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PILOT SCALE EVALUATION OF PREOZONATION FOR TALLINN DRINKING WATER TREATMENT

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Abstract. The prechlorination stage at the Tallinn Water Treatment Plant will be replaced by preozonation in 1995. The purpose of the pilot plant tests was to determine the best operating conditions for the preozonation stage to obtain the minimum colour, turbidity, and algae content in the treated water. The optimum preozone doses depending on the season were determined.

Key words: lake water; preozonation; colour, turbidity, and algae removal.

INTRODUCTION

The Tallinn Water Treatment Plant was built in 1927 by the British Company W. Patterson Engineering Co Ltd and it processed 24 000 m^3/d of the Lake Ülemiste water at that time. After World War II the plant has been reconstructed several times. In 1979 a new plant was put into operation, which increased the capacity up to 225 000 m^3/d. In 1993 the total drinking water production in Tallinn was 236 600 with 201 600 m^3/d processed at the Tallinn Water Treatment Plant. In recent years several technological problems have risen due to the significant worsening of the raw water quality. In summer, the raw water has been highly algae-loaded and bacteriologically polluted. In 1988, phenols and the stems of the vaccine of poliovirus were for the first time determined in raw lake water. Later, in 1991–92, the poliovirus was also identified in drinking water that totally met the existing standards in other respects.

The water treatment process at the Tallinn Plant consists of microscreening, prechlorination, coagulation, flocculation, clarification, granulated activated carbon–sand filtration, and postchlorination. To prevent infectious diseases and to destruct algae cells, enhanced doses of prechlorine (up to 8–10 g/m^3) have been used. This has led to a higher content of trihalomethanes in drinking water (up to 0.1–0.2 mg/l). The necessity for improving the quality of drinking water became evident already several years ago. This aim can be reached by replacing prechlorination by preozonation. To find out the impact of ozone on the Lake Ülemiste raw water quality parameters and to establish the ozone consumption of lake water, laboratory and pilot plant studies have been carried out by the Chemical Engineering Department of the Tallinn Technical University since 1960. Extended pilot plant tests were carried out in spring and summer 1991. The tests enabled to study the coimpact of ozonation, coagulation, flocculation, clarification, and filtration on drinking water quality in dynamic conditions, to establish the optimum doses and places of the introduction of reagents, and to find confirmation for the results of laboratory experiments [1].

PILOT PLANT DESCRIPTION AND EXPERIMENTAL

The pilot plant designed to simulate the full-scale water treatment process comprised preozonation, coagulation–flocculation, clarification, and filtration stages. The layout is shown in Fig. 1. The dimensions of equipment and process parameters are given in Table 1.

