ANALYSIS AND ASSESSMENT OF TECHNOLOGICAL PROCESSES OF THE MIEDWIE LAKE SURFACE WATER TREATMENT PLANT FOR THE CITY OF SZCZECIN

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Abstract

Miedwie Lake is the biggest post-glacial lake of the West-Pomeranian Voievodship. At the same time it is the fifth of the largest lakes in Poland. As regards the geographical situation, Miedwie Lake is situated centrally between three big agglomerations i.e. Szczecin, Stargard Szczeciński and Pyrzyce (Fig. 1). The lake lies on the territory of three municipalities: Pyrzyce and Warnice in the District of Pyrzyce as well as Stargard Szczeciński in the District of Stargard (Rozmiarek 1983, Szyper 1990).
At the moment, the reservoir is characterised with the regular, prolonged shape resembling an ellipse. Banks are shallow, regular and sometime very wet. The lake has the belt of the nearshore reaching locally tens metres far from the lake bank, what is the reason, together with the fact that

Fig. 1. Bird's-eye view of Miedwie Lake

the wind blows always here, that it is convenient for practising the various kinds of water sports. The lake area amounts to 3 527 ha; maximal depth – 43.8 m; average depth – 19.3 m; water capacity – 681.7 mln m^3; shore-line length – 38.8 km; water level datum 14.1 m above sea level; maximal width 3.16 km; maximal length 16.2 km.
The lake's bottom is the lowest situated area on the territory of Poland.

Key words: Miedwie Lake, lake's tributaries, protection zones

CHARACTERISTICS OF TRIBUTARIES OF MIEDWIE LAKE

Płonia River – outflows from Uklejno Lake, situated close to Barlinek City. The river's length amounts to 76.0 km. First tributary of Płonia River is Barlinecki Channel with length of 25.0 km.
Ostrawica River – the river's length amounts to 3.5 km, and the river basin covers the area of 319.2 km.
Miedwianka River – the river's length amounts to 5.0 km, and the river basin covers the area of 42.9 km. Miedwianka inflows to Miedwie Lake close to the locality of Morzyczany, situated in its North-West part.
Gowienica River – the river's length amounts to 21.0 km, and the river basin covers the area of 60.0 km. The River inflows into Miedwie Lake in the area of the locality of Wierzchląd, situated at its Eastern bank.
Miedwie Lake is used since 1976 as the potable water source for the City of Szczecin. The reservoir is used not only to the municipal purposes, but also for fishing, tourist and recreation purposes.
On the territory of the lake are caught many species of the fish within the frame of the fishing industry. They are the following fish: whitefish, vendace, eel, pike, pikeperch, perch, bream, roach, etc.
The lake makes also possible to practise the water sports such as: windsurfing, kayaking, yachting; the courses and camps in diving are organised too.

MIEDWIE LAKE POLLUTION SOURCES

"Miedwie" water intake was made in 1976. At that time the lake's water was classified in the first class of purity (Rozmiarek 1983). However the water quality has become deteriorated already after the operational use of the intake having been started, reaching finally the level of the third purity class. The reason was the absence of the sewage treatment plant and the State Farms. The reservoir pollution resulted in the mass fish mortality (Miedwie Whitefish), hydrogen sulfide appeared at the bottom, the algae has massively bloomed (Szyper 1990). Further deterioration of the lake water condition threatened that the water intake would be closed and the biological life would be destroyed in the reservoir and around it as well.
The lake's water quality fall was caused by few factors:
agriculture, Russian military camp in Kluczewo, tourism, tributaries of the Lake, bio-manipulation of the Miedwie waters.

Fig. 2. Indirect sanitary protection zone

SANITARY PROTECTION ZONE

Direct protection zone.
The water intake composed of the intake point, pipelines and pumping station P1 with the access road as well as the territory of the water treatment plant situated in the distance of about 2 km from the water intake. Those areas, with the fragment of the lake in the radius of 400 m from the intake point, are the territory of the direct protection of the water intake (Szyper 1990).
Indirect protection zone.
The indirect protection zone, because of its large dimensions, has been divided into two sub-zones with the differentiated protection requirements:
A – with the sharpened regulations;
B – with the softened bans and limitations.
Sub-zone A covers in the water part: Miedwie Lake (except of the part covered by the direct protection zone), Płonia River, on the section between Płoń and Miedwie Lakes, as well as Płoń Lake, left-bank tributary of Płonia River – Młyński Channel on the section from Pyrzyce to the mouth, estuarial section of Ostrowica River with Będgoszcz Lake, Miedwianka and Gowienica Rivers from their riverheads to the estuary.

In the land part, it is composed of the lands around Miedwie Lake (approximately, the direct basin area except of the territories covered by the direct protection zone) as well as around the other lakes and streams (the belt 200 m wide) (Fig. 2).

Borders of the sub-zone A run generally on roads, what is very important for its administrative determination in the field. They cross a number of localities situated around Miedwie Lake among others: Żelewo, Nieznań, Bielkowo, Jęczydół, Kobylanka, Mataniec, Lipnik, Okunica, Brzezin, Młyny, Giżyn.

The sub-zone B covers the other part of the lake's basin.

LOCATION OF THE WATER TREATMENT PLANT

"Miedwie" Water Treatment Plant is composed of the water intake with the pumping station P1 situated on the Western bank of the lake, nearby the Northern border of Żelewo village, Municipality of Stare Czarnowo, as well as the water treatment plant in the locality of Nieznań, Municipality of Stare Czarnowo (Fig. 3).

Fig. 3. Miedwie Lake surroundings

TECHNOLOGICAL FLOW CHART OF THE WATER TREATMENT PLANT

Main technological line is one system, and for the further considerations it shall be divided into sections (Heidrich 1986, Justatowa and Wiktorowski 1980):
intake point – pumping station P1; pumping station P1 – coagulation; coagulation – filters; filters – Miedwie tank; Miedwie tank – Pomorzany tank.

CHANGES OF PARAMETERS OF THE RAW AND CLEAN WATER IN MIEDWIE LAKE WATER TREATMENT PLANT WITHIN THE SPECIFIED PERIOD

On the Miedwie water treatment plant is situated the laboratory in which are made the tests of all parameters of the raw and clean water, as well as measurements of the pollutant's contents in the lake, in the intake point section on the depths of 0, 6, 12, 18, 20 m as well as the water testing in the tributaries of Miedwie Lake. The specified examinations are made as: daily testing, weekly, monthly and quarterly testing.
The results presented below are based on the testing performed in week intervals. However the selected months present the change of pollutants' parameters during the year and correspond to the quarters of the year.
The presented results describe the years 1998, 1999, 2000 and 2004. Years 2001--2003 were not taken into account, since in those years were performed the works connected with the replacement of the bed in the rapid filters and the data concerning the water parameters for that period could be misleading. Below are presented the means used for the water treatment in the specified testing days. Comparing the testing results depending on the means used we could observe their efficiency in the water treatment process at ZPW Miedwie (tables 1, 2, 3, 4).

