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Organic matter in miocene water: occurrence and removal. Case study

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ABSTRACT

In Poland, over 70% of the water taken from the environment for human consumption is sourced from ground water. The most significant technological problem associated with water treatment, apart from significant amounts of iron and manganese, is the presence of organic matter and the color associated with it. Elevated values of parameters such as total organic carbon (TOC) result from numerous layers of lignite within the aquifer, enriching the extracted water with humic acids. Organic matter in water serves as a source of carbon and energy for bacterial growth and development, contributing to the formation and development of biofilm in the water distribution network. The use of chlorine-based disinfection for microbiological stability leads to the generation of disinfection by-products such as chloroform. This article presents a preliminary analysis of the efficiency of removing DBP precursors from Miocene water, in the water supply system in Środa Wielkopolska. The research was conducted for water after classical treatment, including aeration with filtration, as well as after the application of coagulation process using four different pre-hydrolyzed aluminum coagulants from the PAX series. In addition to typical indicators such as color, TOC, dissolved organic carbon (DOC), chemical oxygen demand (COD $KMnO_4$), UV absorbance, the biodegradable dissolved organic carbon (BDOC) was also determined to assess the presence of organic compounds that can potentially serve as a source of carbon and energy to support bacterial growth and development in the water distribution network. The research results serve as the basis for developing a model for chloroform generation in the water distribution network in Środa Wielkopolska for different water intake conditions, varying water quality, and different treatment methods.

Keywords: Organic matter; Chloroform; Color; Groundwater; Coagulation; Total organic carbon (TOC)

1. Introduction

The elevated concentrations of organic carbon and discoloration are caused by the migration of brown coal formations located directly above the aquifer or overlaying the water extraction layer. Humic substances constitute 60% to 80% of the total mass of organic substances present in the aquatic environment [1,2]. Their content in water depends not only on soil type and composition, but also on contact time and water pH. They are a source of unacceptable odor and water discoloration. Both surface and groundwater naturally contain organic and inorganic compounds. Organic substances such as humic acids or fulvic acids can serve as precursors for reactions with chlorine in water. The presence of bromides also contributes to the formation of organic compounds that are included in the total trihalomethanes (THM). Organic matter refers to a complex mixture of organic compounds that can exist in two basic forms - dissolved and suspended, with the total sum of these two parameters representing the total organic carbon (TOC) content [3–6]. The presence of humic substances in extracted water causes many problems during water

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treatment and is a reason for the water's lack of acceptability to consumers. Therefore, it is crucial to remove them from the water. These compounds act as precursors to disinfection byproducts THM. This is extremely important from both a water supply safety perspective, as THM are known carcinogens, as well as their potential mutagenic effects [7]. There are numerous methods for removing humic substances from water, including coagulation, adsorption, biodegradation, membrane techniques, and ion exchange [8,9].

One of the more significant challenges is controlling the generation of THM. The process of disinfection byproduct formation continues until either chlorine or organic substances are depleted. The quantity of THM formed depends on the quality of water subjected to chlorination [4,10–13]. The issue of disinfection byproduct formation must be considered in water treatment processes to ensure microbiological quality [7]. Simultaneously, the World Health Organization (WHO) [14] highlights the necessity of a disinfecting agent in water to guarantee its biological stability in the water distribution network. Many countries have implemented permissible levels of chloroform or total THM. Germany, for example, sets the acceptable THM concentration at a maximum of 25 mg/m^3. For comparison, the same parameter in the US and Poland may reach a value of 100 mg/m^3, while in Canada it is 350 mg/m^3. In the 1970s, the first information emerged regarding the formation of disinfection byproducts in chlorinated water. Chloroform was identified during this time, and toxicological studies confirmed its carcinogenic properties. To minimize the secondary pollution effects of water, it is essential to manage the technological process effectively. This involves removing organic compounds and reducing the use of disinfectants or eliminating them entirely [6,10].

Chemical disinfection consists of adding oxidizing agents such as sodium hypochlorite, chlorine dioxide, chlorine gas, bromine, iodine, or chloramines to water. Ozone and occasionally potassium permanganate are also included in the chemical disinfectants used. The normal redox potential values allow for ranking disinfectants according to decreasing oxidizing ability: O_3- ClO_2- Cl_2- Br_2- J_2 [15], while the stability and effective disinfecting time of various oxidizing agents decrease as follows: chloramines - chlorine dioxide - free chlorine - chlorine - ozone [16]. During the water disinfection process, oxidation reactions of both organic and inorganic substances occur. By using a chemical disinfectant such as sodium hypochlorite, we can ensure that the water meets the appropriate microbiological quality [10]. However, we also pose a potential risk by producing potentially hazardous disinfection by-products, especially chloroform [4,10–12]. Since THM are harmful to health [17,18], monitoring their concentrations in water supply systems is crucial.