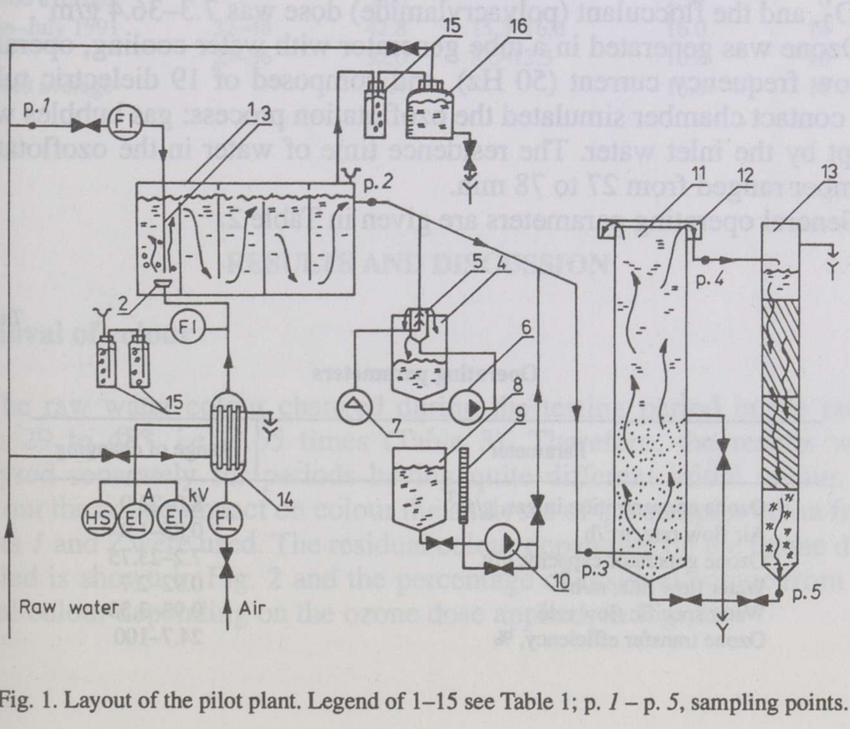

Fig. 1. Layout of the pilot plant. Legend of 1–15 see Table 1; p. *1* – p. *5*, sampling points.

Table 1

Characteristics of the pilot plant

Position	Designation	Parameter
1	Ozoflotator	$V = 1.2\ m^3$
2	Gas diffuser	$d = 230$ mm; $\Phi = 20\ \mu$ m; porous surface $0.29\ m^2/m^2$
3	Water pipe	$d = 10$ mm
4	Coagulant reservoir	$V = 40$ l
5	Air-lift	
6	Circulation pump LR-40	
7	Microcompressor	$Q = 1.5$ l/min
8	Flocculant reservoir	$V = 40.0$ l
9	Burette	$V = 50.0$ ml
10	Swirl pump	$Q = 0.12$ l/min
11	Sludge blanket clarifier	$D = 0.84$ m; $H = 6.0$ m
12	Water collector	
13	Three-layer filter	$D = 0.2$ m; $H = 6.0$ m
14	Ozone generator	19 tubes; $I = 250$ A; $U = 9.0$ kV
15	Bubble columns	$V = 0.5$ l
16	Tubus-bottle	$V = 4.0$ l

The tests were performed using Lake Ülemiste raw water after microscreening and prechlorination, the flow rate was 0.9–2.7 m^3/h. The coagulant (aluminium sulphate) dose was in the range of 5–22.8 g/m^3 Al_2O_3, and the flocculant (polyacrylamide) dose was 7.3–36.4 g/m^3.

Ozone was generated in a tube generator with water cooling, operating on low frequency current (50 Hz), and composed of 19 dielectric tubes. The contact chamber simulated the ozoflotation process: gas bubbles were swept by the inlet water. The residence time of water in the ozoflotation chamber ranged from 27 to 78 min.

General operating parameters are given in Table 2.

Table 2

Operating parameters

Parameter	Range of changing
Ozone concentration in gas, g/m^3	8.0–23.0
Air flow rate, m^3/h	0.85–1.9
Ozone generator capacity, g/h	7.2–23.75
Water flow rate, m/h^3	0.92–2.7
Water specific flow rate	0.93–3.33
Ozone transfer efficiency, %	24.7–100

After reaching the steady-state conditions samples were taken from five different points: *1* – initial water, *2* – the outlet of ozonation chamber, *3* – coagulated and flocculated water, *4* – clarified water, and *5* – filtrated water (Fig. 1).

The samples were analysed in the laboratory of the Water Treatment Plant using the established methods for colour, turbidity, biomass, and algae content measurements.

As the determination of the two last parameters was time-consuming, the analyses were carried out only with samples from points *1*, *2*, and *5*. Colour and turbidity were determined in all samples.

During the testing period (March–July 1991), the initial parameters of the raw lake water changed in a rather wide range. The physical parameters of raw lake water are given in Table 3. The biomass and the algae species content after and before ozonation are given in Table 4.

Table 3

Water parameters

Time period	Colour, °		Turbidity, mg/l		Temp., °C
	Range	Average	Range	Average	
March–April 1991	36–41	38.5	1.2–2.6	1.76	5
	32–43	37.5	1.9–5.0	3.38	7
Period average		38.0		2.57	6
June–July 1991	32–48	42.8	15.3–16.6	16.0	14
	29–36	32.0	8.0–13.3	10.0	18
Period average		37.4		13.0	16

RESULTS AND DISCUSSION

Removal of colour

The raw water colour changed during the testing period in the range from 29 to 48°, i.e. 1.65 times (Table 3). Therefore, the results were analysed separately for periods having quite different initial colour. To find out the ozone impact on colour the analyses of the samples taken from points *1* and *2* were used. The residual colour depending on the ozone dose applied is shown in Fig. 2 and the percentage of residual colour from the initial colour depending on the ozone dose applied, in Fig. 3.

