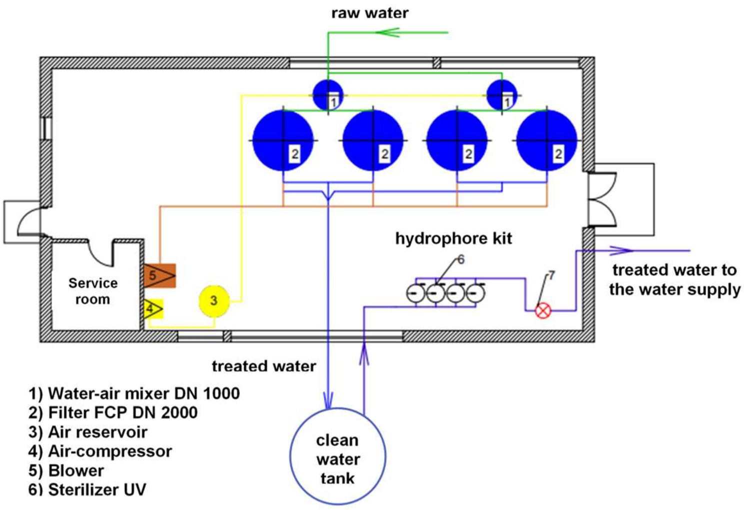

Fig. 1. Technological diagram of the Water Treatment Station in Drzenin

The equipment is supervised remotely through a monitoring system that is supervised by employees servicing the "Tywa "Water Treatment Plant in Gryfino.

3. RESULTS AND DISSCUSION

3.1. Raw water quality

Research carried out in 2015-2018 on abstracted raw water (Table 2) revealed pH in the range of 7.2 to 7.6 and a conductivity of 571.0 to 782.0 μS. At the time considered, the turbidity of raw water ranged from 2.0 to 17.3 NTU, and the overall hardness ranged from 285 to 475 $mgCaCO_3/dm^3$. Low chloride content ranging from 18.6 to 50.1 mg/dm^3 indicates good quality of raw water and relatively good isolation of the aquifer from anthropogenic pollution. However, taking into account the hydrogeological data of the intake in question, the periodical inflow of polluted waters through exposed aquifers is possible. The concentration of ammonium nitrogen in the absorbed water ranged from 0.08 to 0.39 mg/dm^3 and did not exceed the required value - 0.5 mg/dm^3.

Table 2. Average values of parameters for ground water (raw) during the period 2015 to 2018

Parameter	**Concentration in raw water**			**Standard for drinking water***
	Min.	**Max.**	**Average**	
pH	**7.2**	**7.6**	**-**	6.5 ÷ 9.5
Conductivity, µS/cm	**571**	**782**	**681±91**	2,500
Turbidity, NTU	**2.0**	**17.3**	**7.9±5.4**	1.0
Total hardness, $mgCaCO_3/dm^3$	**285**	**475**	**365±69**	60 – 500
Total iron, $mgFe/dm^3$	**1.83**	**3.28**	**2.85±0.48**	0.20
Manganese, $mgMn/dm^3$	**0.41**	**0.67**	**0.53±0.09**	0.05
Chlorides, mg/dm^3	**18.6**	**50.1**	**30.5±11.3**	250
Ammonium, mg/dm^3	**0.08**	**0.39**	**0.24±0.14**	0.50
Nitrate, mg/dm^3	**0.17**	**0.99**	**0.45±0.34**	50
Nitrite, mg/dm^3	**0.015**	**0.031**	**0.022±0.006**	0.50

* Regulation of the Minister of Health from 7th of December 2017 on the quality of water intended for human consumption (The Journal of Laws of the Republic of Poland, item. 2294).

Iron concentration in raw water samples in the years 2013 - 2015 ranged from 1.83 to 2.50 mg/dm^3 (on average: 2.25 mg/dm^3). Since 2016, when there was a significant increase in the amount of water absorbed, higher levels of iron in raw water were also observed. In the years 2016 - 2018, the iron content in water ranged from 3.00 to 3.28 mg/dm^3 (on average: 3.10 mg/dm^3). Literature data indicate that the level of iron in groundwater may increase as a result of hydrogeochemical changes in the vicinity of the water intake in connection with its exploitation and the resulting lowering of the surface of the water table around its intake [2,6].

In the years 2015-2018, testing of extracted raw water (Table 2) showed manganese concentration in the range of 0.41 to 0.67 mg/dm^3 (on average: 0.53 mg/dm^3).

3.1. Treated water quality

In the years 2013-2017, treated water samples had a pH in the range of 7.2 to 7.6 and a conductivity of 592.0 to 705.0 µS.

Colour values (Fig. 2) before the increase in the amount of purified water ranged from 3.0 to 12.0 mgPt/dm³. Increased water production caused an increase in the value of this parameter to the the range from 17.0 to 23.0 mgPt/dm³. After completion of modernization works, the colour of treated water ranged from 9.0 to 11.0 mgPt/dm³ and was in accordance with the requirements.

