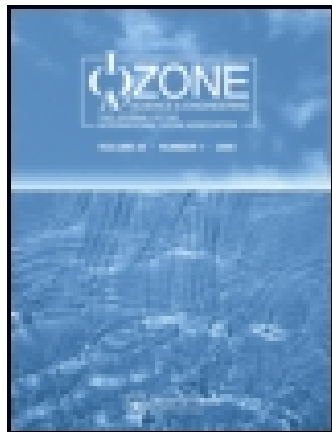


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# Which is the Best Oxidant for Complexed Iron Removal from Groundwater: The Kogalym Case

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*A short overview of the significance of a preoxidation stage groundwater treatment is presented. As an example the case of complexed iron removal from Kogalym groundwater (Tjumen, Siberia, Russian Federation) using different preoxidants (ozone, oxygen, chlorine, hydrogen peroxide, and potassium permanganate) is discussed. The key problem is stable di- and trivalent iron-organic complexes in groundwater which after aeration tend to pass through the hydroanthracite-sand gravity filters. The total organic carbon (TOC) content in raw groundwater is in the range of 3.2–6.4 mg/L, total iron content 2.7–6.0 mg/L and divalent iron content 2.4–4.0 mg/L. Separation from Kogalym groundwater by XAD-16 adsorbent humic matter fraction was homogeneous, with only 1 peak on the chromatogram with maximum  $R_t = 10.75$  min and corresponding molecular mass 1911 ( $< 2000$ ). The final developed treatment technology is based on the water oxidation/reduction potential (ORP) optimization according to the iron system  $pE$ - $pH$  diagram and consists of intensive aeration of raw water in the Gas-Degas Treatment (GDT) unit with the following sequence: filtration through the hydroanthracite and special anthracite Everzit, with intermediate enrichment of water with pure oxygen between the filtration stages.*

**Keywords** Ozone, Groundwater, Iron, Iron-Organic Complexes, Oxidation, Filtration

## INTRODUCTION

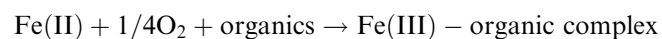
Production of safe and reliable drinking water from groundwater is in many cases complicated by the increased content of iron and manganese, hydrogen sulfide and

sulfides, free carbon dioxide, radon or other dissolved gases as well as of iron-and/or sulfur bacteria.

Iron and manganese are present in natural waters in their most reduced state, and most soluble forms: Fe(II) and Mn(II). They enter groundwater under reducing conditions existing in waters that have not been exposed to atmospheric oxygen for long periods or in zones having active anaerobic bacterial populations. Waters containing iron can be divided into two main groups: waters that separate iron just after aeration and waters where iron remains in the solution after aeration for endlessly long periods (Sommerfeld, 1999). This type of iron is difficult to remove by the conventional treatment methods. In the latter case we have groundwater in which the iron behavior depends on organics types and concentrations. Organic substances (or silica) in water may interfere with the iron removal process, forming stable complexes with iron, both Fe(II) and Fe(III), and manganese. The Fe(III)-humic complexes are stronger and more stable as compared to Fe(II)-humic complexes. Considerable research has been conducted to explain the chemical nature of the complexed iron.

Soil scientists have been quite consistent in stating that organics which cause these complexes or peptized small metallic colloids are of relatively high molecular weight (greater than 2,000), whereas water chemists generally concede that low molecular weight organics are responsible for holding iron (Oldham and Gloyna, 1968).

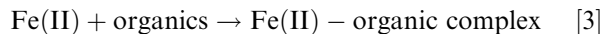
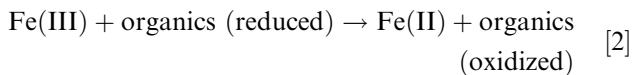
Jobin and Ghosh (1972) established that in the presence of organic matter, Fe(II)-Fe(III) redox couple acts as a catalyst for the oxidation of the organic matter. In such systems, both complexation of Fe(II) and reduction of Fe(III) by organic matter are possible:



[1]

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The relative rates of reactions [1] and [2] dictate the eventual oxidation of Fe(II) in the presence of organics. In such cases, the ferrous-ferric system acts as an electron transfer catalyst for the oxidation of organic material. Depending on the relative rates of Fe(II) oxygenation and Fe(III) reduction by organic material, substantial retardation of the over-all oxidation of Fe(II) by organic material is possible (Ghosh, 1965). The higher the pH, the more the oxidation process of the Fe(II)-organic complex is retarded. For example, at pH 8, decrease in rate constant by a factor of 10 results in doubling the half-life of the Fe(II)-organic complex with respect to oxidation (Stumm, 1990). It is well known that temperature plays a key role in chemical reactions kinetics. Unfortunately, there are no data available on divalent iron or iron-complexes oxidation rate at lower temperatures (below 10°C).