The quality of tap water is dependent on the water source composition, the method of its treatment, and its distribution to the consumer's faucet [6,7]. The research, which is the focus of this article, involves the identification and removal of disinfection by-product precursors in the water supply system in Środa Wielkopolska, located in the Greater Poland Voivodeship in the central-western part of Poland. It was divided into two stages. The aim of the first stage was to analyze the content of total organic carbon (TOC), dissolved organic carbon (DOC), biodegradable dissolved organic carbon (BDOC), chemical oxygen demand (COD $KMnO_4$), UV absorbance, and, indirectly, color in each of the exploited urban wells in Środa Wielkopolska. In the second stage, the goal was to determine which coagulant would most effectively remove color and TOC from water after classic treatment methods such as aeration and filtration, using different doses. Additionally, the levels of DOC, BDOC, COD $KMnO_4$ and UV absorbance were examined. The same dose and process conditions were applied for each of the selected coagulants in the study.

2. Research object

The subject of the research is Środa Wielkopolska, a medium-sized city located in the Greater Poland Voivodeship in central-western Poland (Fig. 1). It is inhabited by nearly 24,000 residents.

In central Greater Poland Voivodeship, the water supply systems rely on water taken from the third layer of the aquifer, characterized by high levels of iron, manganese, ammonium ions, total organic carbon (TOC), and high coloration. This water is extracted by the Środa Water Supply System (WSS), which consists of six supply zones, utilizing two urban intakes and five rural intakes (Fig. 2). In total, approximately 2 million m^3 of water is extracted annually, with 75,000 m^3 being taken from the Quaternary aquifer, accounting for 4% of the total water intake. The remaining water is taken from the Tertiary aquifer. A total of 30 wells, approximately 150 m deep, and two wells approximately 50 m deep, are exploited. The raw groundwater composition from the urban well in Środa Wielkopolska does not meet the drinking water quality parameters.

The length of the water distribution network in the system operated by Municipal Company of Thermal Energy, Water Supply, and Sewage Ltd., in Środa Wielkopolska is

Fig. 1. Location of Środa Wielkopolska.