Table 4

Removal of biomass and different algae species by ozonation

O_3 dose, mg/l	Biomass			Diatomite			Green			Blue			Flagellate		
	before, mg/l	after, mg/l	reduction, %	before, mg/l	after, mg/l	reduction, %	before, mg/l	after, mg/l	reduction, %	before, mg/l	after, mg/l	reduction, %	before, mg/l	after, mg/l	reduction, %
20.0	6.48	3.41	47.3	0.78	0.15	80.5	1.05	0.66	38.6	4.61	2.61	43.5	0.09	0.04	54.0
10.24	11.45	5.53	53.4	0.87	0.79	9.5	2.63	1.20	54.2	7.87	3.30	58.1	0.08	0.04	50.6
21.90	9.42	8.88	5.7	1.35	0.97	17.9	1.36	1.06	21.6	6.67	6.79	0	0.04	0.05	0
21.70	10.30	6.81	33.4	1.83	1.82	0	2.58	1.06	58.8	5.81	3.92	32.5	0.07	0.04	40.0
9.26	8.22	5.59	34.0	0.74	0.49	33.4	0.84	0.65	22.9	6.60	4.41	33.2	0.04	0.036	5.3

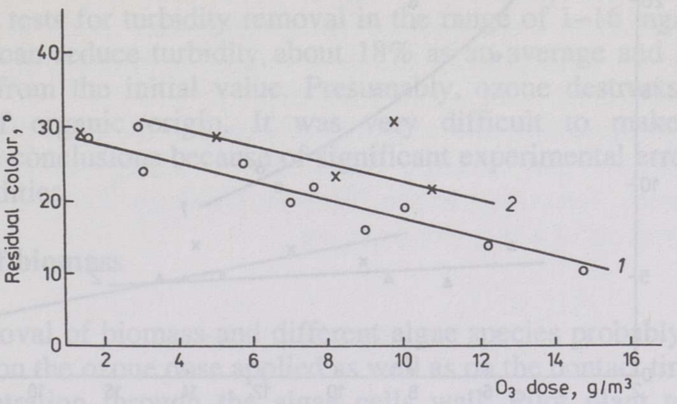

Fig. 2. Colour reduction versus ozone dose applied; average initial colour 38° (*1*) and 43° (2). *1* – March–April 1991 (turbidity 1.8–3.4 mg/l); 2 – June–July 1991 (turbidity 10–16 mg/l, biomass 9.4–11.45 mg/l).

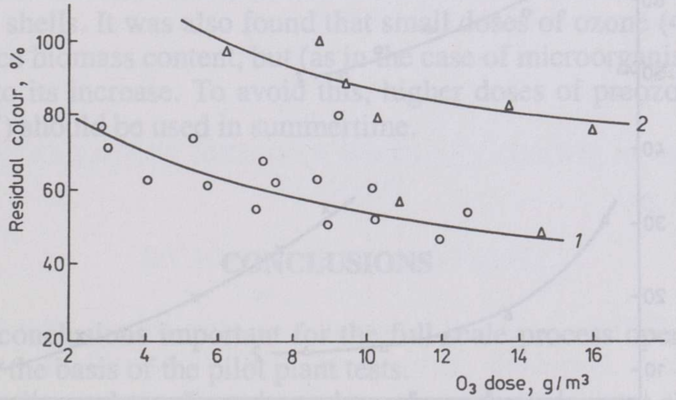

Fig. 3. Residual colour versus ozone dose applied. Legend see Fig. 2.