Table 1

Characteristic parameters of raw and clean water data relating to 1998

Date	Water	Temp [^{o}C]	B [mg/l]	pH	Zas [mval/l]	Utl [mg/l]	Cl' [mg/l]	CHZT [mg/l]	CO$_2$agr [mg/l]
1	2	3	4	5	6	7	8	9	10
4/03/98	raw water	2.7	12.0	8.3	2.5	6.1	46.5	21.8	0
	clean water	3.0	8.0	8.0	2.4	5.3	47.0	17.2	0
10/03/98	raw water	3.0	12.0	8.2	2.5	6.3	46.0	21.8	0
	clean water	3.2	8.0	7.9	2.4	5.6	48.0	20.0	0
18/03/98	raw water	-	12.0	8.3	2.5	6.6	44.5	22.6	0
	clean water	-	8.0	8.0	2.4	5.7	46.5	21.5	0
25/03/98	raw water	3.8	12.0	8.5	2.6	6.3	45.0	22.6	0
	clean water	3.3	8.0	8.1	2.5	5.3	47.0	21.8	0

1	2	3	4	5	6	7	8	9	10
5/05/98	raw water	6.3	13.0	8.4	2.6	6.8	45.5	22.6	0
	clean water	5.9	4.0	7.2	2.1	3.7	47.0	17.1	11.0
12/05/98	raw water	7.5	14.0	8.5	2.6	7.0	45.0	16.8	0
	clean water	7.2	5.0	7.3	2.1	4.1	46.5	14.4	11.0
20/05/98	raw water	7.5	13.0	8.4	2.6	6.2	46.0	27.9	0
	clean water	6.7	4.0	7.2	2.1	3.9	47.0	20.9	13.2
27/05/98	raw water	7.4	14.0	8.3	2.7	6.6	43.5	25.8	0
	clean water	7.0	4.0	7.2	2.1	4.0	45.5	18.6	11.0
4/08/98	raw water	7.5	12.0	7.6	2.7	6.6	47.5	25.6	0
	clean water	9.9	8.0	7.5	2.6	5.3	47.0	23.8	0
11.08.98	raw water	7.5	14.0	7.8	2.7	6.6	45.0	20.8	0
	clean water	9.3	9.0	7.6	2.6	5.6	47.0	18.4	2.2
19/08/98	raw water	8.0	12.0	7.6	2.7	7.0	45.5	21.1	0
	clean water	8.6	8.0	7.5	2.6	5.2	46.5	18.6	2.2
26/08/98	raw water	8.0	12.0	7.6	2.7	6.2	46.0	24.7	0
	clean water	9.0	8.0	7.5	2.6	5.1	47.0	17.5	0
3/11/98	raw water	8.4	13.0	8.2	2.5	6.6	46.0	22.0	0
	clean water	9.0	8.0	7.8	2.4	5.8	50.0	20.3	0
17/11/98	raw water	6.9	12.0	8.1	2.5	6.5	46.5	21.6	0
	clean water	7.3	8.0	7.8	2.4	5.7	48.0	19.4	0
25/11/98	raw water	5.0	12.0	8.2	2.6	6.7	46.0	25.4	0
	clean water	5.8	8.0	7.9	2.5	5.6	47.5	23.0	0

Table 2

Characteristic parameters of raw and clean water data relating to 1999

Date	Water	Temp [°C]	B [mg/l]	pH	Zas [mval/l]	Utl [mg/l]	Cl' [mg/l]	CHZT [mg/l]	CO_2agr [mg/l]
1	2	3	4	5	6	7	8	9	10
3/03/99	raw water	1.0	13.0	7.9	2.7	6.8	48.0	22.7	0
	clean water	1.4	8.0	7.7	2.6	5.4	48.5	18.0	0
9/03/99	raw water	1.5	12.0	8.0	2.6	6.3	49.0	23.6	0
	clean water	1.8	8.0	7.8	2.5	5.5	50.0	21.7	0
17/03/99	raw water	1.2	13.0	8.0	2.8	6.6	49.0	20.6	0
	clean water	1.9	9.0	7.7	2.7	5.5	50.5	18.5	0
24/03/99	raw water	2.7	12.0	8.1	2.8	6.6	49.0	22.8	0
	clean water	2.2	8.0	7.8	2.7	5.6	50.5	19.8	0

1	2	3	4	5	6	7	8	9	10
4/05/99	raw water	6.2	13.0	8.2	2.9	6.0	46.5	22.9	0
	clean water	5.5	4.0	7.8	2.7	5.6	50.0	19.8	0
11/05/99	raw water	7.1	14.0	8.2	2.8	6.5	48.5	23.8	0
	clean water	6.0	3.0	7.7	2.7	5.1	50.0	19.4	0
19/05/99	raw water	8.5	13.0	8.2	2.8	7.0	46.0	22.5	0
	clean water	8.0	4.0	7.7	2.7	5.1	47.5	18.9	0
26/05/99	raw water	7.0	14.0	8.1	2.8	7.0	48.0	16.5	0
	clean water	6.2	1.0	6.9	2.3	4.2	49.0	12.3	11.0
3/08/99	raw water	7.8	13.0	7.7	2.9	6.4	47.5	22.9	2.2
	clean water	7.6	2.0	6.9	2.4	3.8	50.0	18.1	8.4
10/08/99	raw water	7.7	13.0	7.6	2.9	6.5	48.0	22.3	0
	clean water	7.9	3.0	7.5	2.7	4.8	51.0	19.7	2.6
18/08/99	raw water	8.1	13.0	7.7	2.9	6.4	47.0	18.2	0
	clean water	7.9	3.0	7.5	2.7	4.4	50.0	15.0	1.8
25/08/99	raw water	7.9	14.0	7.7	3.0	7.0	46.5	20.6	0
	clean water	7.8	5.0	7.3	2.8	5.3	49.5	18.1	2.7
2/11/99	raw water	10.6	13.0	8.0	2.5	7.0	46.0	18.3	0
	clean water	10.4	3.0	7.4	2.3	4.9	52.0	16.8	4.2
8/11/99	raw water	10.2	13.0	8.0	2.5	6.5	47.5	22.4	0
	clean water	9.7	6.0	7.4	2.3	4.4	53.5	17.0	4.2
17/11/99	raw water	8.7	13.0	7.9	2.5	7.0	46.5	21.8	0
	clean water	8.2	2.0	7.3	2.4	4.7	54.0	15.8	3.7
24/11/99	raw water	7.4	16.0	8.0	2.6	6.9	48.5	20.0	0
	clean water	6.9	3.0	7.4	2.4	4.8	54.0	17.4	7.6

Table 3

Characteristic parameters of raw and clean water data relating to 2000

Date	Water	Temp [°C]	B [mg/l]	pH	Zas [mval/l]	Utl [mg/l]	Cl' [mg/l]	CHZT [mg/l]	CO$_2$agr [mg/l]
1	2	3	4	5	6	7	8	9	10
1/03/00	raw water	2.8	13.0	8.1	2.6	6.3	47.5	19.3	0
	clean water	2.2	2.0	7.3	2.3	3.2	60	14.1	5.9
8/03/00	raw water	3.3	13.0	8.0	2.8	7	48	-	0
	clean water	2.3	2.0	7.4	2.5	4.2	57	-	2.2