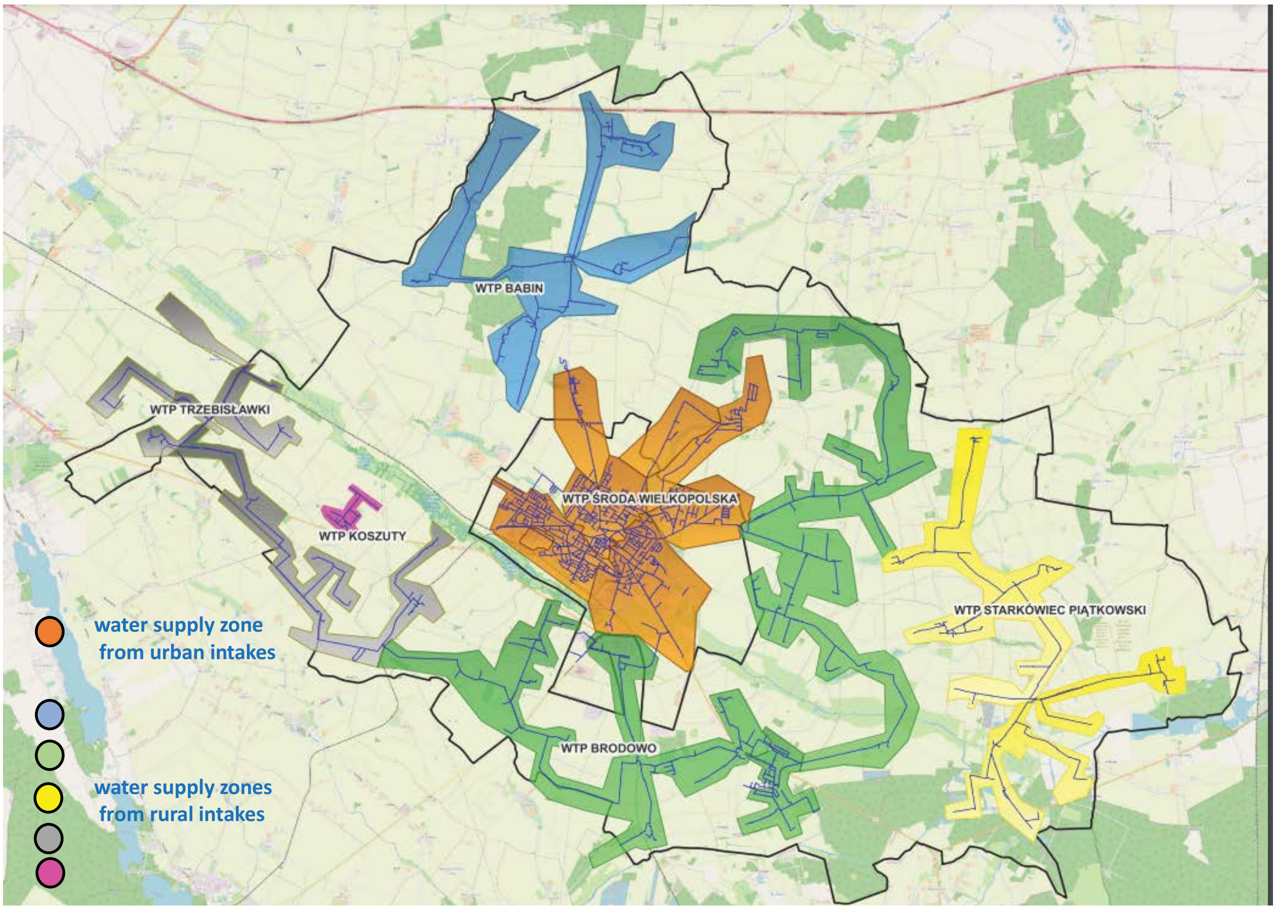

Fig. 2. Water supply system operated by the Municipal Company of Thermal Energy, Water Supply, and Sewage Ltd., in Środa Wielkopolska.

273 km. The water distribution network is primarily made of PE (41%) and PVC (49%), with iron, steel, and AC comprising the remaining 10%. The urban supply zone is dominated by a ring water distribution network arrangement, while the rural zones have a branching water distribution network configuration. The pipe diameters range from 80 to 350 mm, with the most common sizes being 110 and 160 mm. The age of the water distribution network varies, with 18% of the total length being less than 10 y old, 29% between 10 and 25 y, and 48% between 25 and 50 y. The water distribution network older than 50 y constitutes 5% of the total length. The diverse parameters of the water distribution network, as well as its extensive nature, create favorable conditions for the formation of THM.

The water intake in Środa Wielkopolska is located on the north-western outskirts of the city in the area of Kórnicka Street. It consists of seventeen deep wells that extract water from the Tertiary-Miocene aquifers (Table 1).

3. Research methodology

The experiment was carried out in three replications, and the results presented are the mean value. For the research, water samples were utilized from the following sources:

- raw water samples taken from 17 wells located in the city of Środa Wielkopolska, sourced from third-order intakes used for the water supply of the city's residents;
- water samples taken after filtration at the Water Treatment Plant on Kórnicka Street in Środa Wielkopolska;
- water samples taken after filtration at the Water Treatment Plant on Kórnicka Street in Środa Wielkopolska, subjected to a coagulation process under test vessel conditions, utilizing four different pre-hydrolyzed types of aluminum-based coagulants from the PAX "Poly Aluminium Chloride" series by KEMIPOL, such as:
- low-alkalinity coagulants: PAX XL 60 and PAX 18,
- medium-alkalinity coagulant: PAX XL10,
- high-alkalinity coagulant: PAX XL19 F.

The distinguishing characteristic of the four chosen coagulants for the conducted study is their elevated alkalinity due to the presence of hydroxyl groups. These selected coagulants vary in terms of alkalinity, aluminum content, chloride ion content, the ratio of aluminum to chloride content, and the degree of polymerization of the compound.

