

**Jadwiga KALETA, Adam PIECH,
Alicja PUSZKAREWICZ**

*Technical University of Rzeszów
Department of Water Protection and Purification
Rzeszów*

MODERNIZATION OF WATER CONDITIONING PROCESSES FOR WATER INTAKE IN HUTA KOMOROWSKA

MODERNIZACJA TECHNOLOGII UZDATNIANIA WODY Z UJĘCIA W HUCIE KOMOROWSKIEJ

W artykule, przedstawiono badania laboratoryjne, których celem było opracowanie technologii uzdatniania wody wgłębniej z ujęcia w Hucie Komorowskiej, spełniającej wymagania sanitarne dotyczące jakości wody przeznaczonej do spożycia. Uzyskane w badaniach wyniki posłużyły do opracowania projektu modernizacji ciągu technologicznego realizowanego na istniejącej stacji uzdatniania wody. Opracowana technologia zakładała dwa stopnie filtracji. Z uwagi na obecność w ujmowanej wodzie kompleksów żelaza ze związkami humusowymi konieczne było wprowadzenie do układu technologicznego procesu koagulacji kontaktowej realizowanej na filtrze trójwarstwowym – I^o filtracji (warstwa podtrzymująca, którą stanowił aquacleanit, warstwa właściwa z piasku kwarcowego oraz warstwa nawierzchniowa z antracytu). Najlepszym koagulantem okazał się glinian sodu (SAX - 18) w dawce 2 mg Al/dm³. Wybór tego koagulantu podyktowany był nie tylko uzyskaniem dobrych efektów w zakresie zmniejszenia barwy, mętności, żelaza, utleniałości i absorbancji ale również podwyższeniem odczynu pH oraz zasadowości wody, co skutkowało zmniejszeniem jej agresywności. W ramach drugiego stopnia filtracji zastosowano filtr z masą chemicznie aktywną (Defemen + piasek). Filtrację pierwszego i drugiego stopnia prowadzono z prędkością 7,5 m/h.

1. Introduction

Impurities most often met in underground waters are various forms of iron and manganese as well as nitrogen compounds. In addition to the above impurities, some underground waters contain also natural organic matter represented mainly by humus compounds. Water becomes enriched with humus substances in consequence of humus leaching from humus-rich soils and from brown-coal formations. Their content in natural waters depends on the type of soil, time of contact of percolating water with the

ground layer, on chemical composition and, first and foremost, on water pH. Underground waters containing natural organic matter are characterized by high coloring and oxygen consumption [6, 10, 12].

Until recently, humus substances were not believed to be harmful for humans. They were removed from water for drinking primarily because of esthetics. Research of the recent years has shown humus substances may be a source of undesirable smell and color of water as well as may accumulate some toxic substances while creating complexes with heavy metals, compounds of phosphorus, ammonia, and adsorption of organic compounds (pesticides, phthalates, polycyclic aromatic hydrocarbons). In consequence of reaction of humus substances with chlorine undesirable secondary halogen micro-impurities are created [2, 9, 11].

One of the most popular technological processes applied for removing of humus substances from water is coagulation. In case of coagulation of those impurities, higher doses of coagulants are frequently necessary than for coagulation of particles which cause water turbidity, as well as strict observation of optimum process conditions, mainly the pH.

When the doses of ferric coagulants are too low or pH is not suitable a colorful combinations (chelates) of humus acids with iron may result/be created. In some cases the coagulation process must be supported by chemical oxidation and/or polyelectrolytes [1, 3, 4, 7, 8].

The presence of natural organic matter in waters taken in for communal needs is problem faced by many conditioning stations (SUWs), like that in Huta Komorowska.

The purpose of research presented in this paper was the technological analysis of underground water taken in from four deep wells in Huta Komorowska, in respect of its conditioning for human consumption. The results achieved in the tests served to develop modernization project of technological process to be realized in existing water conditioning station.

2. Characteristic of drawn water from well

The research was performed on drawn water directly from well. The basic physical and chemical index were executed in laboratory of Water Purification and Protection Department of Rzeszów University of Technology, in accordance with the standards obligatory in Poland.

Obtained results were compared with the effective standards (Table 1) as determined in the Regulation of the Ministry of Health of 29th March 2007 on the requirements concerning the quality of water for human consumption (*Official Gazette* Dz.U. No. 61, item 417).

Raw water from the well had substandard color, turbidity, iron, manganese contents as well as low reaction pH.

High color of water in correlation with increased oxygen demand and high absorbance UV suggest presence natural organic matters in water, which can be in combination with iron and manganese compounds.

Besides, the tested water had low alkalinity and pH, that witness about its aggressiveness properties.

