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Analysis of Coagulation Processes for the Groundwater Treatment

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Abstract

Coagulation process is widely used for removal of natural organic matters (NOM) and for water color intensity reduction. The efficiency of coagulation process depends on many different factors. Aim of this research is to investigate coagulation process under different conditions. During the research coagulation process was held at different pH values (5.5; 6.0; 6.5), at different water alkalinity and at different water turbidity. It was found that removal of NOM and water color intensity reduction is most effective at pH values from 5.5 to 6.0. At these conditions water color intensity reduction is most efficient, but removal of dissolved organic carbon (DOC) is the lowest. During the research it was also found that different water alkalinity and turbidity do not make significant influence on efficiency of coagulation process.

Key words: drinking water, natural organic matter, coagulation, pH, alkalinity, turbidity

1 Introduction

One of the most wide spread method of NOM removal is coagulation. This method is based on adhesion of small particles into larger particles and sedimentation. NOM removal mechanism during the coagulation process by using aluminium salts is described in three steps: charge neutralization, entrapment and absorption. The efficiency of coagulation process depends on: 1) concentration of NOM; 2) nature of organic compounds; 3) coagulation type; 4) dose of coagulant; 5) pH; 6) ionic forces; 7) duration of coagulation; 8) temperature; 9) alkalinity; 10) turbidity [1 & 2].

The most significant influence on coagulation process makes pH of water. Gregory [3] writes that to achieve efficient coagulation, water must be acidified until it reach pH 5.0. It leads to formation of soluble NOM and aluminium complexes, then coagulants must be inserted. Later it is needed to insert caustic soda to the water to increase pH until 7.0. It helps to form insoluble aluminium hydroxide flakes that catches and absorbs soluble NOM and aluminium complexes. Gregory [3] also has defined that best pH interval for soluble NOM removal and minimal residual aluminium formation is 6.0 – 7.0. Edzwald and Tobiason [4] estimated that coagulation is most efficient when pH is 5.5. However under these conditions big amount of residual aluminium are formed. Meyn and Leiknes [5] say that when powdered activated carbon (PAC) and ferric chloride are used, removal of NOM is most efficient when pH is in interval 5.0 – 6.0. But in these conditions residual aluminium and iron concentrations increase and exceed regulated norms. Lee and colleagues [6] affirm, that neutralization of negative charge of organic compounds, during the coagulation runs when pH is in interval from 4.0 to 5.5, but to form big insoluble hydroxide flakes pH must be in the interval from 6.0 – 8.0. During the research Eikebrokk [7] defined that water color intensity can be effectively reduced in pH 5.5 – 6.8. By using aluminum sulphate the optimal pH interval is 5.5 – 6.5 and using ferric chloride – 4.0 – 5.5.

Water alkalinity depends on pH and water saline. Pernitsky and Edzwald [8] determined that alkalinity makes significant influence on coagulation process. To increase alkalinity of water high base coagulants have to be used. Eikebrokk [7] says that best conditions for coagulation is when alkalinity of the water is 0,6 – 1,0 mmol/l and calcium concentration is 15 – 25 mg/l. In water with low alkalinity formation of soluble NOM and aluminium complexes is very poor. Turbidity is less important than organic compounds, pH and alkalinity. But it is hard to form big flakes when turbidity of the water is low. To reduce turbidity of the water with different concentrations of NOM it is better to use PAC with sulphate [8].

The aim of this research is to determine efficiency of coagulation process at different conditions, such as: different pH levels, low and high alkalinity levels, low and high turbidity levels.

2 Materials ant methods

Ground water from drilled wells of Nida and Preila-Pervalka wellfields was used for analysis. Water samples were collected from Nida and Preila-Pervalka wellfields water well mixture. Water samples were collected in October and November of 2011. From each sampling point there were taken 20 liters of water. Water samples were analyzed in Norwegian Science and Technology University Water chemistry laboratory. During the three day transportation water samples were kept in refrigerating containers where was maintained at fixed 5°C temperature. Nida and Preila-Pervalka wellfields are located in Curonian spit from one side they are surrounded by Baltic Sea and from other side by Curonian Sea. Preila-Pervalka and Nidos wellfields ground water quality indicators shows in 1 table.