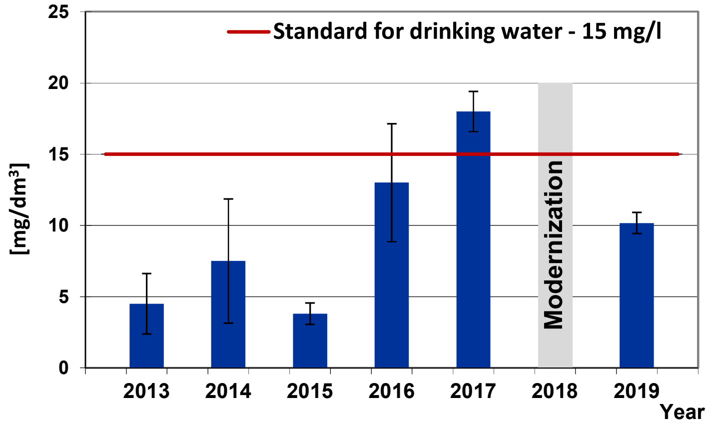

Fig. 2. Colour in treated water before and after modernization

Water turbidity (Fig. 3), before the increase of the hydraulic load of the technological line, in most samples it met the requirements. After an increase in water production, its value increased significantly and ranged from 2.6 to 9.2 NTU, for the required 1.0 NTU. After completion of modernization works, except for one exceeding due to the fault of the station operator, all turbidity values were lower than required and ranged from 0.82 to 0.96 NTU.

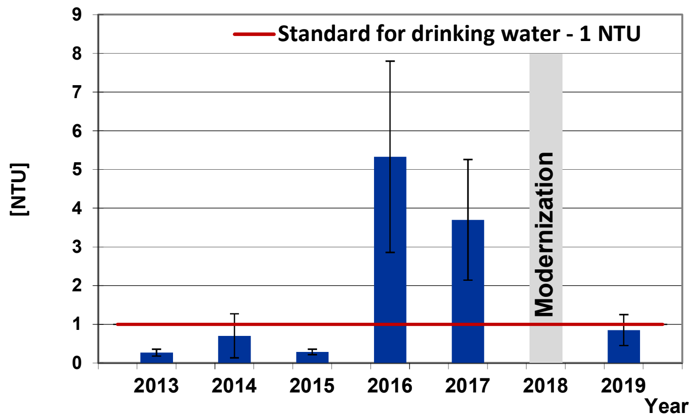

Fig. 3. Turbidity in treated water before and after modernization

Turbidity measurement can also be used to determine inter-filtration cycles. The production and quality of water that changes over time does not always coincide with the frequency of filter flushing assumed by the station operator, which may cause problems with maintaining water parameters at an appropriate level.

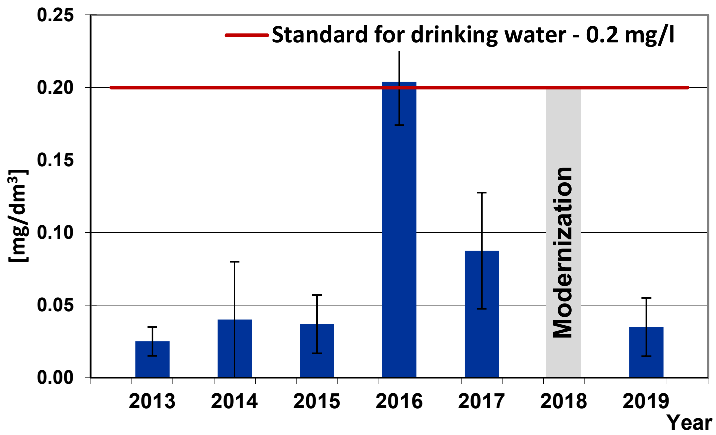

Fig. 4. Iron concentration in treated water before and after modernization

For iron compounds (Fig. 4), properly designed water-air mixers, filters and the structure of the filling of the filter bed, allowed to obtain a concentration of total iron in treated water in the range from 0.011 to 0.058 mgFe/dm^3, much lower than the values required for waters intended for human consumption, i.e. 0.2 mgFe/dm^3. Before modernization, only one excess of iron concentration in the water sample was found at the level of 0.398 mgFe/dm^3. The previously used solution for aerating the water did not guarantee the adequate contact time of the water with the air and caused problems in conducting maintenance works (e.g. cleaning). With increased water production, it could also lead to iron concentration exceedances in water.

In the period before modernization, until the increase in water production, the manganese concentration ranged from 0.01 to 0.03 mgMn/dm^3 and did not exceed the normalized value of 0.05 mgMn/dm^3. After increasing the water intake from the station, manganese concentration values deteriorated significantly, ranging from 0.191 to 0.801 mgMn/dm^3. After completing all the works, in accordance with the designed technical and technological solutions, the concentration of manganese in treated water was reduced to the level in accordance with the Regulation of the Minister of Health of 07.12.2017. on the quality of water intended for human consumption (Journal of Laws of 2017, item 2294).