Based on literature information, pre-hydrolyzed polyaluminium chloride chlorides have been proven to be more effective in removing pollutants than aluminum (VI) sulfate. They are less sensitive to low temperatures and changes

Table 1
Characteristics of the municipal intake well in Środa Wielkopolska

Well No.	Characteristics of the municipal intake well in Środa Wielkopolska				
	Year of completion	Depth (m·BGL)	Efficiency (m^3/h)	Static mirror level (m)	Dynamic mirror level (m)
Well 7 B	2004	147	22.2	23.16	40.88
Well 1 E	1989	150	21.6	25.98	36.95
Well S2C	1989	156	25.2	27.98	35.94
Well 12 B	1987	150.0	19.2	26.22	33.49
Well S1C	1989	154	21.6	26.03	35.67
Well 12 C	1989	150.0	19.8	26.4	38.88
Well 10 D	1989	150.0	24.6	25.68	37.22
Well 7 C	1989	150	25.2	24.18	38.66
Well 9AW	1989	147.5	22.8	18.2	29.78
Well S2B	1986	155	19.2	27.2	39.72
Well 1 D	1986	152.0	23.4	25.78	37.65
Well 9 B	1983	142.0	0.84	18.63	20.87
Well 9 C	1984	149.0	15	21.13	29.47
Well 10 C	1987	150.0	21.6	25.26	36.96
Well 11 B	1992	154.0	25.2	23.8	39.42
Well 13	1989	153.5	11.4	25.42	28.98
Well of the Grey	1990	145	16.2	23.55	38.7

in pH levels, as well as reducing post-coagulation water corrosiveness [19].

To accomplish the set research plan, the quality parameters of water (Table 2) susceptible to generating THM during the chlorination process were examined. The analyses were conducted using standard analytical methods (Table 2).

In addition, the ultraviolet absorbance value of SUVA was calculated as the value of UV absorbance related to 1 g of RWO/m^3 [20] in order to enable the comparison of measurement results obtained at different lengths of the light path that light travels in the tested water sample in the cuvette (cm/m). The notation of the SUVA unit is often found in the form of $m^3/(g{\cdot}C{\cdot}m)$, in which the cubic meters of volume, assigned RWO values in water, are clearly separated from the meters of light path length assigned to absorbance. It seems that this notation can be reduced to the form $m^2/g{\cdot}C$, which corresponds to the proper active cross-section in the Lambert–Beerian law [21].

For each of the tested samples (average: raw water, water after filtration, water after coagulation) the $SUVA_{254}$ index was determined, which was calculated on the basis of the UV absorbance to DOC ratio.

The research process consisted of two stages.

- Stage I - involved the analysis of organic compounds measured by indicators such as TOC, color, DOC, BDOC, COD $KMnO_4$ and UV absorbance in water from each of the groundwater intakes in Środa Wielkopolska. Additionally, a chemical and biological assessment of water stability was carried out based on archival data covering a 10-y period of water monitoring in Środa Wielkopolska (2012–2022). The following parameters were analyzed: total hardness, ammonium ions, nitrates, nitrites, phosphates, chlorides, sulfates, turbidity, iron, manganese, and bacteriology.
- Stage II - the efficiency of removing TOC from the Miocene water in the coagulation process was tested using four different pre-hydrolyzed aluminum-based coagulants (polyaluminum chloride) at variable doses. Coagulation was carried out using a conventional method model tests were conducted using a 4-position coagulator from Velp Scientifica, and Stage II of the study consisted of two series. In the first series (series I), coagulation tests were performed to select the two most effective reagents. The tests were conducted for four different coagulants at a dose of 100 mg/L (corresponds to the dose of pure aluminum for PAX 18–9 mg·Al/L, PAX XL 60–7.5 mg·Al/L, PAX XL 10–5 mg·Al/L, PAX XL 19 F –8.5 mg·Al/L) added to 1 L of water sampled after filtration at the Water Treatment Plant on Kórnicka Street.

After dosing the coagulant, the water was subjected to a 2-min rapid mixing at a rotational speed of 200.0 rpm, followed by a reduction in speed to 25 rpm, and the mixing continued for 20 min. After this duration, the mixer was turned off, and sedimentation of the sludge began. After approximately 10 min of sedimentation, decantation was performed, and the water was filtered and analyzed according to the procedures outlined in Table 2.

The collected samples were tested for color, TOC, DOC, BDOC, COD $KMnO_4$, and UV absorbance.