Some researchers have expressed an opinion that utilization of a strong oxidizing agent like ozone to break the organic molecules, thus reducing the color, can also make the organic substance much less tenacious as a complexing agent (Knocke et al., 1992). On the contrary, other researchers (Knocke, 1991) have found that the capability of either KMnO<sub>4</sub> or free chlorine or hydrogen peroxide, and even ozone to oxidize Fe(II) complexed with dissolved organic carbon (DOC) was greatly reduced.

The capability of an oxidant to oxidize involves both kinetics (or oxidation power) and stoichiometry (Tables 1 and 2), i.e., both the overall strength of the oxidant, and the speed with which it works should be considered. For example, hydrogen peroxide is a more powerful oxidant than chlorine; however in water it is very slow to act, often too slow to be of practical application. At the same time, using hydrogen peroxide in combination with ozone or UV light to form very powerful oxidizing hydroxyl radicals is very difficult to control because the radicals may be consumed before they reach divalent iron or manganese in water.

Cromley and O'Connor (1976) compared ozone with oxygen for the oxidation of iron in a groundwater of high DOC content. They found that ozone resulted in more rapid precipitation of the iron, although it was not clear how much of this iron was organically bound. These authors proposed that too high ozone doses resulted in the formation of very stable iron-organic complexes which could not be oxidized subsequently, i.e., ozonation may not always be superior to simple aeration in the removal of iron by filtration.

It was established (Reckhow et al., 1991) that ozone oxidizes iron very quickly in the absence of organic matter. However, in the presence of humic substances at pH 6.3, the iron may be completely protected from oxidation and precipitation, if the iron-organic complexes were formed under reducing conditions.

Among the technologies now in use for dealing with these challenges are the injection of air, oxygen or ozone

**TABLE 1.** Relative Power of Oxidizing Species

Species	Oxidation power, V	Relative oxidation power*
Fluorine	3.06	2.25
Hydroxyl radical	2.80	2.05
Atomic oxygen	2.42	1.78
Ozone	2.07	1.52
Hydrogen peroxide	1.77	1.30
Chlorine	1.36	1.00
Oxygen	1.20	0.88

\*Based on chlorine as reference point = 1.00.

**TABLE 2.** Theoretical Stoichiometry Amounts of Oxidants for Iron

Oxidant	mg/mg of iron
Oxygen	0.14
Hydrogen peroxide	0.30
Ozone	0.43
Chlorine (HOCl)	0.64
Potassium permanganate	0.94
Chlorine dioxide	0.24

into water streams for unwanted gases stripping, hydrogen sulfide, iron and manganese oxidation, precipitate filtration and post-disinfection (Voorinen, 1988). Iron and manganese can also be removed using biological as opposed to physical/chemical means. However, biological treatment requires specific raw water qualities and conditions, and not all groundwaters or surface waters can be treated economically using this technique (Mouchet, 1992).

The aim of the present study was to compare the efficiency of different oxidants (chlorine, hydrogen peroxide, ozone, oxygen, potassium permanganate) for complexed iron removal from the groundwater in Kogalym (district of Tjumen, Siberia, Russian Federation) in pilot plant conditions. Studies on humic matter composition and metal-organic complexes were carried out in laboratory of the Chemical Engineering Department of TUT. The city of Kogalym is supplied by groundwater from 42 wells of 170 m in depth. The water is quite cold (0–(+2°C), contains free dissolved carbon dioxide (50–60 mg/L), colloidal iron (2.7–6.0 mg/L), some hydrogen sulfide, organic compounds (TOC 3–6 mg/L) and silica (40 mg/L SiO<sub>2</sub>). About 63% of all the samples taken from local groundwater in Kogalym do not meet the Russian nor EU standard on drinking water quality (correspondingly 0.3 and 0.2 mg Fe/L). Table 3 summarizes the ranges of the main raw water quality parameters.