1	2	3	4	5	6	7	8	9	10
22/03/00	raw water	4.2	13.0	8.1	2.6	6.8	13	22.4	-
	clean water	4.0	2.0	7.6	2.4	3.8	17.4	13.4	1.2
29/03/00	raw water	4.0	13.0	8.1	2.6	6.7	47.5	20.8	-
	clean water	4.2	2.0	7.5	2.4	3.7	57	15.1	1.2
9/05/00	raw water	6.5	13.0	8.0	2.7	6.7	47.0	18.0	0
	clean water	6.9	3.0	7.5	2.4	4.2	54.5	12.4	3.8
16/05/00	raw water	6.7	13.0	8.0	2.7	6.5	47.0	18.8	0
	clean water	6.4	2.0	7.2	2.3	3.4	52.0	12.3	9.8
24/05/00	raw water	6.6	13.0	8.1	2.7	6.8	48.5	18.3	0
	clean water	6.8	2.0	7.1	2.2	3.5	52.5	13.2	12.8
31/05/00	raw water	6.7	12.0	8.0	2.8	6.5	47.0	18.4	0
	clean water	7.0	2.0	7.4	2.4	3.3	58.0	12.0	4.4
1/08/00	raw water	7.0	12.0	7.7	2.8	6.6	49.5	16.5	0
	clean water	7.9	2.0	7.3	2.6	3.5	60.0	8.3	5.6
8/08/00	raw water	7.0	14.0	7.5	2.6	5.9	47.0	22.6	4.4
	clean water	7.3	2.0	7.3	2.5	3.0	61.0	15.0	4.6
23/08/00	raw water	8.5	14.0	7.5	2.8	6.0	48.5	19.4	2.2
	clean water	9.0	2.0	7.3	2.5	2.9	63.5	14.8	9.3
30/08/00	raw water	7.8	12.0	7.5	2.7	6.5	48.5	13.7	2.6
	clean water	9.5	2.0	7.2	2.4	3.2	63.5	10.3	10.7
7/11/00	raw water	10.8	14.0	8.0	2.3	6.8	48.5	-	0.0
	clean water	10.4	4.0	7.7	2.3	5.5	49.0	-	0.9
13/11/00	raw water	10.0	13.0	8.0	2.4	7.2	50.0	-	0.0
	clean water	10.0	2.0	7.2	2.2	3.4	62.5	-	6.4
22/11/00	raw water	8.8	13.0	7.9	2.5	6.9	48.0	-	0.0
	clean water	9.0	2.0	7.3	2.2	3.4	60.5	-	4.8
29/11/00	raw water	8.5	14.0	7.6	2.5	6.7	46.5	-	0.0
	clean water	8.3	2.0	7.1	2.2	3.5	64.0	-	8.8

Table 4

Characteristic parameters of raw and clean water data relating to 2004

Date	Water	Temp [°C]	B [mg/l]	pH	Zas [mval/l]	Utl [mg/l]	Cl' [mg/l]	CHZT [mg/l]	CO₂agr [mg/l]
1	2	3	4	5	6	7	8	9	10
1/03/04	raw water	2.4	13.0	8.0	2.4	6.9	52.0	19.4	0
	clean water	2.0	2.0	7.5	2.3	3.5	64.0	13.9	5.5
10/03/04	raw water	2.3	13.0	8.0	2.5	6.7	49.0	22.2	0
	clean water	2.1	2.0	7.6	2.3	4.6	53.5	18.6	5.3
17/03/04	raw water	2.8	12.0	8.0	2.5	6.7	51.0	20.6	0
	clean water	2.5	2.0	7.5	2.2	4.0	60.0	12.5	5.0
24/03/04	raw water	3.9	12.0	8.0	2.5	6.3	51.0	19.8	0
	clean water	3.5	1.0	7.4	2.3	3.3	63.0	12.9	5.2

Temp   – temperature [°C]
B   – colour [mg/l]
pH   – reaction [pH]
Zas   – alkalinity [mval/l]
Utl   – oxidizability [mg/l]
Cl'   – chlorides [mg/l]
ChZT   – chemical oxygen demand [mg/l]
CO_2agr – aggressive carbon dioxide [mg/l]

ANALYSIS OF DATA CONCERNING PARAMETERS OF THE RAW AND CLEAN WATER

Surface water temperature depends, among others on the atmospheric air temperature and it is changing depending on the season of the year. During the summertime, temperature at the surface is higher than temperature of the lower water layers. During the wintertime the water temperature at the surface approaches 0°C, and the deeper measurement the temperature is higher.

Analysis

The biggest difference of the raw water temperatures during the year amounted to 9.8°C, for the maximal temperature of 10.8°C and the minimal temperature of 1°C.
The biggest difference of the clean water temperatures during the testing period amounted to 9.0°C, for the maximal temperature of 10.4°C in November 2000 and the minimal temperature of 1.4°C in March 1999.
Water temperature is different in the testing months and so (Table 5).
In spite of the fact that the air temperature in November is low, the water in the lake reaches the highest temperature of the year. It is connected with the fact that the wa-

Water temperature in the particular months

Month	Raw water	Clean water
March	$1.0°C \div 4.2°C$	$2.0°C \div 4.2°C$
May	$6.2°C \div 8.5°C$	$5.5°C \div 8.0°C$
August	$7.0°C \div 8.5°C$	$7.3°C \div 9.9°C$
November	$5.0°C \div 10.8°C$	$5.8°C \div 10.4°C$

ter warms quickly but cools slowly. The water warmed during the summertime, when the air temperature is the highest, keeps its temperature still in November.

Summary

The water temperature does not depend on its treatment process, but it determines the efficiency of the technological processes, since the major part of the reactions depend thereon. Temperature influences on such water parameters as alkalinity, saturation with the dissolved gases, carbon-acid stability, as well as on such processes as coagulation and sedimentation (Hermanowicz 1984, 1999).
At low water temperatures the coagulation process becomes slower. It is caused by the fact that the density of the water having the higher temperature is lower, and therefore the particles having the density higher than the water density have settled easier therein.
On temperature depends also the solvability degree of gases in the water. The higher temperature, the gas solvability is lower. The gases solvable in the water are most
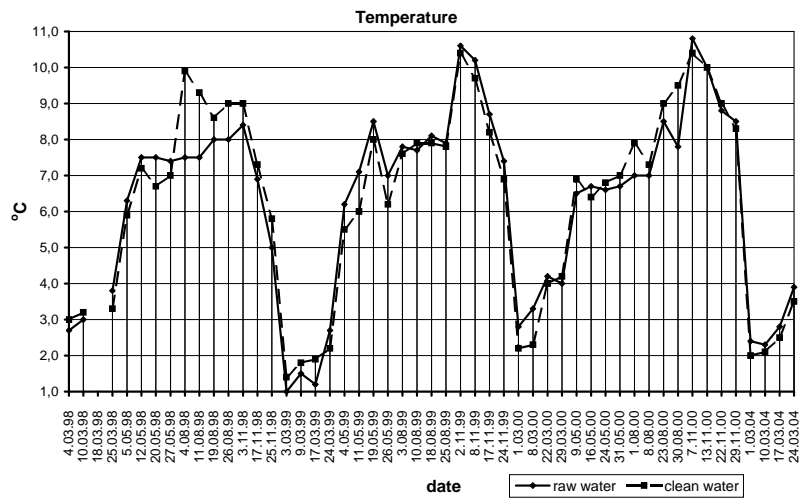
Fig. 4. Diagram of the raw water and clean water temperatures changes in time

frequently the following gases: CO_2, O_2, H_2S and N_2. With the temperature grows the water alkalinity.

Clean water temperature is not standardised, but it is assumed that the best range is 7-12°C (Fig. 4).

COLOUR

The water colour is caused by the dissolved compounds, colloidal compounds and algae. There are two kinds of colours: real and apparent.

The real colour is caused by the colloids or compounds dissolved in the water (Hermanowicz 1984). The water with the "real colour", after having been filtered through the filter paper loses the suspended solids contained therein, but it does not lose its colour.

The apparent colour is caused by the suspended colour solids contained in the water, which, after having been filtered by the filter paper remains on the filter and the water becomes clear.

Analysis

Colour of the raw water is within the range of 12-16 mg/l Pt. There are the considerably low values. Maximal value of 16 mg/l was noted on 24/11/1999, and therefore it was within the range of the admissible values even for the clean water.

That is why we can say, that the water colour removal is not the necessary action. However during the preliminary oxidization and coagulation, a part of the water colour has been removed from it.

The clean water, not being coagulated, only after the preliminary chlorination oxidizes its colour by 4.2 mg/l on the average. The water has then the colour within the range of 8-9 mg/l Pt.

Preliminary chlorination and coagulation using aluminium sulphate lowers the colour by 9.25 mg/l on the average; the colour is then within the range 4-5 mg/l Pt. It is the value approximately two times lower, in comparison with the result obtained when using chlorine only.

In the period May-August 1990, as the oxidant was used ozone, the coagulation was disabled.