Based on the visual assessment of the coagulation process and the results of the tests conducted in series I, two coagulants were selected for further testing in second series (series II). These coagulants were PAX XL 60 (with the

Table 2
Research methodology used for conducting the analysis

Indicator	Research methodology	Equipment
Color	PN-EN ISO 7887:2012+Ap1:2015-06	Cary 50 Spectrometer Manufacturer: Varian
pH	PN-EN ISO 10523:2012 - Water Quality — Determination of pH	OMNIS Analyzer Manufacturer: Metrohm
TOC DOC	PN-EN 1484:1999 Water Analysis — Guidelines for determining total organic carbon (TOC) and dissolved organic carbon (DOC)	TOC-L Organic Carbon Analyzer Manufacturer: SHIMADZU
BDOC	Water samples intended for the determination of biodegradable dissolved organic carbon are filtered on 0.45 µm filters. Then the sample is poured into 250 mL bottles containing sand taken from a fast filter, which works in the system without pre-chlorination. The samples are stored in an incubator at 20°C ± 2°C for a period of 5–7 d. After this time, the analysis is performed according to PN-EN 1484:1999 Water Analysis — Guidelines for determining total organic carbon (TOC) and dissolved organic carbon (DOC)	TOC-L Organic Carbon Analyzer Manufacturer: SHIMADZU
Permanganate index determination	PN-EN ISO 8467:2001 Water Quality — Determination of Permanganate Index	Digital III Digital Burette Manufacturer: Merck
UV absorbance	PB/PCH-14 edition 4 dated 01.10.2018 in-house procedure for determining UV absorbance in water	Cary 50 Spectrometer Manufacturer: Varian
Chloroform	PN-EN ISO 15680:2008	P&T-GC/MS Agilent Gas Chromatograph: GC 5560, MSD 5977B with Teckmar Adapter: Atomx xyz

best-flocculated sludge particles) and PAX XL 19 F (with the lowest water color after the coagulation process). These coagulants were applied in doses of 50.0 mg/L (corresponds to the dose of pure aluminum for PAX XL 60–3.75 mg·Al/L, PAX XL 19 F –4.25 mg·Al/L) and 150 mg/L (corresponds to the dose of pure aluminum for PAX XL 60–10.75 mg·Al/L, PAX XL 19 F –12.75 mg·Al/L) in bench-scale tests, while maintaining the same process conditions as in series I.

4. Results and discussion

The results of the tests conducted in the first stage indicate that water abstracted from the medium-depth wells is characterized by an elevated color of approximately 36 mg·Pt/L (Table 3). This color level is not acceptable to consumers and raises suspicions of a high organic substance content. The water has a pH ranging from 6.7 to 7.8, which is close to neutral. The conducted tests (Table 2) clearly indicate that the water is rich in organic matter, as indicated by the TOC parameter (5.5–6.9 mg/L), UV absorbance (13–18 1/m) and COD $KMnO_4$ (3.8–5.6 mg/L). Tests showed that the highest content of organic compounds, expressed as TOC at a level of 6.9 mg/L, was observed in the water from well 7B, which also had a relatively high concentration of DOC at 5.9 mg/L. The highest DOC content, at 6.2 mg/L, was found in the water from well 7C, which was 5% higher than the DOC concentration in the water from well 7B. However, the TOC content in well 7C was 4.5% lower (6.6 mg/L) compared to that in well 7B. Further analysis revealed that water samples with TOC levels above 6 mg/L exhibited a color of approximately 40 mg·Pt/L.

The lowest content of organic compounds, expressed as TOC at a level of 5.5 mg/L, was found in two wells: 12B and 9AW. In both wells, the concentration of DOC was 5.2 mg/L. In well 12B, the COD $KMnO_4$ was 4.7 mg/L, and the UV absorbance was 15 1/m while in well 9AW, the COD $KMnO_4$ was 4.4 mg/L, and the UV absorbance was 13 1/m. The permissible concentrations of individual carbon fractions are not legally standardized in Poland. According to the current regulations outlined by the Minister of Health [22] concerning the quality of water intended for human consumption, the acceptable content of TOC is defined as "without abnormal changes".

Studies on BDOC and its dynamics in tap water in the water distribution network should be a routine procedure in the operation of the water treatment plant, as their variability indicates the possibility of bacterial growth in the pipe water distribution network. Studies conducted by Bonalama et al. and Chandy et al. showed that organic carbon has the greatest influence on the development of biofilm in the water distribution network [23,24]. The conducted BDOC tests indicate that the water extracted from the wells operated by the Municipal Company of Thermal Energy, Water Supply, and Sewage Ltd. in Środa Wielkopolska does not tend to microbiological contamination, confirming the high microbiological stability of the water. According to available literature sources, the requirement for biostability is a content of biodegradable dissolved organic carbon at a level of 0.15–0.2 mg·C/L [18], while according to Volka et al., the BDOC content should not exceed 0.15 mg·C/l at 20°C and 0.30 mg/L at 15°C, which is critical for water biostability [25].