## EXPERIMENTAL

### Studies on Humic Matter Composition and Metal-Organic Complexes

Preliminary laboratory tests of raw water aeration and oxidation indicated clearly that iron in raw water was complexed by organic compounds or silica, because when oxidized by ozone up to the trivalent state, iron stayed in the solution and was not precipitated. The

humic matter in raw groundwater was analyzed using exclusion chromatography (Lepane, 2001). Also the amount of metal bound with organic matter was established. A groundwater sample was filtered through a 0.45 µm filter, and then acidified instead of HCl with concentrated HNO<sub>3</sub> to the pH value 2.0. Humic matter was extracted by filtration of 2 L of acidified water through the adsorbent XAD-16. The metals content was established in the acidified water as well as in the filtered water. The amount of organically bound metals was calculated from the difference:

Organically bound metals = total metals content  
inacidified water–metals content after adsorption onto XAD

For the organic matter characterization the humic fraction adsorbed onto XAD-16 was eluted using 0.2 M solution of NaOH and immediately neutralized. Exclusion chromatograms of the initial raw water and separated humic matter fraction were taken. The column was calibrated using the protein standards. The calibration straight line corresponded to the equation:

$$\log M_w = -0,4721 \cdot Rt + 8,3543; R^2 = 0.9778 \quad [4]$$

The average molecular masses of humic matter were calculated according to the equations:

$$M_n = \sum |h_i|/(h_i/M_i) \quad [5]$$

$$M_w = \sum (h_i \cdot M_i) / \sum h_i \quad [6]$$

where  $M_n$  is numerical-average and  $M_w$  is mass-average molecular mass,  $h_i$  is the height of the chromatographic peak at certain retention volume  $V_i$ ,  $M_i$  is the corresponding to it molecular mass found by calibration curve (line).

**TABLE 3.** The Main Raw Water Quality Parameters

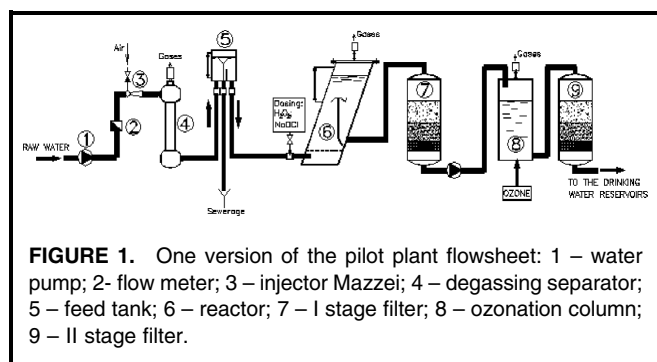
Parameter	Unit	Range
pH	—	6.60–6.80
Conductivity	µS/cm	178–208
Dry residue (105°C)	mg/L	140–165
Color	mg/L Pt	26–55
Turbidity	NTU	4–28
Fe <sub>total</sub>	mg/L	2.7–6.0
Fe <sup>2+</sup>	mg/L	2.4–4.0
COD <sub>Mn</sub>	mgO <sub>2</sub> /L	4.8–6.6
COD <sub>Cr</sub>	mgO <sub>2</sub> /L	8–13
TOC	mg/L	3.2–6.4
NH <sub>4</sub> <sup>+</sup>	mg/L NH <sub>4</sub> <sup>+</sup>	1.34–1.65
Mn	mg/L	0.09–0.16
Alkalinity	mg-eq/L	1.95–2.15

If the polymer is uniform, then  $M_n = M_w$ . The ratio  $d = M_w / M_n$  is called the polydispersity factor. If  $d = 1$ , then the polymer is monodispersal. If  $d$  is close to 1, then the polymer is with narrow molecular masses distribution.