During the tested period the ozone oxidisation caused the fall of the colour by 8.5 mg/l on the average, and the colour was then within the range of 3-5 mg/l Pt. That value is comparable to the water colour removal degree using chlorine and aluminium sulphate.

Since 2/11/1999 PAX was used to coagulate the water. That coagulant with ozone reduces the water colour by 10.94 mg/l on the average, and the colour was stabilised within the range of 1-2 mg/l.

In November 1999 the above-specified processes were used on one technological line only. The colour reduction in that month amounted to 10.25 mg/l on the average.

In days 16 and 25/05/2000 at Miedwie Water Treatment Plant, aluminium sulphate and PAX (on different lines) were used for the water coagulation, and as the oxidant was used ozone. The colour was then reduced by 11 mg/l Pt. It is very high value: the colour in those days was 2 mg/l.

Summary

Since the moment when ozone was included into the water treatment process, the colour was reduced very visibly. Application of ozone alone is comparable to the application of chlorine with aluminium sulphate. Application of the set ozone – PAX reduces the colour to the level of 2 mg/l. That value is now maintained on an almost stable level.
It results from the comparison of the colour removal degree by the sets: ozone – PAX and ozone – aluminium sulphate – PAX that that degree is almost the same. It allows thinking that the higher influence on the colour reduction had the change of the oxidant than the coagulant (Hermanowicz 1984).
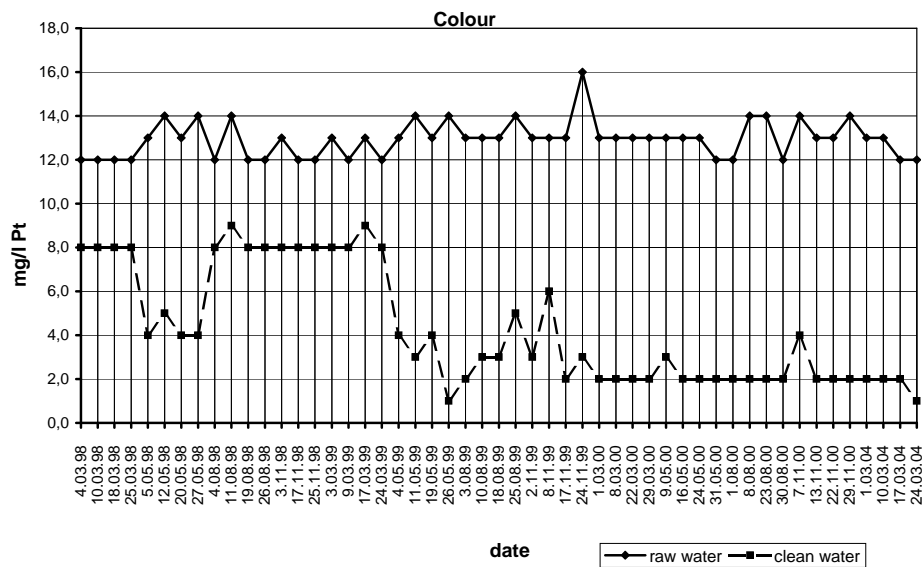
Fig. 5. Diagram of the raw water and clean water colour changes in time

The water is recognised as the colourless if it is within the range of 5-10 mg/l Pt. Generally it may be said that the obtained clean water is colourless, since its range is within the limits 2-9 mg/l (Fig. 5).

CHLORIDES

Chlorides are in all surface waters. They are easily soluble and they do not undergo chemical and biochemical changes. They appear in the waters as a rule in the form of chloride anion Cl. They come mainly from the precipitations coming from oceans, but also from the erosion of rocks and soils, from the industrial and sanitary wastewaters, and from the mine waters as well (Hermanowicz 1999).

Chlorides cause the salty taste of the water in which they appear. The taste intensity depends on the chemical composition of the water (Hermanowicz 1984).

Low concentrations of chlorides are necessary for the functioning of the plants and animals. The human being needs daily about 9 g of chlorides, however high dozes are not recommended for persons with heart diseases.

Chloride anion appears also in the underground waters. The deepest is the aquiferous layer the higher is chloride concentration. Chlorides in the underground waters come from the soliferous layers or from the inflow of the seawaters.

In the water treatment process, chlorides in high concentrations may cause the metal corrosion. As a result of the reaction of chlorides with metals are produced the water-soluble salts, which counteracts the creation of the metal protection coat protecting metals against the corrosion progress. Admissible concentrations of chlorides in the potable water, according to Ordinances of Minister of Health of 1990, 2000 and 2002 amounts maximally to 250 mg/l.

Analysis

Chlorides in the raw water fluctuate between 43.5-52.0 mg/l. It is very low value, requiring no particular attention. Chloride contents in the clean water is not alarming too, the highest concentration reaches the value of 64.0 mg/l. Because of the possibility to present, basing on that parameter, the influence of the substances involved into the treatment on the clean water quality, I shall investigate its changes during the tested period of time.

Increase of the chloride concentration in the clean water is caused by such substances as: chlorine and coagulant in the form of PAX.

During the period tested, in which no coagulation, but only the preliminary chlorination was used on Miedwie Water Treatment Plant, it can be noticed that the increase of the chloride concentrations in the clean water amounted to 1.76 mg/l on the average.

In the period when the coagulation took place using the aluminium sulphate i.e. in the data attached thereto in May 1998 we can see that the chloride concentrations in the clean water are comparable to concentrations of that substance in those times, when the coagulation was not applied. Average increase of chloride concentration in that period amounted to 1.5 mg/l.

On 2/11/1999 it was introduced to the water treatment process a new coagulant, i.e. PAX. The influence of that coagulant on the chloride contents in the water was clearly visible (Kowal and Świderska-Bróż 2000).

In 1990 PAX was introduced into one technological line only, on the second line the coagulant was not used. Therefore we observed the chloride contents increase by

6.25 mg/l on the average. In March 2000, when the coagulant was introduced into the both lines, the average increase of Cl contents amounted already to 10.33 mg/l.

In May 2000 we observed the reduction of the chloride contents in the clean water in relation to the previous results. That fall can be explained by the use of different co-agulants. In the first week PAX was introduced into one line only, the chloride contents increase was noted on the level of 7.5 mg/l. In the second and third week PAX was dozed into one line and the aluminium sulphate was dozed into the second one. Cl contents increase reached then the value of 4.5 mg/l. In the last week, on the first line coagulated PAX, and on the second line PAC. The increase of the contents of the substance tested amounted again to 11.0 mg/l.

In August and November 2000 was noted the highest chloride concentrations in the clean water, and their average increase in relation to the raw water amounted to 13.43 mg/l. Exception was the day 07/11/2000, when no coagulant was added and the increase was insignificant, 0.5 mg/l only.

In March 2004 PAX XL61 was used for the water coagulation. The average chloride contents increase amounted at that time 9.38 mg/l.