Table 1: Preila-Pervalka and Nidos wellfields ground water quality indicators

Indicator	Preila-Pervalka	Nida
	Average (n=2)	Average (n=2)
pH	6.68±0.09	7.55±0.06
Alkalinity, mmol/l	0.81±0.056	2.17±0.07
Turbidity, NTU	50.2±0.32	4.1±0.02
DOC, mg/l	5.98±0.01	7.90±0.09
Color, mg Pt/l	22.91±0.12	33.26±1.92
UV_{254} , 1/m	0.174±0.000	0.245±0.00

2.1 Lab testing

During the research PAC was used. Two different doses of coagulant were selected: 3 mg AL/l and 5 mg AL/l. Level of pH in the samples were: 5.5; 6.0; 6.5. During the Jar test water samples were mixed for 1 min in 200 rpm then for 20 min in 40 rpm and for 20 min samples were let to settle. After the coagulation process water samples were filtrated through 0.45 μm filters and quality analysis was done.

2.2 Instrumental analysis

In Nida and Preila-Pervalka wellfields water samples following indicators were defined: water pH level, turbidity, alkalinity, color of the water, water UV absorption in 254 nm wavelength (UV_{254}) and dissolved organic compounds (DOC). Water pH was analyzed with PHM 83 Autocal pHMETER, turbidity - HACH 2100 AN IS turbidity meter, alkalinity - Metrohm 726 Titroprocessor. For determination of water color, UV absorption and dissolved carbon water samples were filtrated through 0.45 μm membrane filters. Water color was measured in 5 cm cell with 436 nm wavelength Hitachi U-3000 Spectrophotometer. Total organic carbon and dissolved organic carbon was measured with organic carbon analyzer Tekmar Dohrmann Apollo 9000 (USA).

3 Results and discussion

The most significant influence on coagulation process - makes water pH level. Therefore three water pH levels were selected: 5.5; 6.0; 6.5. Defferent scientists offer various pH intervals for efficient coagulation. Mostly given pH interval is 5.0 – 7.0. However, residual aluminium forms when aluminum salts is applied to the water. According to many scientists, insoluble aluminium hydroxide flakes forms when water pH level is 6.0 – 7.0. Two different PAC doses were used for coagulation process (3 and 5 mg AL/l) (Figure 1, 2, 3 and 4).

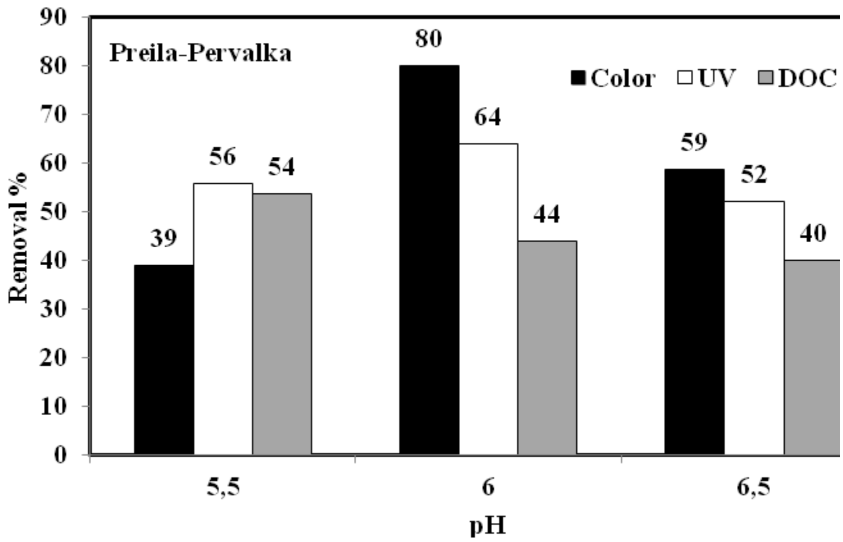

Figure 1: Water color and NOM removal during the coagulation process by using 3 mg AL/l coagulant dose in different pH levels Preila-Pervalka wellfield