### Pilot Plant Tests for Evaluation of the Groundwater Treatment Technology

For the evaluation of optimal treatment technology for the City of Kogalym raw water the pilot plant with the maximum flow rate of water up to  $5 \text{ m}^3/\text{h}$  was constructed. A majority of the tests were carried out at a groundwater flow rate of  $1.58 \text{ m}^3/\text{h}$ . The experimental set-up consisted of a novel Gas-Degas Treatment unit (GDT) from the Mazzei-GDT Corp., (Bakersfield, CA, USA) (GDT DS-100-316), feed tank ( $D=0.8 \text{ m}$ ;  $H=0.5 \text{ m}$ ), contact column ( $D=0.61 \text{ m}$ ;  $H=3 \text{ m}$ ), two sequent filters (both with  $D=0.72 \text{ m}$ ;  $H=3.96 \text{ m}$ ) with different filter media. The filter media in the first filter were: hydroanthracite (diameter of particles  $1.4\text{--}2.5 \text{ mm}$ ;  $h=1.1 \text{ m}$ ) and sand ( $0.4\text{--}0.8 \text{ mm}$ ;  $h=1.0 \text{ m}$ ); and in the second filter correspondingly Pyrolox (20/40 mesh;  $h=1.2 \text{ m}$ ) (Prince Minerals, New York, NY, USA) or special anthracite "Everzit" ( $0.6\text{--}2.0 \text{ mm}$ ;  $h=1.4 \text{ m}$ ) (Evers e.K., Hopstein, Germany) and sand ( $0.4\text{--}0.8 \text{ mm}$ ;  $h=0.5 \text{ m}$ ), ozonation bubble column ( $D=0.14 \text{ m}$ ;  $H=2.5 \text{ m}$ ), ozone generator GOC-2 ( $8 \text{ gO}_3/\text{h}$  from oxygen), oxygen generator AS-12 ( $5 \text{ LO}_2/\text{min}$ ) (AirSep Corp., Buffalo, NY, USA), and the GAC filter ( $D=0.5 \text{ m}$ ;  $H=3.5 \text{ m}$ ,  $h=2.5 \text{ m}$ ). The set-up also included a dosing system for different oxidants (ozone, oxygen, hydrogen peroxide, chlorine (NaOCl), potassium permanganate) injection. One version of the pilot-plant flowsheet is shown in Figure 1.

We were convinced by the first laboratory tests that to avoid formation of very strong and stable Fe(III)-organic complexes, the first step of the raw water treatment— aeration—must proceed with the maximum speed and minimum retention time of water. This is why we chose for aeration a very efficient and novel Gas-Degas Technology (GDT). The GDT aeration unit (Figure 1) consists of a patented Mazzei venturi injector to dynamically introduce gases (air, oxygen, ozone), a patented centrifugal degassing separator to quickly and effectively



**FIGURE 1.** One version of the pilot plant flowsheet: 1 – water pump; 2 – flow meter; 3 – injector Mazzei; 4 – degassing separator; 5 – feed tank; 6 – reactor; 7 – I stage filter; 8 – ozonation column; 9 – II stage filter.

remove unwanted entrained gases, a degas relief valve to release the captured gases for processing or venting, and a back-pressure control valve on the water outlet pipeline from the separator. The GDT process has proven to be extremely efficient in dynamically transferring gases into pressurized solutions while removing unwanted entrained or dissolved gases. In addition to its technological benefits, the GDT process features a small footprint, low costs of capital, installation and operation, easy installation, and nonfouling pressurized operation.

For the pilot plant tests, the smallest GDT unit with the water flow rate of  $1.1\text{--}11.4 \text{ m}^3/\text{h}$  was purchased (Mazzei injector model 885-X together with the degassing separator model DS-100-316). The pilot plant in Kogalym was in operation with some short intervals for more than 2.5 years (December, 1999–September, 2002).

During the tests, the main operating parameters for determining the quality of oxidized and filtered water were measured and varied: detention time of water in the GDT aerator, doses and injection points of the oxidants ( $\text{O}_2$ ,  $\text{O}_3$ ,  $\text{H}_2\text{O}_2$ , NaOCl,  $\text{KMnO}_4$ ), type of filtration medium, filtration rate, etc. The pH and oxidation-reduction potential (ORP) of water were measured by Testo 230 (Testo GmbH, Lenzkirch, Germany), the temperature and concentration of dissolved oxygen by electrode-analyzer model MJ 97, the concentration of dissolved  $\text{CO}_2$  by the method of Hach Corp. (titration with  $0.01 \text{ N}$  solution of NaOH), color/turbidity by spectrophotometer DR/2010 (Hach Corp., Loveland, CO, USA). The color of water was measured at  $455 \text{ nm}$  (Pt-Co scale) and turbidity at a wavelength of  $860 \text{ nm}$ . The iron content (ferrous and ferric) was determined by spectrophotometer DR/2010 at the wavelength of  $510 \text{ nm}$ .