Table 3
Raw water quality characteristics

Well No.	Results						
	Color	pH*	TOC	BDOC	DOC	COD KMnO_4	UV absorbance
	mg·Pt/L	– (°C)	mg/L	mg/L	mg/L	mg/L	1/m
Well 7 B	40	7.3 (18.3°)	6.9	<0.10	5.9	5.6	17
Well 1 E	30	7.3 (18.6°)	6.1	<0.10	5.8	4.6	16
Well S2C	30	7.2 (18.8°)	6	<0.10	5.7	4.3	15
Well 12 B	35	7.3 (19.4°)	5.5	<0.10	5.2	4.7	15
Well S1C	30	7.3 (19.4°)	6.1	<0.10	5.1	3.8	14
Well 12 C	35	7.3 (19.2°)	6.1	<0.10	5.5	4.6	15
Well 10 D	40	7.4 (18.8°)	6.4	<0.10	5.7	4.7	17
Well 7 C	40	7.3 (18.9°)	6.6	<0.10	6.2	5.2	17
Well 9AW	30	7.4 (18.7°)	5.5	<0.10	5.2	4.4	13
Well S2B	30	7.2 (18.6°)	5.9	<0.10	5.8	3.9	14
Well 1 D	30	7.3 (19.2°)	5.8	<0.10	5.4	4.8	16
Well 9 B	>60	7.7 (19.0°)	5.9	<0.10	4.8	3.7	13
Well 9 C	>60	7.3 (18.7°)	6	<0.10	5.5	3.8	13
Well 10 C	45	7.3 (19.1°)	6.3	<0.10	5.5	5.4	18
Well 11 B	30	7.3 (18.6°)	6.2	<0.10	5.8	3.4	14
Well 13	15	7.3 (19.6°)	6.1	<0.10	5.7	3.4	13
Well of the Grey	40	7.3 (18.0°)	5.9	<0.10	5.4	4.6	16
Min	15	7.2	5.5	–	4.8	3.4	13
Max	60	7.7	6.9	–	6.2	5.6	18
Average	36	7.3	6.1	–	5.5	4.4	15
Median	35	7.3	6.1	–	5.5	4.6	15
Standard deviation	11.15	0.11	0.35	–	0.34	0.66	1.64

*Effect of temperature on the pH value is corrected by automatic temperature compensation (ATC).

The following charts (Figs. 3 and 4 represent the results of a 10-y study on the quality of raw water as part of monitoring efforts.

Furthermore, the results of research conducted by the Municipal Company of Thermal Energy, Water Supply, and Sewage Ltd., regarding water quality monitoring over the same period indicate that water extracted from the middle-depth wells is moderately hard (with an average of 255.0 mg·CaCO_3/L; ranging from 193.9 to 293.0 mg·CaCO_3/L). It is characterized by an elevated content of geogenic ammonium ions (0.668–1.12 mg·NH_4/L) and low nitrate concentrations (mostly <0.05 mg·NO_2/L), as well as low phosphate content (0.43 mg·PO_4/L). Chloride and sulfate concentrations (average 10.0 mg·Cl/L and average 6.15 mg·SO_4/L) are minimal. The water has a medium sodium content (51.0–56.4 mg·Na/L). The water exhibits elevated turbidity (0.58–31.0, average 5.47 NTU), most likely due to the precipitation of iron compounds present in increased amounts (0.064–4.42 mg·Fe/L, average 1.279, with a drinking water limit of 0.20 mg·Fe/L). It also contains slightly elevated amounts of manganese compounds (0.02–0.167 mg·Mn/L, average 0.039 mg·Mn/L with a drinking water limit of 0.05 mg·Mn/L). Bacteriologically, it is unqualified.