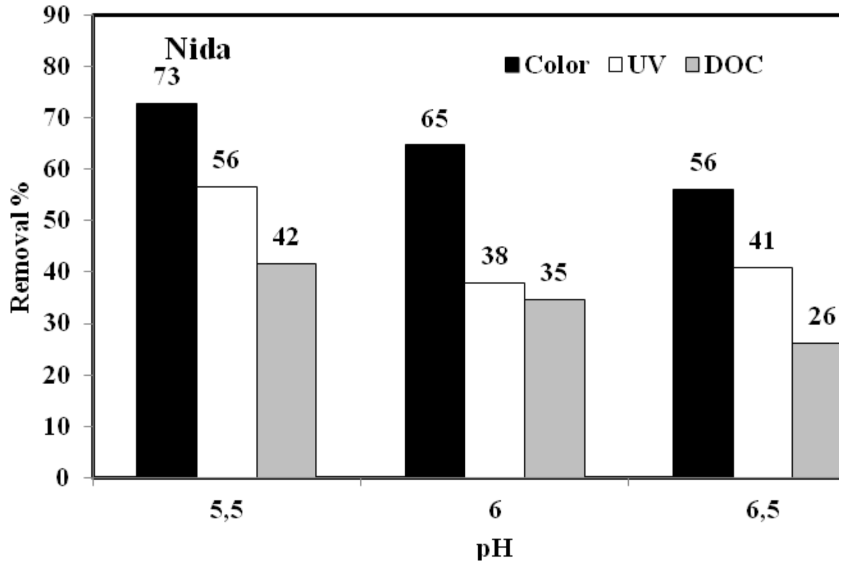

Figure 2: Water color and NOM removal during the coagulation process by using 3 mg AL/l coagulant dose in different pH levels Nida wellfield

After coagulation and filtration water samples were analyzed to assess DOC, water color and UV_{254}. Analysis showed that reduction of water color and UV_{254} is most efficient in Preila-Pervalka wellfields water samples when coagulation process is held in water with pH level 6.0, whereas DOC concentration is mostly reduced when water pH is 5.5. In certain case water color was removed for 80%, UV_{254} for 64% and DOC for 54%. It can be said, that during the coagulation water color intensity is reduced mostly. Water becomes colored because of humic acids which are mainly composed of aromatic compounds [9 & 10]. Therefore it can be said that dominating compounds in the water are hydrophobic aromatic compounds with high molecular weight which are easily removed from the water during coagulation process. According to the results of dissolved organic carbon analyses, when during the coagulation only 50% of organic carbon was removed, it can be said that water contains not only hydrophobic aromatic compounds with high molecular weight but also different organic matter (e.g. short-chain aliphatic organic compounds). Water color intensity is mostly reduced when water pH level is 5.5 whereas DOC concentration after coagulation remains highest when pH is 6.5. During the research of coagulation process efficiency in different water pH levels it was defined that the best results during the removal of NOM and reduction of water color intensity and UV_{254} in Preila-Pervalka wellfields were achieved at water pH level 6.0.

During the coagulation analysis on Nida wellfield ground water samples it was observed that reduction of water color intensity, UV_{254} and removal of DOC concentration increase when pH level decrease. The best efficiency was reached at water pH level 5.5. In these conditions water color intensity reduction was highest and reached 73%, DOC removal was lowest and reached 42%.

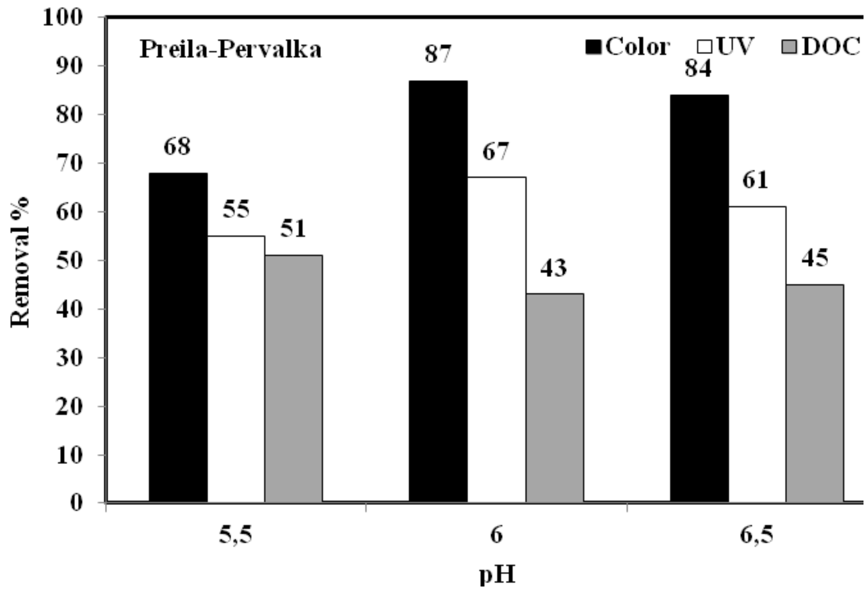

Figure 3: Water color intensity and NOM removal efficiency during the coagulation process by using 5 mg AL/l coagulant doses in different pH levels Preila-Pervalka wellfield