The ozone impact is quite clear, and so is its consumption by the biomass resulting in a lower colour reduction (curves *1* and *2* in Fig. 3). Thus, to reach a higher colour reduction, preliminary removal of algae biomass is required. It can also be seen that ozone can reduce colour by 20–50% and more, resulting in a final colour degree of about 10. The ozonated and floated water underwent coagulation with aluminium sulphate. The dose applied was 15–20 g/m^3 Al_2O_3. This was the optimum dose of the coagulant for the raw water during the testing period. The summary impact of ozonation and coagulation on colour was expressed, as before, by the residual colour degrees and the residual colour percentage versus the ozone dose applied (Figs. 4, 5).

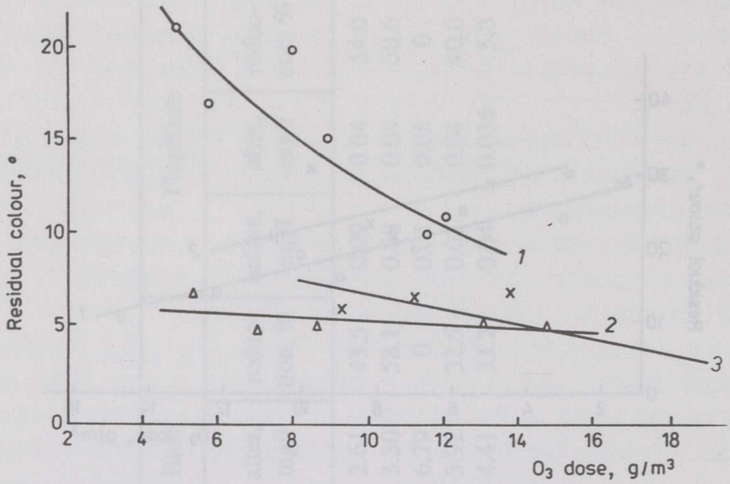

Fig. 4. Colour reduction versus ozone dose applied together with coagulation: *1* – initial colour 38°, turbidity 1.6 mg/l, Al_2O_3 dose 18 mg/l; *2* – initial colour 38°, turbidity 3.2 mg/l, Al_2O_3 dose 24 mg/l; *3* – initial colour 32°, turbidity 9.6 mg/l, Al_2O_3 dose 14.4 mg/l.

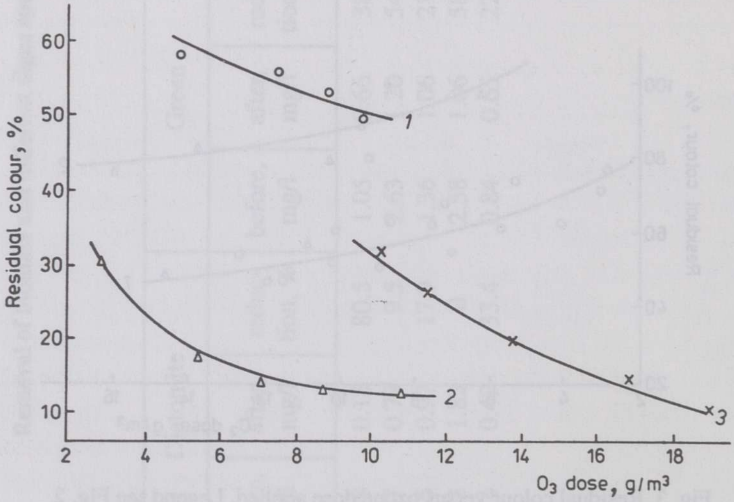

Fig. 5. Residual colour versus ozone dose applied at Al_2O_3 doses 18 (*1*), 24 (*2*), and 14.4 mg/l (*3*). Other conditions see Fig. 4.

The curves in Fig. 4 indicate that the colour of low-turbidity water is mainly reduced by ozone. In case of higher turbidity, the role of the coagulant becomes more dominant in colour reduction. This is clearly demonstrated in Fig. 5, curves *1* and *2*, which were received as a result of the coagulation of water with relatively low turbidity using different doses of the coagulant. Consequently, preozonation will be very effective, especially in wintertime, at high colour, low turbidity, and low temperature. Under these conditions, the coagulation proceeds very slowly and is not suitable for colour reduction.