In the second stage of the conducted jar test using 4 aluminum-based coagulants at a dosage of 100 mg/L (corresponds to the dose of pure aluminum for PAX 18–9 mg·Al/L, PAX XL 60–7.5 mg·Al/L, PAX XL 10–5 mg·Al/L, PAX XL 19 F –8.5 mg·Al/L) it was shown that in each case, the water color decreased from 20 to 5 mg·Pt/L. Regarding the organic matter expressed as TOC, the greatest reduction was observed when using PAX XL 10 (corresponds to the dose of pure

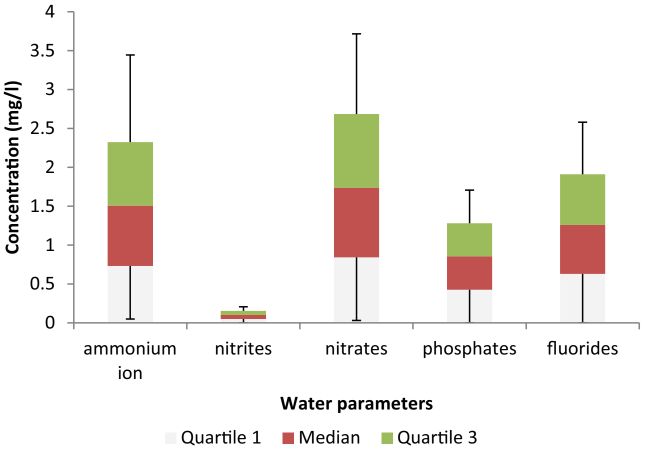

Fig. 3. Characteristics of selected raw water parameters from the period 2013–2023 - ammonium ion, nitrites, nitrates, phosphates and fluorides.

aluminum 5 mg·Al/L) and PAX XL 19 F (corresponds to the dose of pure aluminum 8.5 mg·Al/L), where the value decreased from 5.8 to 4.7 mg/L, representing a 19% reduction when both coagulants were used (Table 4). Similar trends were observed for absorbance and COD $KMnO_4$ Nevertheless, for further laboratory-scale investigations, the coagulant demonstrating the highest efficiency in the flocculation process, namely PAX XL 60 and PAX XL 19 F which exhibited the lowest water color after volumetric coagulation, was selected. The PAX XL 60 coagulants selected for further study were used at doses of 3.75 and 10.75 mg·Al/L, while the coagulant PAX XL 19 F was used at doses of 4.25 and 12.75 mg·Al/L.

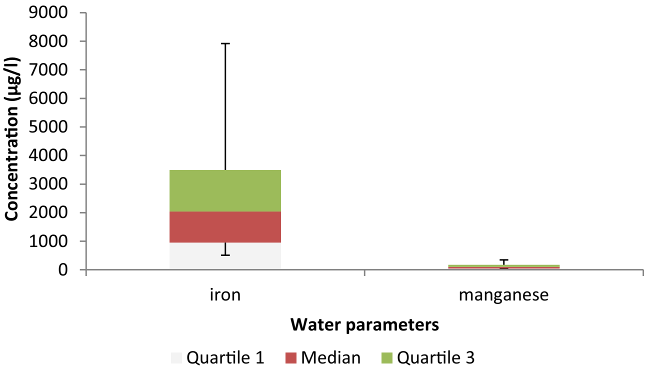

Fig. 4. Characteristics of selected raw water parameters from the period 2013–2023 - iron and manganese.

From the results obtained in the second series of tests presented in Table 5, the highest efficiency in removing organic matter from water was achieved using the aluminum-based coagulant PAX 19 F at a dosage of 12.75 mg·Al/L. In this case, TOC decreased from 5.8 to 3 mg/L, representing a 48% reduction, while DOC decreased from 5.7 to 2.9 mg/L, signifying a 49% reduction.

The results for raw water, aerated and filtered water, and water treated with the coagulation process are presented in Table 6.

The conducted tests on raw water, aerated and filtered water, and water treated with the coagulation process have shown the effectiveness of the coagulant PAX 19 F at a dosage of 12.75 mg·Al/L in removing organic matter, expressed as TOC, within the range of 51% (from 6.1 to 3 mg/L), while DOC decreased from 5.5 to 2.9 mg/L, resulting in a reduction of 47%. At the same time, UV absorbance was reduced by 66% during the coagulation process.

5. Conclusions

Stage I:

- The level of organic substances (TOC) in the tested samples from the wells in Środa Wielkopolska ranges from 5.5 to 6.9 mg/L (with an average of 6.1 mg/L). This represents a relatively high concentration of organic compounds, posing an unacceptable risk of secondary water contamination during its transportation to consumers.