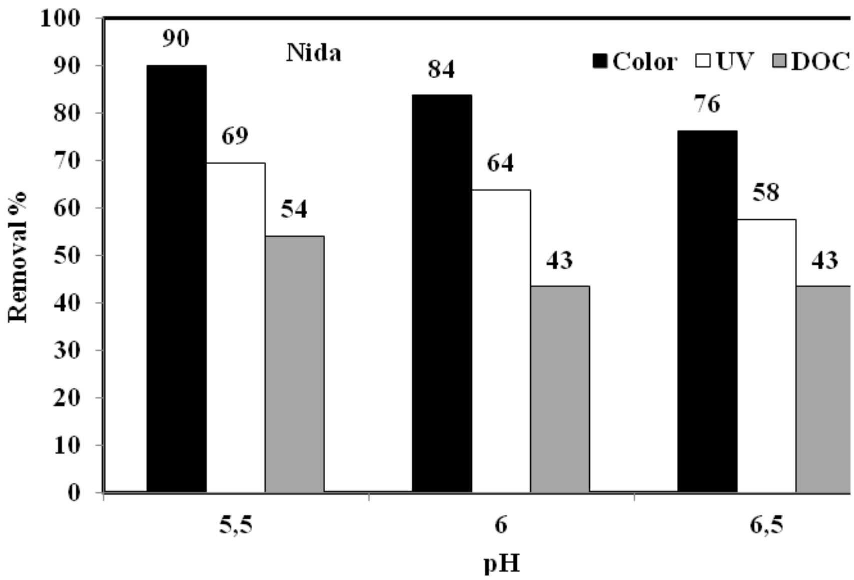

Figure 4: Water color intensity and NOM removal efficiency during the coagulation process by using 5 mg AL/l coagulant doses in different pH levels Nida wellfield

As coagulant dose increased from 3 mg AL/l to 5 mg AL/l reductions of water color intensity and UV_{254} and DOC removal efficiency increased in both Preila-Pervalka and Nida wellfields water samples. Water color reduction efficiency increased from 80% to 87% (samples from Preila-Pervalka) and in Nida wellfield samples from 73% to 90%. Best water color reduction efficiency in Preila-Pervalka water samples was achieved when pH of water was 6.0 and in

Nida – pH 5.5. UV_{254} reduction also increased from 64% to 67%. By using higher concentration of coagulant in Preila-Pervalka water samples DOC concentration increased for 3% but Nida water samples cleaning efficiency increased from 42% to 54%.
In both cases coagulation process is most efficient when water pH is 5.5 – 6.0, however formation of residual aluminium was not investigated in certain research. In purpose to choose best dose of coagulant it must be considered that lower dose is more appropriate since removal efficiency don't have significant difference. But with lower coagulant doses residual aluminium formation can be avoided and it is more efficient in economical aspect.