Summary

Because of the fact that the coagulant now in use, in the form of poly-aluminium chloride of PAX type, contains chlorides in its contents, just such results can be expected. Chloride contents increase reaches however very low values in relation to the maximal acceptable value fixed by the Minister of Health, therefore it does not
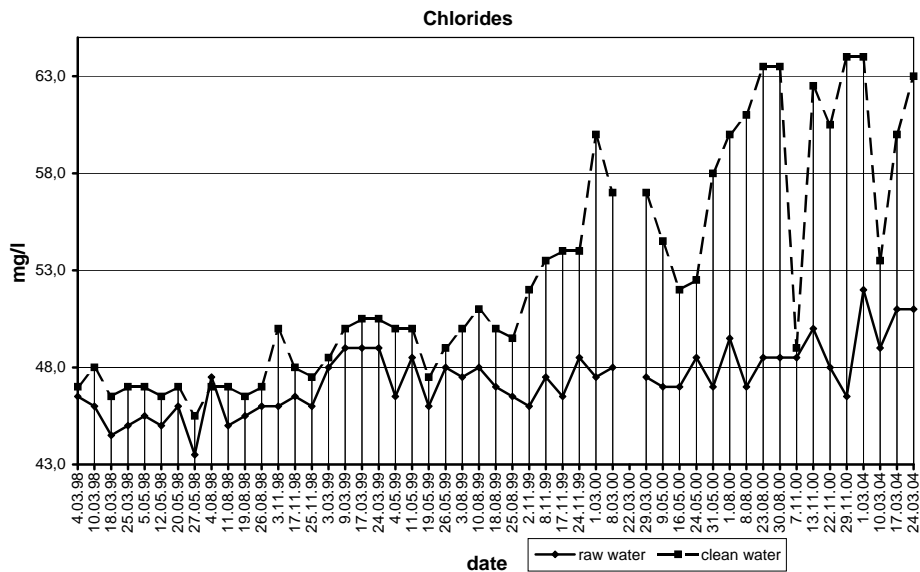
Fig. 6. Diagram of the raw water and clean water chlorides content changes in time

influence on the assessment of the quality of the potable water. However it can be noticed on that example, how important influence has the substances in use on the increase of some parameters (Fig. 6).

CHEMICAL OXYGEN DEMAND

Chemical oxygen demand is the conventional value, determining the quantity of oxygen collected from the oxidant to oxidise the organic compounds contained in 1 dm³ of the water in the exactly defined determination conditions.

Determination of COD (in Polish – ChZT) is made using dichromate of the formula $K_2Cr_2O_7$. The determination method name came from the oxidant used and it is named as dichromate method.

The carbon-nitrogen and carbon organic compounds are contained in the water. That method gives almost 100% oxidisation of the organic compounds contained therein.

Under the influence of dichromate, the carbon compounds are fully oxidised. In carbon – nitrogen compounds – carbon is oxidised and ammonia is formed from the amine group.

COD in the dichromate method determines only the carbon oxygen demand.

The potable water, in light of the Ordinance of the Minister of Health issued in 2000 could contain 5mg/l COD as the maximum. In the ordinances of 1992 and 2002 were no standards for COD parameter.

Analysis

COD quantity in the raw water is between 13.7 and 27.9 mg/l. The highest values were noted in the second half of May 1998.

In the clean water, depending on the substances used for its treatment, COD quantity is differentiated. For the whole tested period that value reached the maximum of 23.8 mg/l, and the minimum of 8.3 mg/l.

In the period when only chlorine was used, and it was no coagulation in use, the average fall of COD amounted to 2.66 mg/l. For the comparison – in the period when only ozone was used, the average COD reduction amounted to 3.49 mg/l. The substances remained after the chlorine and ozone oxidisation were directed to the rapid filters, where they were stopped on the filtration bed.

The preliminary chlorination connected with the coagulation using aluminium sulphate reduced COD value by 5.53 mg/l on the average. The preliminary ozonisation connected with PAX coagulation resulted in the reduction of COD by 6.18 mg/l on the average. Ozonisation with coagulation using $Al(SO_4)_3$ and PAX reduced COD by 5.8 mg/l.

Summary

Organic compounds oxidised and coagulated are removed to the higher degree than the compounds exposed only on the oxidants and filtration. It may be connected
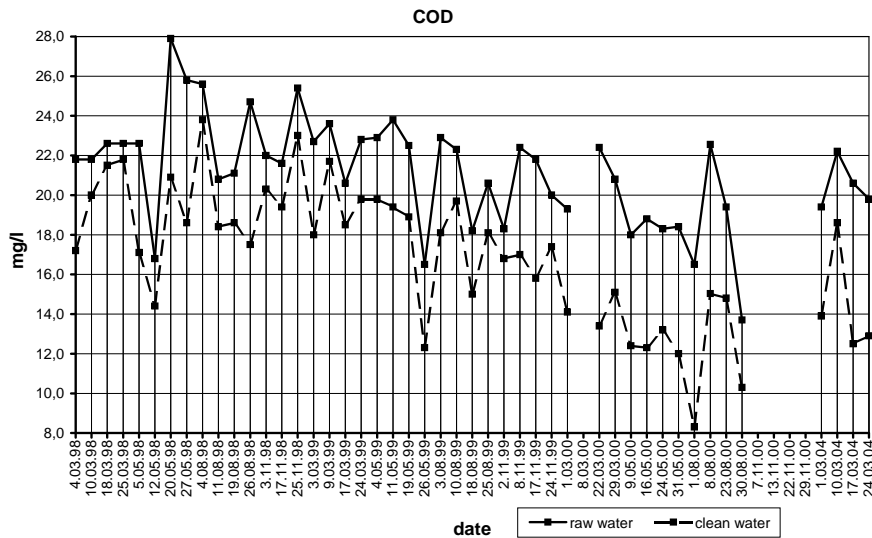
Fig. 7. Diagram of the raw water and clean water COD changes in time

with the fact that the complex substances are reduced under the influence of the oxidant into the simpler substances, which have to be removed through the coagulation. It can be also observed that the kind of oxidant influences also on the COD reduction degree. It can be said that the stronger oxidant removes more organic substances from the water. Ozone plays therefore its role well (Fig. 7).

Coagulant in the form of PAX binds better the substances resulted from COD oxidisation, which are removed from the water during the sedimentation. Due to that fact COD is additionally reduced. During the oxidisation of the organic substances CO_2 is released what affected adversely its increase in the clean water (Kowal and Świderska-Bróż 2000).

OXIDIZABILITY

Oxidizability means the quantity of oxygen provided by KM_nO_4 to oxidise the organic substances present in $1 dm^3$ of the tested water.

Substances of animal origin contaminate the water with nitrogen compounds and chlorides; oxidizability of such waters has increased. Substances of plant origin cause the oxidizability increase as well as the water colour increase too (Hermanowicz 1984).

Oxidizability measuring method is called permanganate method, since potassium permanganate is used for the oxidisation. That method consists in the oxidant action onto the water containing organic impurities in order to verify its pollution degree.

Oxidizability is only the general index of the pollutants' contents in the water. The more detailed index is COD, which reveals 90-100% of organic substances to be oxidised. In the case of oxidizability that share amounts to 50-70%.

Oxidizability, in the regulations concerning the potable water quality issued by the Minister of Health in 2000 and 2002, cannot exceed the value of 5mg/l in the clean water.

In the ordinance of 1990 oxidizability is not taken into account at all.

Analysis

The raw water in Miedwie water treatment plant has the oxidizability as a rule exceeding 6mg/l (the lowest noted value was 5.9 mg/l O_2) and it does not exceed as a rule 7 mg/l O_2 (the highest noted oxidizability amounted to 7.2 mg/l O_2).

In the months: March, August, November 1998 the water was only preliminarily oxidized using the chlorine water. Average value, by which the oxidizability has been reduced amounted to 1.04 mg/l O_2.

In May 1998 aluminium sulphate was used for the coagulation, which together with chlorine reduced the oxidizability by 2.73 mg/l on the average.

Using ozone, without coagulation, the average value of the oxidizability reduction amounted to 1.75 mg/l, and after having introduced the PAX coagulation on one line the reduction amounted to 2.15 mg/l. Using PAX on the both lines that value has increased up to 3.08 mg/l O_2 on the average.