## RESULTS AND DISCUSSION

### Iron/Manganese Complexes with Humic Matter

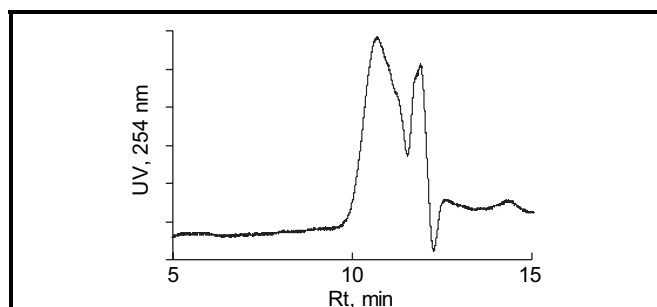
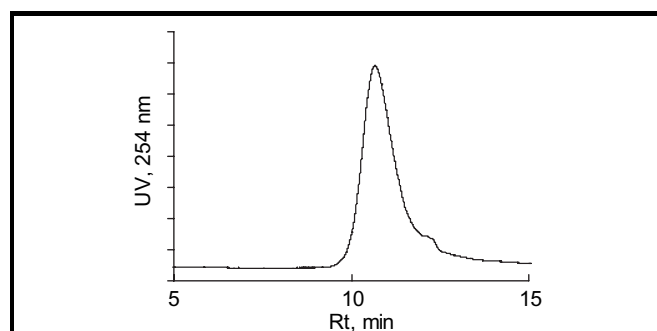
The results of metals (iron and manganese) analyses in raw groundwater after filtration through a  $0.45 \mu\text{m}$  mechanical filter are presented in Table 4. It was established that almost 60% of iron and 7% of manganese were organically bound into complexes. The humic matter molecular masses and the polydispersity factor are given in Table 5. In Figure 2 the exclusion chromatogram of the raw filtered groundwater is presented, and in Figure 3 the chromatogram of the humic matter fraction separated from the groundwater. In Figure 2 the two peaks of organic matter fractions with different molecular masses can be easily identified. The first one represents humic matter, the second one represents the mixture of monodispersal polymer. Separated from water by XAD-16, humic matter fraction was homogeneous; there is only one peak on the chromatogram in Figure 3 with the maximum  $R_t = 10.75 \text{ min}$  and corresponding molecular mass 1911. Thus, by our investigation and differently from the soil scientists statement, the organic matter

**TABLE 4.** Iron and Manganese Concentrations in Groundwater and Humic Fraction

Sample	Fe (mg/L)	Mn (mg/L)
Groundwater	2.1	0.09
In humic fraction	1.25	0.006
Metals organically bound, %	59.5	6.7

**TABLE 5.** Molecular Masses Of Humic Matter and Polydispersity Factor d

Water sample	Rt, Min	M <sub>n</sub>	M <sub>w</sub>	D
Without humic matter separation (filtered through a 0.45 μm filter)	10.65	1130	1860	1.65

**FIGURE 2.** Exclusion chromatogram of Kogalym's groundwater without separation of humic matter. Column BIOSEP-SEC-S 2000 (300×7.5 mm); eluent: 0.02 M phosphate buffer; pH 6.8; I=0.2M; flow rate 1ml/min; UV detector, wavelength 254 nm.**FIGURE 3.** Exclusion chromatogram of humic matter fraction separated from groundwater. Column BIOSEP-SEC-S 2000 (300×7.5 mm); eluent: 0.02 M phosphate buffer, pH 6.8, I=0.2M; flow rate 1ml/min; UV detector, wavelength 254 nm.

responsible for metals complexing in this case is not of high molecular mass (<2000).