Removal of turbidity

Separate tests for turbidity removal in the range of 1–16 mg/l showed that ozone can reduce turbidity about 18% as an average and 30% as a maximum from the initial value. Presumably, ozone destructs first the turbidity of organic origin. It was very difficult to make definite quantitative conclusions because of significant experimental errors at low initial turbidities.

Removal of biomass

The removal of biomass and different algae species probably depends essentially on the ozone dose applied as well as on the contact time for the ozone penetration through the algae cells wall. Pilot plant tests were performed in June–July 1991 with ozone doses in the range of 9.3–22.0 g/m^3 applied. The ozone transfer efficiency was 52–83%. Samples were taken from points *1* and *2* (i.e. before and after ozoflotation). The results are summarized in Table 4.

The total biomass content was removed by 54%, and different algae species as follows: diatomite – 33%, green – 59%, blue – 58%, and flagellate – 54%. The most resistant towards ozone are diatomite algae with strong shells. It was also found that small doses of ozone (4–6 g/m^3) do not reduce biomass content, but (as in the case of microorganisms) even contribute to its increase. To avoid this, higher doses of preozone (up to 20–22 g/m^3) should be used in summertime.

CONCLUSIONS

Several conclusions important for the full-scale process operation can be made on the basis of the pilot plant tests.

1. The optimum dose of preozone depends on the raw water quality and should be in the range of 6–25 g/m^3.

2. The optimum preozone dose depends also on the basic water quality parameters. If one takes the algae content as a basis, the preozone dose should be 20–25 g/m^3.

3. Turbidity as a summarized parameter for inorganic and organic floating material in water cannot be wholly relied on. The use of chemical oxygen demand can be suggested. On its basis the optimum preozone dose is in the range of 6–10 g/m^3.

4. Reducing colour below 20° with ozone only is economically ineffective.

5. Applying the scheme preozonation–coagulation–clarification–filtration, it is possible to reduce the colour of water by 80–90% and achieve the residual colour of 5–10°.

6. Preozonation is the most effective method for clear cold water where coagulation is not satisfactory, i.e. under winter conditions.

7. Preozonation with doses of 10–20 g/m^3 can reduce the biomass content by 50% having nearly the same impact on different algae species, except for diatomite, which is very resistant.

8. The preozonation and coagulation stages in the pilot plant scheme were so effective that filtration almost did not change the water quality data any more. According to the Estonian Drinking Water Standard, the treated water was of a very good quality.

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TALLINNA JOOGIVEE EELOSOONIMISE TEHNOLOOGILINE HINNANG

Hilja LOORITS, Rein MUNTER

Seoses Tallinna joogivett puhastava osoonimisjaama käikulaskmisega 1995. aastal korraldati kevadsuvel 1991 tööstuslikku tehnoloogiat imiteerivad pooltööstuslikud katsed. Katseseade koosnes eelosoonimise, koagulatsiooni-flokulatsiooni, selitamise ja filtrimise aparaatidest. Katsete eesmärk oli määrata optimaalsed tööparameetrid, et tagada värvuse, hägususe ja biomassi näitajate maksimaalne alanemine minimaalse eelosooni annuse juures. Katsete tulemusel määrati erinevatel aastaaegadel vajalikud eelosooni annused ja osooni toime planktoni eri liikidele.

ПИЛОТНЫЕ ИСПЫТАНИЯ ПРЕДОЗОНИРОВАНИЯ ПИТЬЕВОЙ ВОДЫ В ТАЛЛИННЕ И ИХ ОЦЕНКА

Хилья ЛООРИТС, Рейн МУНТЕР

В 1995 г. на Таллиннской водоочистной станции предхлорирование воды будет заменено ее предозонированием. В связи с этим весной-летом 1991 г. были проведены пилотные

испытания, имитирующие заводской технологический процесс. Предложенная схема включала стадии предозонирования, коагуляции-флокуляции, осветления и фильтрации. В результате испытаний были установлены наилучшие технологические условия, позволяющие довести показатели цветности и мутности воды, а также содержание в ней планктона до минимума, и определены оптимальные дозы озона в зависимости от сезона.