Ozone, together with aluminium sulphate and PAX brought to the effect of the oxidizability reduction by 3.2 mg/l.
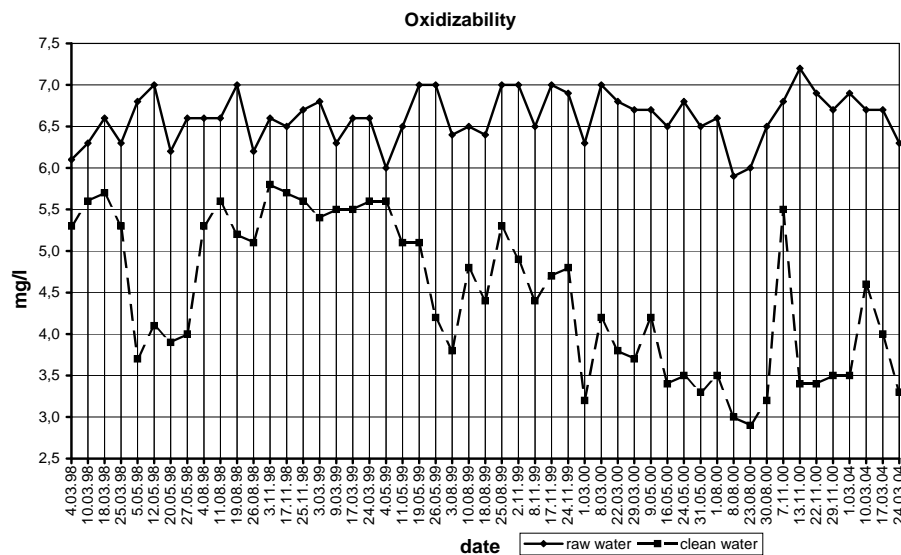
Fig. 8. Diagram of the raw water and clean water oxidizability changes in time

Summary

Use of the strong oxidiser in the form of O_3 to remove the organic compounds is purposeful. Average oxidizability removal degree is better, when ozone is used to-

gether with PAX. The above considerations show that the best period, in which the highest oxidizability reduction took place was the period, when it was used ozone with aluminium sulphate and PAX. It should be mentioned that it was only two days of measurements.

That result could be other, if we would consider the longer period. However the quality of removal of the oxidizability from the water for the blocks ozone – PAX and ozone – sulphate – PAX can be similar, since the oxidizability removal depends mainly from the oxidiser. Taking into account the individual results of each day, the highest oxidizability reduction was noted on 13/11/2000. That reduction amounted then to 3.8 mg/l O_2 (Fig. 8).

pH REACTION

Water reaction can be acid, alkaline or neutral. It is assumed that the neutral waters have the pH reaction equals 7, acid waters pH<7, and alkaline pH>7 (Heidrich 1986). Natural water reaction depends on:
– carbonate contents; carbonate waters are alkaline, waters with low carbonate content are acid;
– kind of subsoil, from which the alkaline and acid compounds are washed out;
– disposed pollutants (wastewaters, precipitations).

Reaction in the surface waters is within the range of pH 6.5-8.5, but there are cases of the waters having higher or lower pH reaction. The water reaction can change under the influence of contamination with some substances. Acid rains, acid wastewaters, humus acids lower the pH level to about 4. Alkaline wastewaters, algae increase pH reaction. In underground waters pH range is wider and it is within the range from less than 5 to 14 depending on the situation of the aquiferous layer.

The water reaction influences on the living organisms. Deviations from the neutral reaction, i.e. excessive acidity or alkalinity of the water results in decaying of the biological life. pH is of the great importance in the household use of the water. The lower pH is, the water is more corrosive. And the waters with high pH are characterised by the foaming inclinations. That is why it is important to keep pH on the stable and proper level.

According to the Polish standards concerning the potable water, pH should be maintained within the limits 6.5-9.5.

Analysis

Raw water has the alkaline reaction, if its pH is within the range 7.5-8.5. The raw water reaches the lowest pH in August, and the highest one in May and November. It is connected with the algae blooming and the biological life of the lake (Rozmiarek 1983).

Reaction of the clean water depends on the substances added in the technological process. However all of them reduce pH. pH range for the clean water amounted to 6.9-8.1.

The effect of use of the aluminium sulphate preceded by chlorination was the reduction of pH by 1.18 on the average. Coagulation with aluminium sulphate and PAX with ozonization reduced pH of the water by 0.9 on the average. Coagulation by PAX and the preliminary ozonization resulted in the pH reduction by 0.51, and application of PAX on one line by 0.6. Application of chlorine only reduced pH by 0.25 and of ozone only by 0.4.

Summary

Water reaction is important in the coagulation process, since some coagulants work better in the reactions being optimal for them, e.g. use of aluminium sulphate with pH higher than 7.5 results in the instability of the water. Lower pH is connected with the lower alkalinity and thus higher corrosivity of the water. Coagulants in use acidify the water resulting in the reduction of its pH reaction. Oxidants reduce the pH reaction too. The most favourable composition of oxidant and coagulant is PAX and
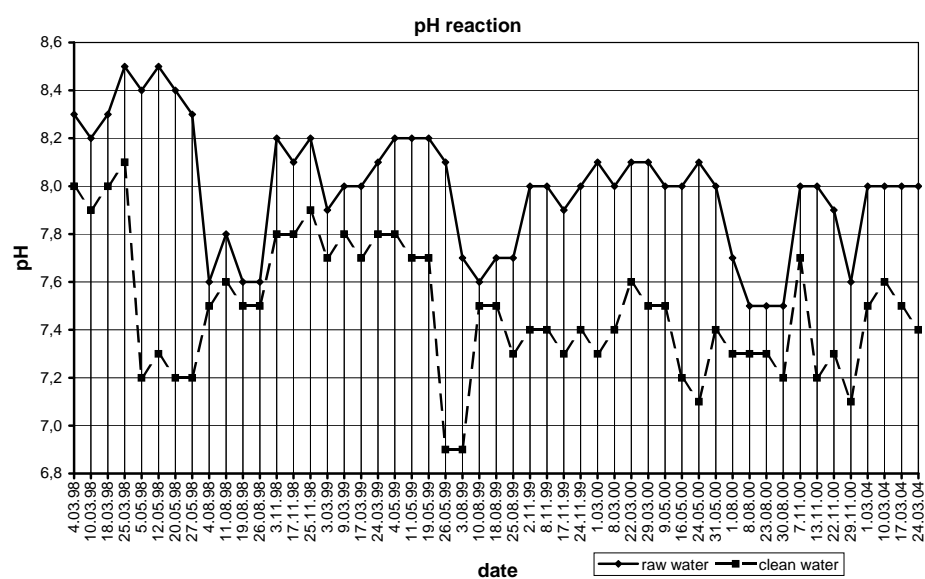
Fig. 9. Diagram of the raw water and clean water pH reaction changes in time

ozone (Fig. 9). Use of those two substances results in the lowest reduction of pH reaction. It can be said, that the change of coagulant was favourable as regards the water reaction. However ozone reduces pH almost two times more in relation to chlorine, what influences on the fact that it is less favourable for the water (Kowal and Świderska-Bróż 2000).

ALKALINITY

Term alkalinity describes reactions, taking place due to the action of bicarbonates, carbonates and hydroxides, which neutralize strong acids contained in the water (Hermanowicz 1999).

Water alkalinity depends on its pH reaction. If the water reaction amounts to more than 4.6 pH we can read the general alkalinity. It characterises the compounds, which enter into reactions with the methyl orange. After the orange having been added, the colour of the sample tested shall be changed from yellow into onion-like or yellow.

When the water reaction amounts to more than 8.3 pH we can read the phenol-phthalein alkalinity. It characterises the compounds, which enter into reactions with phenolphthalein. After having added phenolphthalein, the tested sample colour changes from amaranth-purple into the colourless.

Waters with pH reaction less than 4.6, since they are acid, they not influence on the decomposition of strong acids (Hermanowicz 1984).

Water alkalinity is important for the boiler water preparation, however in the case of the potable water it is of no considerable importance (Kowal and Świderska-Bróż 2000).