### Impact of Different Oxidants on Iron-Organic Complexes Removal

In 1999–2000 several flow sheets (schemes) for raw well water treatment were tested on the pilot plant in Kogalym (Figure 1). Here, the main results are briefly summarized

and the final flow sheet for full-scale application was developed. The following four schemes were tested:

- GDT – feed tank – reactor – filter (Pyrolox)

Into the reactor were dosed ozone or hydrogen peroxide or at the inlet to the filter were injected ozone or NaOCl

- GDT – reactor – filter (Pyrolox) – ozonation column – GAC filter

Into the reactor was dosed NaOCl

- GDT – reactor – filter (hydroanthracite) – filter (Pyrolox) – ozonation column – GAC filter

Into the reactor was dosed NaOCl

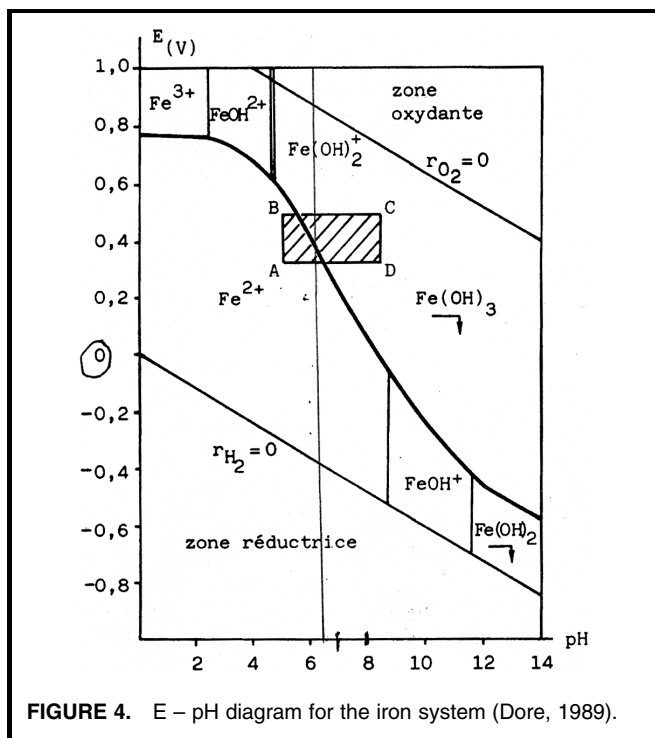
- GDT – filter (hydroanthracite) – filter (Everzit) – clean water reservoir

The doses of oxidants were in the range of 0.5–10 mg/L of active compound.

Between the I and II stage filters pure oxygen and into the clean water reservoir NaOCl for disinfection were injected.

Measurements of the ORP on the pilot plant showed that the ORP of raw well water was in the range of (–56) – (–100) mV (i.e., pE = – (1.0–1.8)), which at pH of water 6.6–6.8 corresponds to the area of stable Fe<sup>2+</sup> ions or iron-organic complexes in water (E – pH diagram for the iron system in Figure 4). It is important to keep in mind here that this diagram was compiled for pure iron system only without organics content. In the latter case obviously some shift of the borderlines between the areas may take place, which is difficult to predict. Using aeration or chemical oxidation it is necessary to achieve the ORP values + (300–500) mV to precipitate Fe(OH)<sub>3</sub>. At higher values of ORP (> 500 mV) Fe(OH)<sub>3</sub> will dissolve with the formation of Fe(OH)<sub>2</sub><sup>+</sup> and OH<sup>–</sup> ions (Roques, 1999).

Impact of the chemical oxidants on iron removal was studied mostly in the case of the first flowsheet:



- GDT – feed tank – reactor – filter (Pyrolox)

Pyrolox is a very rare form of almost pure (100%) manganese dioxide. This material is extremely hard, like garnet, and heavy (hardness 1–2, density 4.5–5.0 g/cm<sup>3</sup>). It does not need chemical regeneration with a solution of potassium permanganate like Birm, Filox and Manganese Greensand, but only mechanical backwash at the rate of 60–70 m/h in 24 hrs, and dosing of a relatively small amount of active chlorine (0.1–1.0 mg/L) at the inlet of the filter to keep the medium active.

Unfortunately, Pyrolox does not remove the complexed iron. To break down the iron complexes formed in the aerated water reservoir, NaOCl or ozone (0.5–1.5 mg/L) were injected into water before the Pyrolox filter. The total iron content after the Pyrolox filter was < 0.3 mg/L. The best quality parameters of water filtered through the Pyrolox were obtained in the case of using preozonation: the total iron content was reduced by 93% and divalent iron content by 98.7%. The color of the filtered water was 1 deg. (Pt-Co) and turbidity 0 mg/L.