The results of analyses performed from January to April 2019 showed manganese concentrations in the range from 0.036 to 0.045 mgMn/dm³ (Fig. 5).

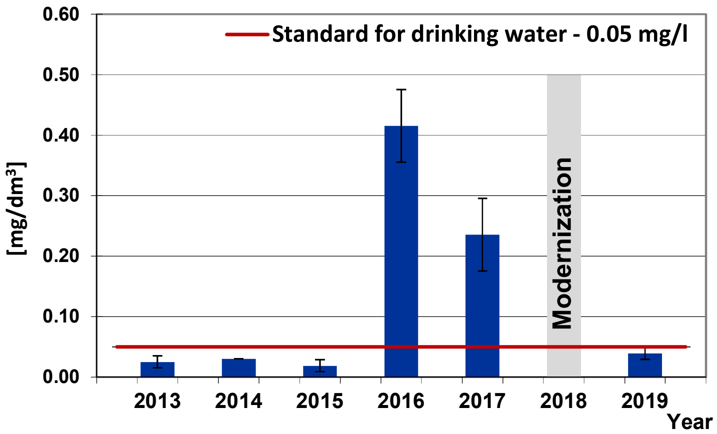

Fig. 5. Manganese concentration in treated water before and after modernization

4. CONCLUSIONS

The analysis of the effectiveness of six years of water treatment station operation showed that the rapid increase in hydraulic load resulting from the growing demand for water caused operational problems and difficulties in maintaining water quality parameters at a level required by legal provisions.

After the modernization of the water purification station, its operational efficiency is $Q_{h\ max}$= 50.0 m³/h, providing residents of Gardno and Drzenin as well as companies located in the created industrial zone in Gardno with water of the quality required by applicable law. Analysis of the physical and chemical properties of water before and after modernization showed the correct selection of devices used in the new technological system of water treatment and the effectiveness of water purification processes.

REFERENCES

1. Barloková, D and Ilavský, J 2009. Iron and manganese removal from small water resources. Polish Journal of Environmental Studies. 19(6), 1117–1122.
2. Główny Inspektorat Sanitarny 2018. Żelazo w wodzie przeznaczonej do spożycia przez ludzi.
3. GUS. Ochrona środowiska w 2018r.

4. Jakubaszek, A and Mossetty, J 2019. Changes to water quality in the water supply network of Zielona Góra. *Civil and Environmental Engineering Reports* **29**, 92–101.
5. Jordanowska, J and Jakubus, M 2014. *Evaluation of effectiveness technological process of water purification exemplified on modernized water treatment plant at Otoczna,* Civil and Enviromental Engineering Reports, 13 (2): 049-062.
6. Kowal, AL and Świderska-Bróż, M 2009. *Oczyszczanie wody.* PWN, Warszawa.
7. Krupińska, I 2018. Removal of natural organic matter from groundwater by coagulation using prehydrolysed and non - prehydrolysed coagulants. *Desalination and Water Treatment* **132**, 244-252.
8. Piekarski, J, Piecuch, T and Bartkiewicz, B 2000. Praktyczne aspekty wydłużenia czasu pracy kolumny sorpcyjnej bez wspomagania oraz z wspomaganiem z poprzedzającym złożem filtracyjnym. Rocznik Ochrona Środowiska (Annual Set the Environment Protection). 2, 297–316.
9. Piekarski, J, Piecuch, T and Malatyńska, G 2013. The Equation Describing the Filtration Process with Compressible Sediment Accumulation on a Filter Mesh. Archives of Environmental Protection, Issue 1, DOI: 10.2478/aep2013-0009.
10. Płuciennik-Koropczuk, E and Kumanowska, P 2018. Chemical stability of water in the water supply network - preliminary research*. Civil and Environmental Engineering Reports* **28**, 79–89.
11. Płuciennik-Koropczuk, E, Krupińska, I and Nowogoński, I 2019. Zmiany jakości wody w sieci wodociągowej. In: Innowacje w inżynierii środowiska. Wyd. Polskiej Akademii Nauk, Gdańsk, 163, 97 – 115.
12. Regulation of the Minister of Health on quality requirements for water intended for human consumption, Journal of Laws 2017 item 2294.
13. Skoczko, I, Piekutin, J and Roszczenko, A 2015. Usuwanie z wody związków żelaza i manganu metodą filtracji na wybranych złożach Annual Set The Environment Protection, Rocznik Ochrona Środowiska Volume 17, str 1587-1608.
14. Sozański, MM and Dymaczewski, Z 2002. Wodociągi i Kanalizacja w Polsce. Tradycja i współczesność. Wyd. Polska Fundacja Zasobów Wodnych.

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