Physical and chemical composition drawn water suggested also in treatment process which can be.

Tab. 1. The physical and chemical composition of sampled water

Index	Acceptable value	Value of raw water
Reaction pH	6,5 – 9,0	6,40
Alkalinity (mval/dm ³)	-	0,9
Oxygen Demend (mgO ₂ /dm ³)	5,0	4,85
Hardness (mval/dm ³)	1,2 – 10,0	1,76
(mgCaCO ₃ /dm ³)	60 - 500	88
Turbidity (NTU)	1,0	17,0
Color (Hazen)	15	40
Manganese (mg/dm ³)	0,05	0,40
Iron (mg/dm ³)	0,20	2,75
Ammonium nitrogen (mg NH ₄ ⁺ /dm ³)	0,50	0,30
Absorbance UV (254 nm)	-	0,291

3. Existing technological system of water treatment

The raw water from well is directed on three stages of filtration. First stage contain 4 filters with quartz sand and speed of filtration is 5 m/h.

The filters of second stage (3 apiece) are packed alkalite mass (containing MgO) - *aquacleanit*, speed of filtration oscillate about 7,5 m/h. In the frame of third stage realize filtration on 3 filters with chemical active mass – *Defeman*, at speed about 7,5 m/h.

That technological system not ensure obtainment of water meeting the acceptable standards, so took decision about necessity of modernization of water treatment process.

4. Technological study for modernizing the water conditioning process

The purpose of the laboratory tests was to develop a process that meets the following conditions and requirements:

- reduce water color and turbidity, as well as its oxygen demand, to standard values,
- guarantee maintaining of standard pH as well as good results of iron and manganese removal from water,
- utilize the existing, currently operated equipment and facilities of the water conditioning station (SUW), thus minimizing the modernization costs.

The technological study was carried out in three stages. The first stage served to enable selection of the type of coagulant and optimization of its dose. The second stage

was devoted to coagulant dose verification in the process of contact coagulation, as well as to defining the filtration parameters. The third stage dealt with the second stage of filtration and its main objective to remove manganese from water.

4.1. Study concerning volumetric coagulation process

Coagulation of water was conducted in classical manner, based on 'jar test' and using a 6-stand laboratory coagulator having mechanical stirrer with regulated r.p.m.[5]. The effectiveness of coagulants was assessed experimentally and their doses were determined.

The following coagulants, produced by Kemipol company, were tested:

PAX – 16 (aqueous solution of poly-aluminum chloride),

PAX XL – 61 (aqueous solution of aluminum poly-chloride),

PIX – 111 (aqueous solution of ferric chloride III),

SAX – 18 (sodium aluminate).

The first three reagents are pre-hydrolyzed coagulants (of alumino- and ferric), that last coagulant is sodium aluminate. Because of low alkalinity of water the traditional coagulants were eliminated from tests, because of the effectiveness of their activity conditions by the presence of certain quantity of bicarbonates (main ingredients of water alkalinity).

These coagulants would cause a lowering of both the alkalinity and pH.

Prior to coagulation process water was aerated. The time of rapid mixing was 3 min, whereas the flocculation process (slow mixing) was run for 30 minutes. After coagulation process completion, the samples were left for 30-minute sludge sedimentation. The following check determinations were carried out, in accordance with Polish Standards, in decanted and percolated samples: reaction, alkalinity, color, turbidity, oxygen demand, iron and the UV absorbance. The results from the selection of coagulant type and its optimum dose are presented in Table 2.

As expected, the PIX – 111 (ferric coagulant) appeared to be the worst coagulant. With its rising dose of it the quality of water after coagulation became worse.

Aluminum coagulants (PAX – 16 and PAX XL – 61 in the doses of 1 mgAl/dm³ caused a worsening of water quality. Doses of 5 and 10 mgAl/dm³ produced better effects but the resulting water still did not meet standard parameters in respect of its color, turbidity and iron.

Water with best quality parameters was obtained in the process of coagulation with sodium aluminate (SAX – 18) and therefore the next stage of the study focused on optimization of dose of that coagulant (Table 3).