At higher doses of oxidants (5.0–10 mgCl<sub>2</sub>/L, 4–5 mgO<sub>3</sub>/L) the iron removal process deteriorated and the total iron content in filtered water increased to 0.4–0.6 mg/L. This was obviously due to the excess increase in ORP > 500 mV. Hydrogen peroxide addition did not improve the iron removal, obviously due to its very slow reaction. Application of potassium permanganate was not of help either. Prolongation of the contact time of oxidants with water (injection before the reactor) had a positive impact; iron content in filtered water was reduced. Combination of the oxidants (O<sub>3</sub>/H<sub>2</sub>O<sub>2</sub>), i.e.,

creation of active °OH-radicals in water did not lead any increase in iron removal, probably due to their quick passivation by bicarbonate ions and ammonia.

### The Optimum Treatment Technology for the City of Kogalym Groundwater

The total and divalent iron content, color and turbidity were chosen as the main quality parameters of treated water. At the first stage of the pilot tests our main attention was paid to a new efficient catalytic filter medium for iron oxidation and removal—Pyrolox. However, by the end of the cycle of pilot tests Pyrolox had lost about 50% of its initial activity due to the formation of a quite tight yellowish precipitate (iron phosphates) on the surface of its particles.

In 2000 the scheme of the pilot plant was modified: as the protecting prefilter, a filter with hydroanthracite (40% sand 0.35–1.0 mm) was connected to the scheme, aerated water was led directly to the hydroanthracite filter without the feed tank to avoid very strong trivalent iron complexes formation, and to the Pyrolox filter about 35% of sand was added to improve the filtration properties. The tests with hydroanthracite prefilter clearly indicated that in the case of using both filters the total iron content in filtered water was 1.7 times and color 1.5 times lower.

At the last stage of the pilot tests, it was decided to replace Pyrolox in the second filter by a new special anthracite- Everzit-Special. This is a rather new filtration material from Germany which efficiently removes trihalomethanes (THM) and other chloroorganic compounds (AOX), ammonia and phosphates from water. Everzit-Special has the particle diameter of 0.6–2.0 mm and specific interfacial area of about 350 m<sup>2</sup>/g. It is used in open filters at the filtration rates of 5–10 m/h with the water backwash rate of 30–35 m/h. Its great advantage is that this material is able to reduce iron and manganese content in water significantly, including also *complexed iron*.

At the same time there is no need to use stronger oxidants such as chlorine, ozone, hydrogen peroxide. It is only needed to have enough dissolved oxygen in water (or sufficiently high ORP values) to form the self-regenerating catalytic film of FeO(OH) on the surface of the Everzit particles. Taking into consideration the experience collected during the previous tests, we finally modified the pilot set-up to the following very simple scheme which served as a basis for the design of the full-scale plant. The final flowsheet diagram of the pilot plant is described by the scheme in Figure 5. The raw water is quickly and intensively aerated in the GDT unit and led directly to the first, anthracite filter. The filtered water is enriched with oxygen and then led to the second, polishing filter with Everzit. Average test results of this pilot-plant scheme are given in Table 6.

Our ORP measurements on the pilot plant showed that the iron removal process proceeds successfully when the ORP of water after the GDT is +(300–350) mV, before the I stage filter at least +300 mV, and before the II stage filter about +350 mV, and after the II stage filter

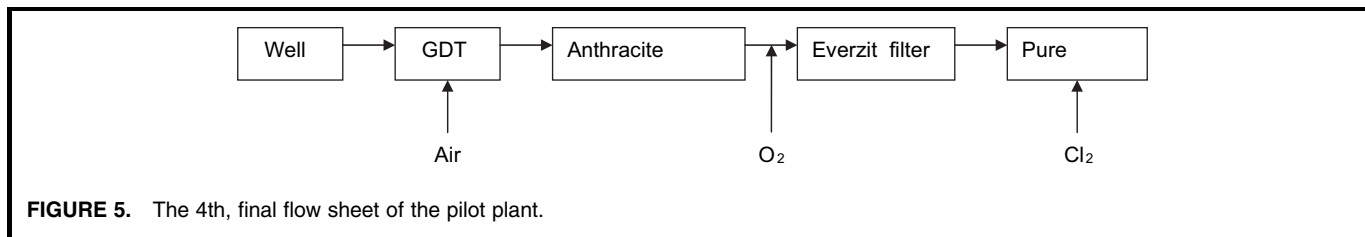


FIGURE 5. The 4th, final flow sheet of the pilot plant.