Alkalinity is closely connected with the appearance of aggressive carbon dioxide – the lower is the alkalinity more CO_2 is released.

Alkalinity is not taken into account in the ordinances concerning the potable water.

The clean water alkalinity changes in the range 2.1-2.8. The lowest noted values appeared in May 1998, and highest value on 25/08/1999.
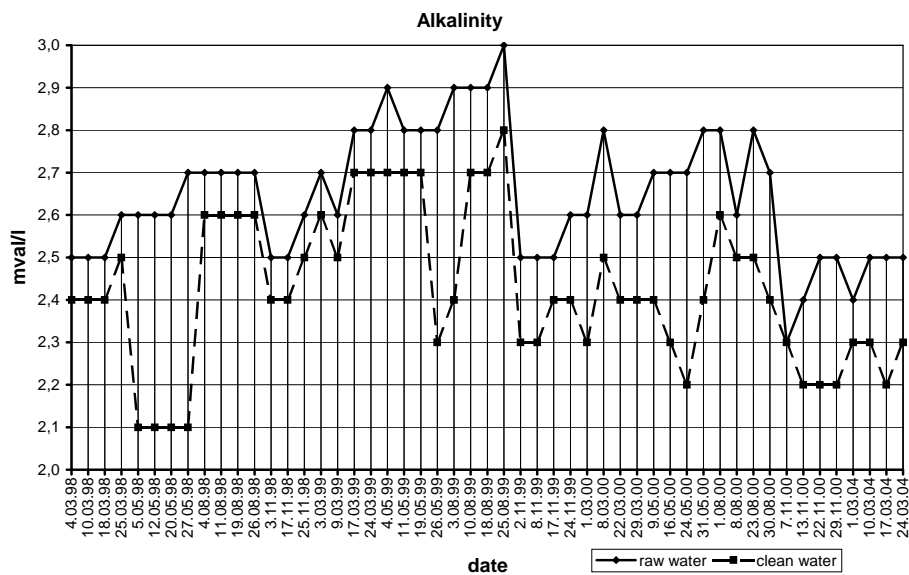

Fig. 10. Diagram of the raw water and clean water alkalinity changes in time

As a result of actions of aluminium sulphate and chlorine on the treated water, the alkalinity is reduced by 0.53 mval/l on the average, and of aluminium sulphate, PAX and ozone by 0.42 mval/l. When on the technological lines was used the preliminary ozone oxidization with the coagulation using poly-aluminium chloride of PAX type the alkalinity was reduced by 0.19 mval/l on the average. Use of chlorination without coagulation resulted in the alkalinity reduction always by 0.1 mval/l; use of ozone without coagulation reduced the alkalinity by 0.16 mval/l on the average.

Summary

Miedwie waters are low-alkaline waters. Substances added to support the water treatment process cause its acidifying, what results in the further reduction of its alkalinity. The worst influence on the water alkalinity has the application of aluminium sulphate with chlorines. Change of the coagulant into PAX and of the oxidant into ozone was therefore right in those aspects too (Heidrich 1986, Nawrocki 2000). Alkalinity reduction is very unfavourable, since it is connected with the release of carbon dioxide, which as the aggressive CO_2 causes the corrosivity of the water supply network (Fig. 10).

AGGRESSIVE CARBON DIOXIDE

Carbon dioxide is present in all natural waters. It may origin from the atmosphere, from the decomposition of organic compounds or from the metabolic processes.
CO_2 can exist in the water in two forms:
– free carbon dioxide – in the form of dissolved CO_2 or carbonic acid;
– bounded carbon dioxide – in the form of carbonates and bicarbonates.
Part of the free CO_2 is necessary to keep the carbonate – calcium balance. If the alkalinity is high, more carbon dioxide is necessary to maintain that balance. With the reduction of the alkalinity it has increased the aggressive CO_2 concentration.
Excess of free CO_2 is called aggressive carbon dioxide, since it causes the water aggressiveness. Aggressive water facilitates the corrosion of the metal and concrete equipment.
Oxidization of the organic compounds has an influence on the creation of the aggressive carbon dioxide. During the decomposition, they release carbon dioxide, which cannot be bound by anything and remains in the water as free CO_2.
Aggressive carbon dioxide is not covered by the standards, however it is mentioned that the potable water cannot be corrosive (Hermanowicz 1984).

Analysis

The raw water coming from Miedwie Lake contains aggressive CO_2 in three cases only. They were results from August 2000 and the quantity of the aggressive carbon dioxide amounted then 2.2-4.4 mg/l.

The reduction of organic compounds and alkalinity have the most important influence on the aggressive CO_2 contents in the clean water.

Coagulation with aluminium sulphate and oxidization with chlorine caused the increase of aggressive CO_2 by 11.5 mg/l on the average and its level reached the values within the range between 11-13.2 mg/l.

Coagulation with poly-aluminium chloride of PAX type and ozone oxidization increased the aggressive CO_2 concentration in the water by 4.8 mg/l on the average, and its quantity amounted to 1.2-8.8 mg/l. Coagulation with aluminium sulphate, PAX and ozone oxidization increased the aggressive CO_2 contents by 11.3 mg/l on the average, and its values amounted to 9.8-12.8 mg/l.

In the period when the coagulation was not in use, and chlorine was the oxidant, two times the aggressive CO_2 contents amounted to 2.2 mg/l.

When ozone was the oxidant, the average increase of the aggressive CO_2 amounted to 2.36 mg/l, and the values were contained within the range 1.8-2.7 mg/l.

Summary

It is assumed that the aggressive CO_2 in the concentrations exceeding 10 mg/l is the dose being decidedly too high. That gas dissolves in the supplied water the compounds contained in the water-supply piping such as calcium carbonates as well as it results in the corrosivity of those pipes, what results in the secondary contamination of the potable water.

It can be observed, that during the use of coagulants the quantity of the aggressive carbon dioxide has increased (Hermanowicz 1984).
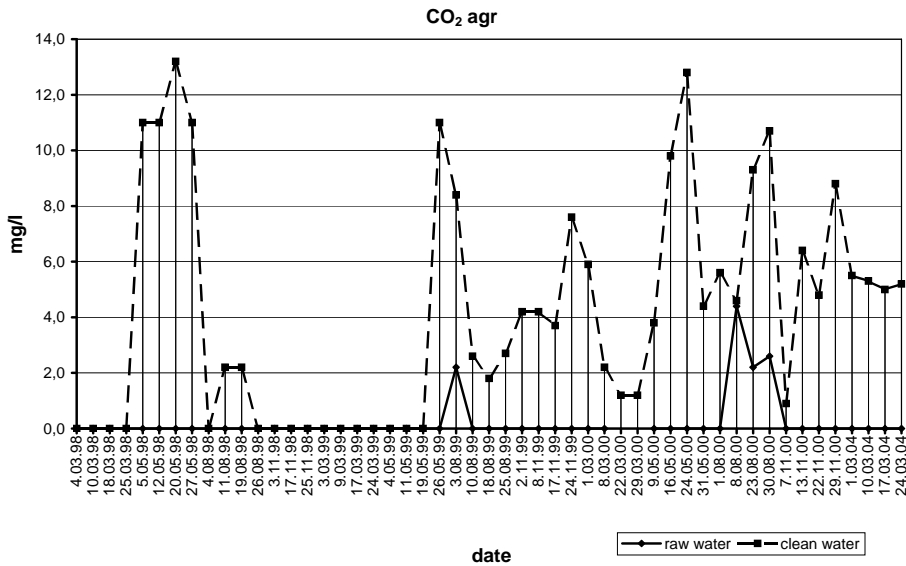

Fig. 11. Diagram of the raw water and clean water aggressive CO_2 content changes in time

Use of aluminium sulphate caused the higher threaten for the water-supply piping and for the water, since the increase of aggressive CO_2 was very high.