Tab. 2. Selection of coagulant type and its optimum dose

Index	Dose PAX – 16 (mg Al/dm ³)			Dose PAX XL – 61 (mg Al/dm ³)			Dose PIX 111 mg Fe/dm ³			Dose SAX – 18 mg Al/dm ³		
	1	5	10	1	5	10	1	5	10	1	5	10
Reaction pH	6,9	6,8	6,8	6,9	6,8	6,7	6,9	6,8	6,8	6,9	7,0	7,2
Alkalinity (mval/dm ³)	1	0,9	0,9	0,8	0,7	0,6	1,0	0,8	0,6	1,0	1,2	1,6
Oxygen demend (mg/dm ³)	2,9	1,3	1,4	2,8	2,2	1,2	3,0	2,8	2,7	0,6	1,2	1,8
Colour (Hazen)	73	30	36	63	74	28	62	143	112	45	14	15
Turbidity (NTU)	6,5	3,3	4,2	5,3	4,6	2,4	4,4	8,8	6,2	4,6	1,6	1,1
Iron(mg/d m ³)	0,8	0,5	0,6	1,1	0,8	0,7	2,0	3,5	>3,5	0,9	0,5	0,1
Absorbance UV (254 nm)	0,294	0,118	0,106	0,3	0,221	0,135	0,344	0,590	0,540	0,280	0,200	0,215

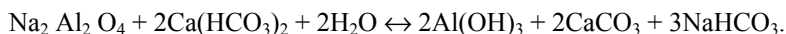
As this coagulant raised pH, while previous reported experience [8] recommended pH of 5-6 for most effective removal of humus compounds, we resigned from initial aeration, which would also cause pH raising.

Tab. 3. Selection of coagulant dose (SAX – 18)

Index	Dose SAX – 18 (mg Al/dm ³)					
	2	4	6	7	8	12
Reaction pH	6,2	6,4	6,6	6,7	6,9	7,4
Alkalinity (mval/dm ³)	0,6	1,3	1,4	1,5	1,6	1,9
Oxygen demend (mg/dm ³)	1,2	1,4	1,3	2,0	2,2	3,8
Colour (Hazen)	43	22	28	19	24	48
Turbidity (NTU)	3,7	1,3	1,8	1,4	1,4	3,0
Iron(mg/dm ³)	0,26	0,16	0,13	0,1	0,05	0,03
Absorbance UV (254 nm)	0,235	0,178	0,119	0,220	0,200	0,240

Water pH and alkalinity grew and the iron content decreased with raising dose of sodium aluminate.

The reaction of sodium aluminate hydrolysis in water has the following course:



In acid and neutral environments, the aluminum hydroxide, resulting from the above reaction, creates positively charged monomers, which combine with negative colloidal particles of humus acids. The floccules produced by these processes easily undergo sedimentation and/or filtration.

Optimum dose of sodium aluminate should be within 2 and 4 mgAl/dm³. Although water turbidity and color after volumetric coagulation process exceed the acceptable values slightly, it was assumed that contact coagulation conducted with that dose may bring better results.

4.2. Study concerning coagulation contact (first stage of filtration)

Contact coagulation studies were conducted in two series.

4.2.1. Series I

Raw water with sodium aluminate in quantity of 2 mgAl/dm³ was directed to sand filter of sand grain distribution 0.5 – 1.5 mm and sand layer height 0.7 m. The rate of filtration was 6,0 m/h. Obtained results are summarized in Table 4.

Since the results achieved, i.e. reduction of color, turbidity and iron content, were insufficient, a second series of testing was carried out.

4.2.2. Series II

Raw water with sodium aluminate in quantity of 2 mgAl/dm³ was directed to sand filter consisting of the following layers:

10-cm thick supporting layer of *aquacleanit* material of grain size 2 – 4 mm,

55-cm thick layer of quartz sand of grain size 0.5 – 0.8 mm,

50-cm thick surface layer of *antracyt (anthracite)* of grain size 0.6 – 1.5 mm.

The filtration rate was 7.5 m/h. The results of this series are summarized in Table 4.

In the 2nd series water of much improved parameters was obtained. Water color and iron content exceeded the acceptable values just slightly. Still remaining higher turbidity, which was caused by magnesium-hydroxide and calcium-carbonate penetration into water. That fact was confirmed by the growth in water alkalinity and hardness. The problem of turbidity and excessive quantity of manganese, as well as a further reduction of iron and coloration, was solved by directing water from that series to a second stage of filtration.

Tab. 4. The results from contact coagulation

Wskaźnik	Seria I	Seria II
Reaction pH	6,75	8,60
Alkalinity (mval/dm ³)	0,9	Zf = 1,3, Zm = 3,4
Oxygen demend (mgO ₂ /dm ³)	1,90	1,30
Hardness (mval/dm ³)	1,70	4,0
(mgCaCO ₃ /dm ³)	85	200
Colour (Hazen)	32	17
Turbidity (NTU)	11	2,39
Iron (mg/dm ³)	1,6	0,35
Manganese (mg/dm ³)	0,14	0,15
Absorbance UV(254 nm)	0,225	0,117

4.3. Studies related to the second stage of filtration

The 2nd stage of filtration was realized on filter filled with *Defeman*, the chemically active substance mixed with quartz sand in 1:1 ratio. The height of its proper layer was 100 cm, granulation of the *Defeman* mass ranged within 0.5 – 1.5 mm, that of sand was 0.5 – 0.8 mm. The applied rate of filtration was as presently used in the SUW station, i.e. 7.5 m/h.