TABLE 6. Average Results of Testing of the Pilot-Plant Optimum Flow Sheet

Sample	O <sub>2</sub> , mg/L	CO <sub>2</sub> , mg/L	pH	Fe(II), mg/L	Fe(tot) mg/L	Color, mg/l (Pt-Co)	COD <sub>Mn</sub> mgO <sub>2</sub>
Raw water	0.180	41.9	6.57	3.30	3.90	24.3	3.17
After GDT	6.71	35.4	6.68	-	-	-	-
After filter I	0.150	33.9	6.57	0.35	0.43	14.7	3.16
After filter II	1.39	31.8	6.52	0.00	0.08	10.4	2.38

+ (270–300) mV. Figure 6 illustrates the actual changes in ORP during the treatment process at Kogalym full-scale WTP (2500 m<sup>3</sup>/h).

The raw water ORP has been in the range of -(56–100) mV. The concentration of dissolved oxygen after the GDT was in the range of 8–10 mg/L. If the concentration of dissolved oxygen after the I stage filter is < 1 mg/L, then the water before the II stage filter must be enriched with oxygen from the oxygen generator. Actually the DO concentration after the I stage filter dropped very often to 0.1 mg/L and enrichment of water with oxygen was necessary. The filtered water is pumped into two reservoirs of drinking water and disinfected with chlorine. It is also planned to put into operation the unit of drinking water stabilization soon to avoid pipeline corrosion (increasing pH from 6.5 to 7.5 by dosing of a 15% solution of soda ash (Na<sub>2</sub>CO<sub>3</sub>).

## CONCLUSIONS

Studies of humic matter composition and metal-organic complexes in Kogalym groundwater using adsorbent XAD-16 revealed that humic matter fraction was homogeneous, with only one peak on the chromatogram with maximum Rt = 10.75 min and corresponding molecular mass 1911. Thus, by our investigation and differently from the soil scientists statements, the organic matter in this specific groundwater responsible for metals (iron, manganese) complexing is not of high molecular mass (> 2000).

Two different ways for complexed iron removal from groundwater were tested: the first, using fast intensive aeration in the GDT unit followed by chemical oxidation with stronger oxidants (ozone, chlorine, hydrogen peroxide) to decompose Fe(III)-organic complexes, and by filtration through catalytic filter material (Pyrolox); and the second, using also aeration in the GDT, but without chemical oxidation, applying only enrichment of water with pure oxygen between the two stage filtration (through hydroanthracite

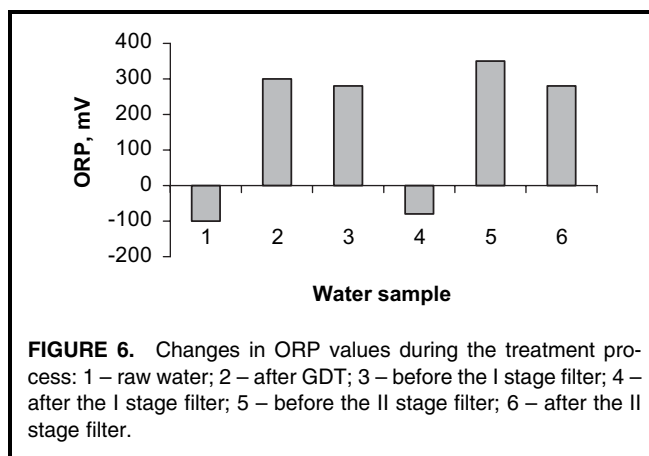


FIGURE 6. Changes in ORP values during the treatment process: 1 – raw water; 2 – after GDT; 3 – before the I stage filter; 4 – after the I stage filter; 5 – before the II stage filter; 6 – after the II stage filter.

and Everzit-Special) to keep the optimum ORP values. The last option was the very successful (98% of total iron removal) and also the cheapest.

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