Table 4
Results of series I tests - coagulant dose 100 mg/L

Series I	Water after filters	Coagulant dose 100 mg/L			
		PAX XL 60 7.5 mg·Al/L	PAX XL10 5 mg·Al/L	PAX XL 19 F 8.5 mg·Al/L	PAX 18 9 mg·Al/L
Color (mg/L)	20	5	5	5	5
TOC (mg/L)	5.8	5.4	4.7	4.7	5.4
DOC (mg/L)	5.7	5.3	4.6	4	5
BDOC (mg/L)	<0.10	<0.10	<0.10	<0.10	<0.10
COD $KMnO_4$ (mg/L)	5.4	3.5	3.1	3.3	3.3
UV absorbance (1/m)	14	9.7	8.3	6.2	9.5

Table 5
Results of series II tests - coagulant dose 50 and 150 mg/L

Series II	Coagulant dose 50 mg/L		Coagulant dose 150 mg/L	
	PAX XL 60 3.75 mg·Al/L	PAX XL 19 F 4.25 mg·Al/L	PAX XL 60 10.75 mg·Al/L	PAX 19 F 12.75 mg·Al/L
Color (mg/L)	5	5	5	5
TOC (mg/L)	5.3	4.1	6.3	3
DOC (mg/L)	4.8	3.6	4.3	2.9
BDOC (mg/L)	<0.10	<0.10	<0.10	<0.10
COD $KMnO_4$ (mg/L)	2.9	2.5	2.8	1.8
UV absorbance (1/m)	9.7	6.4	7.6	5.1

Table 6
Water quality after the coagulation process

Test parameter	Raw water*	Water after aeration and filtration	Water after application PAX 19 F 12.75 mg·Al/L
pH	7.3(+/– 0.11)	7.4	7.0
Color (mg/L)	36 (+/– 11)	20	5
TOC (mg/L)	6.1 (+/– 0.35)	5.8	3
DOC (mg/L)	5.5 (+/– 0.34)	5.7	2.9
BDOC (mg/L)	<0.10	<0.10	<0.10
COD $KMnO_4$ (mg/L)	4.4 (+/– 0.66)	5.4	1.8
UV absorbance (1/m)	15 (+/– 1.64)	14	5.1
$SUVA_{254}$ $m^2/g·C$	2.73	2.46	1.75

*Average results of the tested parameters of raw water from Table 3.

- The Miocene water requires the removal of color and organic matter associated with natural organic pollution.
- The value of BDOC was undetectable in all tested samples, indicating the absence of compounds that could support bacterial growth. Therefore, there is no tendency for microbiological contamination.

Stage II:

- The coagulation process allows for the effective removal of color, decreasing it from 20 to 5 mg·Pt/L, and TOC from 6.1 to 3 mg/L in water.
- The best efficiency in removing TOC was achieved by using the coagulant PAX XL19 F at a dosage of 12.75 mg·Al/L.
- A higher efficiency of UV absorbance removal was found in relation to the efficiency of TOC and DOC removal (15% higher absorbance removal efficiency compared to TOC and 19% higher absorbance removal efficiency compared to DOC).
- In the case of raw water and after the filtration process, the $SUVA_{254}$ $m^2/gC \leq 3$ may indicate the predominance of non-humic and hydrophilic substances and low molecular weights, at which coagulation and additional sorption methods are recommended.

In the case of coagulated water, the $SUVA_{254}$ was 1.75 m^2/gC, indicating that there was no indication for further removal of RWO. In the coagulation process, a very important parameter is the concentration of remaining aluminum, the presence of which in the treated water depends on many factors, not only technological, but also technical and hydraulic. However, in order for the conducted research to enable the interpretation of this indicator, it is necessary to precisely model the process, taking into account filtration (filtration speed, grain size). This is planned for the next series of studies.

The aim of the experiment was to initially determine the efficiency of removal of organic substances in the coagulation process. Because the water samples after coagulation were decanted and filtered on laboratory filters, it was found that the tests of both turbidity and aluminium may not translate into effects in the technical system. It is planned to carry out further series of tests kto.re will determine in detail the conditions for the removal of post-coagulation flocs, considering the technical conditions being the most important cause of turbidity and aluminium exceedances.

From the obtained results of aeration and filtration, it can be concluded that these processes are insufficient for effectively removing organic matter from miocene water; only the color improved. When analyzing the changes in the content of individual fractions of organic carbon after aeration and filtration, it can be observed that the levels of TOC decreased, while DOC increased, and BDOC remained unchanged. The values of other indicators did not change.

The remaining parameters are similar to those of raw water. The application of an additional water treatment method, involving the coagulation process, allows for a reduction in organic matter. The results for color, TOC, DOC, oxidation, and UV absorbance have improved.

The conducted analysis provides the basis for developing a chloroform generation model in the water distribution network in Środa Wielkopolska for different extraction states, water qualities, and treatment methods.

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