Please, refer to Table 5 for the results obtained after the 2nd stage of filtration.

Tab. 5. The results obtained after the 2nd stage of filtration

Index	Parameters of water after two-stage filtration
Reaction pH	8,23
Alkalinity (mval/dm ³)	2,80
Oxygen demend (mgO ₂ /dm ³)	0,70
Hardness (mval/dm ³)	3,70
(mgCaCO ₃ /dm ³)	185
Colour (Hazen)	5,0
Turbidity (NTU)	1,0
Iron (mg/dm ³)	0,16
Manganese (mg/dm ³)	0,02
Absorbance UV(254 nm)	0,101

After two-stage filtration, water met sanitary requirements in analyzed parameters.

5. Summary

Because of the complexes of iron and humus compounds, present in water as taken in, it became necessary to implement coagulation process in the technological system realized at the water conditioning station in Huta Komorowska. Sodium aluminate in doses from 2 to 4 mg Al/dm³ appeared to be the best coagulant among those tested during volumetric coagulation. The selection of that coagulant was dictated not only by good results in reducing water coloring, turbidity, iron content, oxygen demand and absorbance but also by raising water pH and alkalinity, which reduced its aggressiveness.

Classic (volumetric) coagulation, realized in open system in open system, was substituted with contact coagulation conducted in a closed system, more favorable economically and easier to automate. Because of the cost of coagulant and the quantity of sediments generated contact coagulation, lower dose of coagulant (2 mg Al/dm³) was used. The first stage of filtration (contact coagulation) shall be conducted on a three-layer filter, as described in 4.2.2 above, with filtration rate of 7.5 m/h. A filter with chemically active mass (*Defemen* + sand) should be used within the 2nd stage of filtration. The filtration should proceed at the rate of 7.5 m/h.

As the beds reach adequate operation parameters (bed impregnation with coagulant in the first stage of filtration and formation of manganese dioxide envelopes on grains in the 2nd-stage filter), the obtained results should become still better.

References

- [1] Duan J., Wang J., Graham N., Wilson F.: *Coagulation of humic acid by aluminium sulphate in saline water conditions*, Desalination 150, pp. 1-14, 2002.
- [2] Duan J., Wilson F., Graham N., Tay J.: *Adsorption of humic acid by powered activated carbon in saline water condition*, Desalination 151, pp. 53-66, 2002.
- [3] Dumat C., Staunton S.: *Reduced adsorption of calcesium on clay minerals caused by various humic substances*, Journal of Environmental Radioactivity 46, pp. 187-200, 1999.
- [4] Elfarissi F., Pefferkorn E.: *Kaolinite/humic acid interaction in the presence of aluminium ion*, Colloids and Surfaces A: Physicochemical and Engineering Aspects 168, pp. 1-12, 2000.
- [5] Granops M., Kaleta J., *Woda, uzdatnianie i odnowa*, Wyd. SGGW Warszawa 2005.
- [6] Kaleta J., *Zwiazki humusowe w srodowisku wodnym*, Rzeszów, Z.N. PRz., z. 38, str. 39-53, 2004.
- [7] Kam S.K., Gregory J.: *The interaction of humic substances with cationic polyelectrolytes*, Wat. Res. Vol. 35, No. 15, pp. 3557-3566, 2001.
- [8] Melia C., Becker W., Au K.: *Removal of humic substances by coagulation*, Wat. Sci. Tech., Vol. 40, No. 9, pp. 47-54, 1999.

- [9] Odegaard H., Eikebrokk B., Storhaug R.: *Processes for the removal of humic substances from water – an overview based on Norwegian experiences*, Wat. Sci. Tech., Vol. 40, No. 9, pp. 37-46, 1999.
- [10] Perchuć M.: *Żelazo i kwasy humusowe w barwnych wodach podziemnych*, Gaz, Woda i Technika Sanitarna 11, s. 394-397, 2003.
- [11] Smeck N.E., Novak J.M.: *Weathering of soil clays with dilute sulfuric acid as influenced by sorbed humic substances*, Geoderma 63, pp. 63-76, 1994.
- [12] Świdarska-Bróż M., *Przydatność koagulacji w usuwaniu mikrozanieczyszczeń i ich prekursorów*, Międzynarodowa Konferencja Naukowo-Techniczna „Zaopatrzenie w wodę miast i wsi” Poznań, t.I. s. 319-333, 1996,