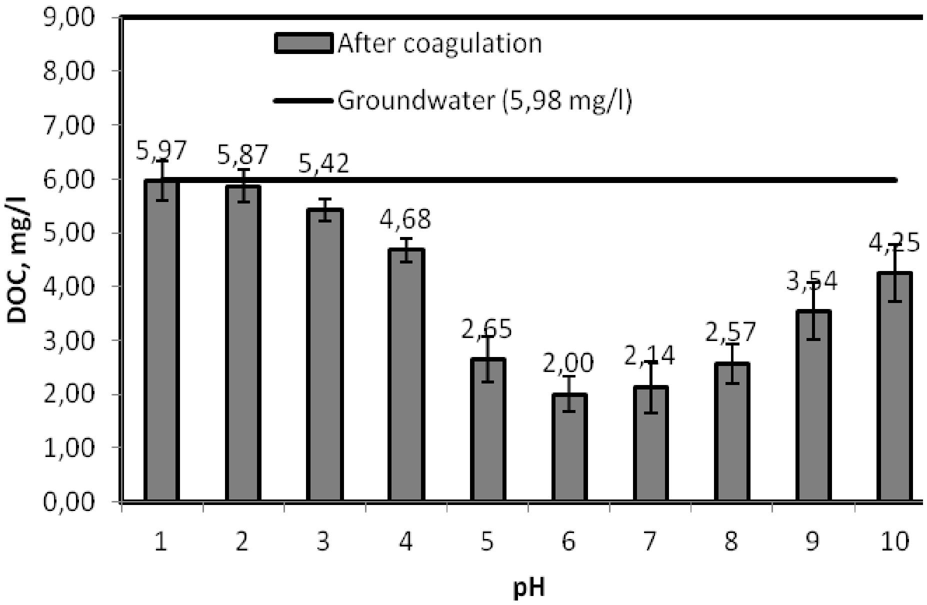

Figure 5: The effect of water pH on DOC change

While water pH increases from pH 2.0 to pH 11.0 the permanganate index decreases until the water pH reach 7.0. From this value DOC start to increase repeatedly. This is explained by the fact that in acidic environment, when water pH is less then 5.0 and in alkaline environment, when water pH is greater that 8.0 almost all aluminum hydroxide change to ion form. These conditions are unfavorable for coagulation and adsorption processes. The biggest decrease of DOC is observed when water pH is in the range from 6.0 to 8.0. A comparison of the research results with similar studies performed by other author's shows similar boundaries of pH values (from 6.0 to 7.0). These studies confirm that effective coagulation process requires proper water pH values. The better water pH values are regulated the better conditions for insoluble flakes formation is created. And as the result the bigger amount of organic matter is removed and water color intensity is reduced effectively.
It is known that alkalinity makes influence of coagulation process. Coagulation is more efficient in more alkaline water. During the research efficiency of coagulation process was compared in water samples with different alkalinity. Water alkalinity is higher in Nida wellfield water samples (2.17 mmol/l) as in Preila-Pervalka it is only 0.66 mmol/l. Water turbidity is less important than alkalinity. However it is hard to form big flakes during the

coagulation process when water turbidity is low. Turbidity in Nida wellfield water samples is quite low (4.1 DV) but in Preila-Pervalka samples is high (50.2 DV). Figure 3 shows the comparison of water samples after coagulation when water pH is 6,0 and coagulant dose is 5 mg AL/l.

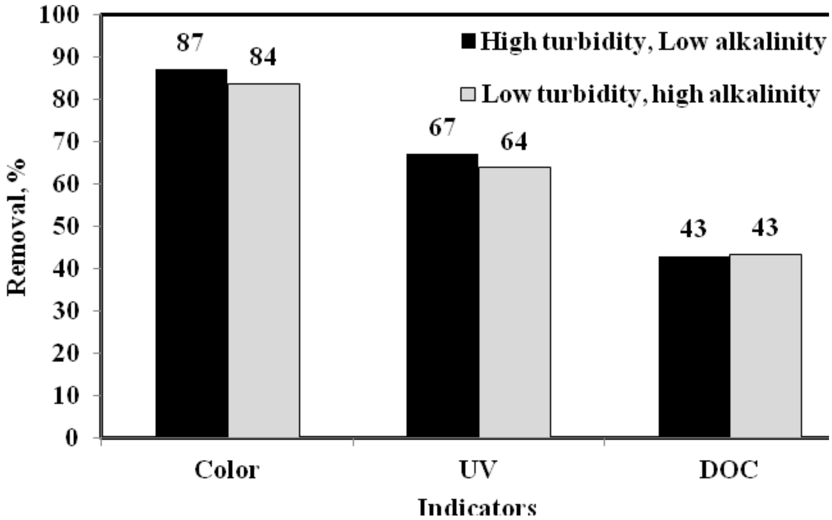

Figure 6: Water color intensity, UV absorption and dissolved organic carbon removal efficiency in different water alkalinity and turbidity.

By comparing different quality water samples when Nida wellfield water is more alkaline and less turbid while Preila-Pervalka water is less alkaline and very turbid it can be said that efficiency of coagulation process is the same by removing NOM, and reducing water color intensity and UV_{254}.

When water is more turbid and less alkaline reduction of water color intensity and UV_{254} during coagulation process is more efficient only for 3%. Removal efficiency of DOC is the same in both samples.

4 Conclusion

1. The research of coagulation process under different conditions by changing coagulant doses and pH was observed effective reduction of water color intensity and low reduction of DOC concentration. Coagulation process had shown that the most effective reduction of DOC, water color intensity and UV_{254} is when chosen doses of coagulant are 5 mg AL/l.

2. Change of coagulation conditions and water pH makes the effect on DOC, UV and water color intensity reduction efficiency. By using both doses of coagulant in Nida water the most efficient reduction of DOC, UV and water color intensity was reached when pH of the water was 5.5, however in Preila water successful reduction effect was observed when pH of

the water reached 6.0. During analysis pH range was from 1 to 10. The biggest decrease of DOC concentration was observed at water pH from 5 to 8.

3. The research of coagulation process had shown that water alkalinity and turbidity do not make influence on coagulation process.

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