Introduction of PAX, giving lower CO_2 contents is more favourable, however those values should be minimised anyway (Fig. 11).

ASSESSMENT OF TECHNOLOGICAL PROCESSES

Technological processes are composed of:
– stopping coarse impurities on grids and screens;
– preliminary oxidization with chlorine or ozone;
– coagulation, flocculation and sedimentation using aluminium sulphate or PAX on rapid and slow mixers and sediment traps;
– filtration on sand beds; sand-anthracite beds;
– final disinfection.

Generally, those processes guarantee the removal of the major part of the pollutants from the water, however some of them were not removed in the appropriate quantities or even their contents have been increased.

The parameters shown in the work were assessed individually, however since they have the mutual influence each on other, they should be assessed jointly too.

Chlorides and water colour can be considered separately. However such parameters as COD (in Polish: ChZT), oxidizability, temperature, pH, alkalinity and aggressive CO_2 are mutually inter-depended each on other to the considerable degree (Hermanowicz 1984).

It can be observed, that if the level of COD and oxidizability are reduced, it has been increased also the contents of the aggressive CO_2. Also the reduction of alkalinity, due to the reduction of pH of the water, results in the increase of the aggressive carbon dioxide contents.

Influence on all those values has the application of various substances treating the water (Heidrich 1986, Nawrocki 2000).

● Grids and screens – mechanical straining out:

Straining out on grids and screens is aimed at separating the floating solids contained in the water with sizes, which could be harmful to the equipment located further in the technological line.
a) On grids are stopped bigger floating impurities such as leaves, wooden chips etc.
b) On the intake point are living numerous bivalves. They are frequently pulled into the pipeline feeding the water to the pumping station. Those organisms could damage the mechanical equipment; therefore the use of screens is necessary. To the pipeline feeding the water to the pumping station get also small fishes. Since it is impossible for them to get out to the lake, they live in those pipes and sometime get even to the pumping station, where they are stopped on the screens.

Stopping of the coarse impurities as the first stage of the water treatment is necessary and serves its turn. The process of straining out does not allow damages to the

equipment as well as it prepares the water to the further treatment (Kowal and Świderska-Bróż 2000).

● Preliminary oxidization – chlorination and ozonization:

a) Germicidal action of ozone is approximately two times stronger than the action of chlorine. It destroys also well such organisms as yeasts, fungus spores, and cysts. It shows also higher activity than chlorine in the process of removal of Escherichia coli.
b) As regards the removal of the water odour, ozone is the best substance too. It is more effective than the gas chlorine, it causes the improvement of the water taste and odour without provoking its specific changes, otherwise than chlorine (Kowal and Świderska-Bróż 2000).
c) The best oxidising substance to remove the water colour is ozone. It oxidizes the compounds causing the colour to simpler forms, which should be removed through the coagulation and filtration. The process of oxidisation of substances responsible for the water colour is connected with breaking the humus compounds by ozone.
d) Ozone is also better for the oxidization of the organic compounds. Ozone breaks the double carbon bonds in the organic compounds having the carbon group. Part of the organic compounds has been oxidised to CO_2, however it is generated considerably lower quantity of aggressive carbon dioxide than in the case of chlorine oxidisation.

Ozone oxidization in "Miedwie" water treatment plant served its turn. Majority of the pollutions subject to the oxidization is removed from the water. The quantity of the by-products of the ozone oxidization is lower than the quantity of the products of chlorine oxidization.

● Coagulation – aluminium sulphate and PAX

a) Aluminium sulphate in comparison with PAX caused about 2 times increase of the aggressive carbon dioxide. The carbon acid aggressiveness of the water on "Miedwie" station is the important problem.
b) PAX can be used for the whole year, since it does not cause such considerable increase of the water aggressiveness. It is moreover effective as regards the removal of the colour, turbidity and oxidizability of the water.
c) Aluminium sulphate in comparison with PAX has the bigger influence on the reduction of the water pH reaction and its alkalinity, causing thus the increase of its aggressiveness.
d) Poly-aluminium chloride of PAX type, in comparison to aluminium sulphate, caused the increase of the chloride contents in the clean water. Change of the coagulant from aluminium sulphate into PAX was necessary and justified. The biggest threaten for the water is its destabilisation. On "Miedwie" station, the process of water stabilisation after the coagulation is not taken into account and therefore, until it will be changed, we should do our best to minimise throwing the water off its carbon acid balance.

● Rapid filters – sand and sand-anthracite beds:

a) As a result of the filtration on the sand bed it appeared a field of impurities, which caused the clog of the filtration bed. Frequent appearance of that impermeable layer has considerably reduced the filtration efficiency, as well as it increased the frequency of the filters rinsing.
b) Application of the filtration layer of anthracite causes that the filter is slower filled up with the impurities. It results from the structure of the anthracite layer. Grains are big enough, that in spite of the impurities adsorption, it remains still the pores through it the water flows. Due to that layer the filter has been polluted more slowly, and the rinsing can take place in longer intervals.

Application of the anthracite layer has improved the filtration process; the filtration layers are now appropriately selected too, and therefore there is a possibility to stop the smaller impurities in bigger quantities.

● Final disinfection – chlorination

Its purpose is to protect the water against the repeated growth of microorganisms in the water supply network. The chlorine dose must be determined so the free chlorine quantity to amount to 0.9-1.1 mg/l.

CONCLUSIONS

● Generally, it can be said that the change of oxidant from chlorine into ozone was right. Ozone causes the higher degree of oxidisation of organic substances. Change of the coagulant into PAX has proved also to be the right decision. Removal of the pollutions through the PAX coagulation is effective, and at the same time the increase of aggressive CO_2 is lower than in the case of use of aluminium sulphate.
● Assessment of the technological process is favourable as regards the change of substances applied to the treatment. The biggest problem of Miedwie water treatment plant is the high level of COD and the contents of aggressive CO_2. Other parameters of the clean water are within the admissible limits.
● On Miedwie water treatment plant shall be installed the carbon filters in the foreseeable future, which shall help in removing COD-s from the water. However that process, though necessary, shall not dissolve the problem of the contents of the aggressive carbon dioxide in the water.
● The best solution would be the application of a substance increasing the water alkalinity and binding aggressive CO_2. Those substances should be added after the flocculation, the compounds created as a result of binding to be able to be stopped on decanters and filters.
● Substances used to bind CO_2 are burnt lime in the form of the milk of lime or limewater. Inclusion of such chemicals into the technological processes would result in restoring the carbonate – calcium balance in the water.

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ANALIZA I OCENA PROCESÓW TECHNOLOGICZNYCH STACJI UZDATNIANIA WODY POWIERZCHNIOWEJ Z JEZIORA MIEDWIE DLA MIASTA SZCZECINA

Streszczenie

Ujęcie wody „Miedwie" powstało w roku 1976. Do tego czasu wody jeziora odpowiadały pierwszej klasie czystości. Jednakże jakość wody zaczęła się pogarszać już po rozpoczęciu eksploatacji ujęcia, dochodząc aż do poziomu trzeciej klasy czystości. Przyczyną był brak oczyszczalni oraz PGR-y. Zanieczyszczenie zbiornika powodowało masowe śnięcia ryb (siei miedwiańskiej), przy dnie pojawił się siarkowodór, masowo zakwitały glony. Dalsze pogarszanie się stanu jeziora groziło zamknięciem ujęcia wody oraz wyniszczeniem życia biologicznego w zbiorniku, jak również wokół niego. Spadek jakości wód jeziora spowodowany był kilkoma czynnikami: rolnictwo, baza rosyjska w Kluczewie, turystyka, dopływy jeziora, biomanipulacja wodami Miedwia.