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EQUIPMENT AND METHODS FOR INDUSTRIAL FERRATE PRODUCTION IN SCOPE OF WATER PURIFICATION

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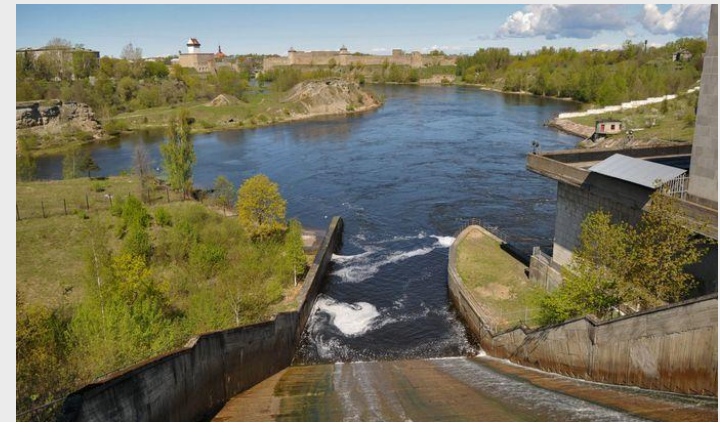
Nowadays the drinking water purification is often done using chlorine-containing chemicals, as they are rather cheap and provide prolonged disinfection. But it has significant disadvantages:


- Chlorine produces hazardous byproducts during pollutant oxidation
- It is difficult to forecast precise dosage of the chlorine-containing reagent, that is needed for current water flow, so subtreatment or overtreatment often takes place
- Chlorine production is dense and it can't be produced in situ, so that it need transportation and storage



Another water treatment problem – sewage waters:

- Huge amount of drainage – often disposed to the natural reservoir
- It is forbidden for chemicals with prolonged effect to be disposed to natural reservoirs
- Industrial disposals can contain wide range of different chemical pollutants





Sodium ferrate (Na_2FeO_4): one of the most powerful oxidant, that can be use for:

- Disinfection
- Chemical contaminants degradation
- Pollutants coagulation
- No toxic byproducts

Ferrate technology: developed technology provides electrochemical production of the liquid sodium ferrate in industrial scale, also it is:

- Green
- Efficient
- Safe

**Our technology is based on membrane electrolysis,
using cation-exchange membrane for ferrate production**

Main expendable resources are metal anode and caustic alkali. The alkali can be obtained at the existing electrolytic chlorine production site as a byproduct. Such synergy can bring two effects:

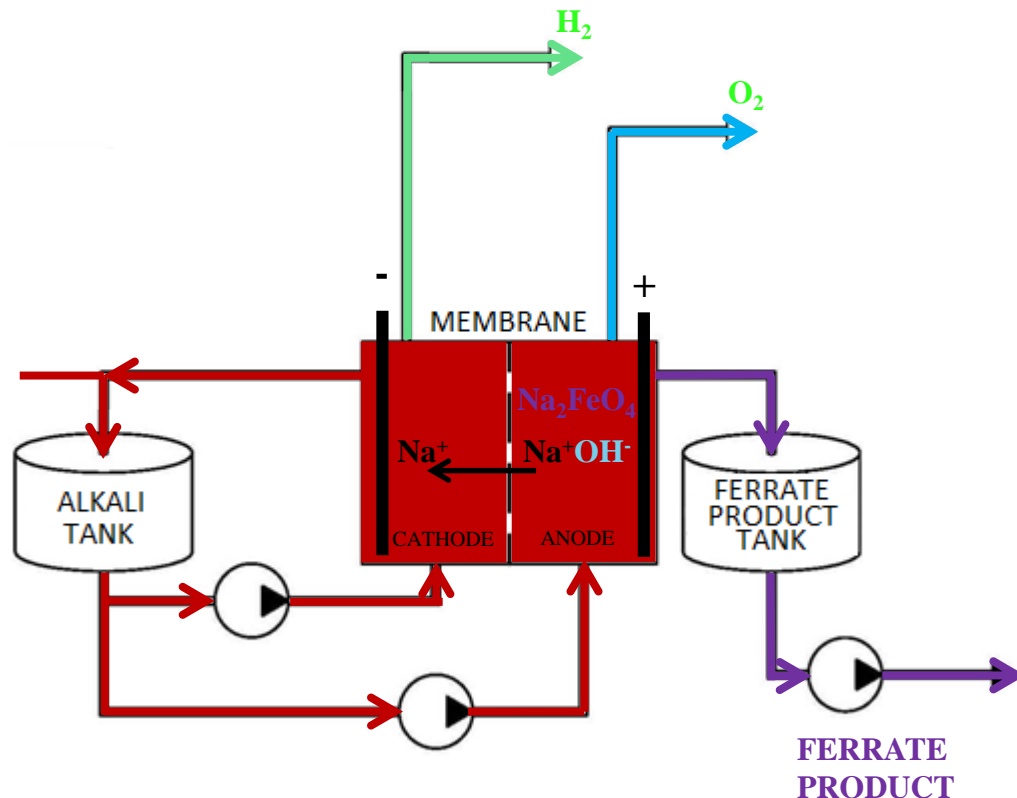
- Safety – the alkali concentration is twice lower than the comparables use (20% caustic alkali instead of 40+ %, in mass)
- Cheaper – lower the ferrate production cost as alkali charge is above 90% of all costs

The technology is implemented in the production process, that is:

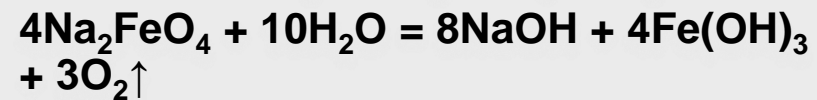
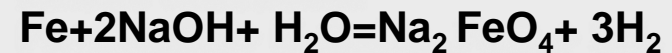
- Automated (using sensors, industrial controller, managed pumps and power supply)
- Safety (all safety parameters are controlled, alarming signal in case of faults)
- Adjustable productivity

Process flow diagram of ferrate production

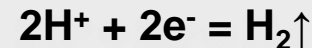
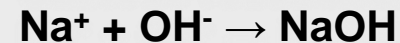
Caustic alkali is stored in alkali tank and pumped into the anode and cathode chambers, where the electrolysis takes place. Cathode chamber alkali is flowed back to the tank, the anode chamber solution, containing the ferrate, is flowed into the product tank



Anode reactions:



Cathode reactions:



The composition of the electrolytic unit for ferrate production



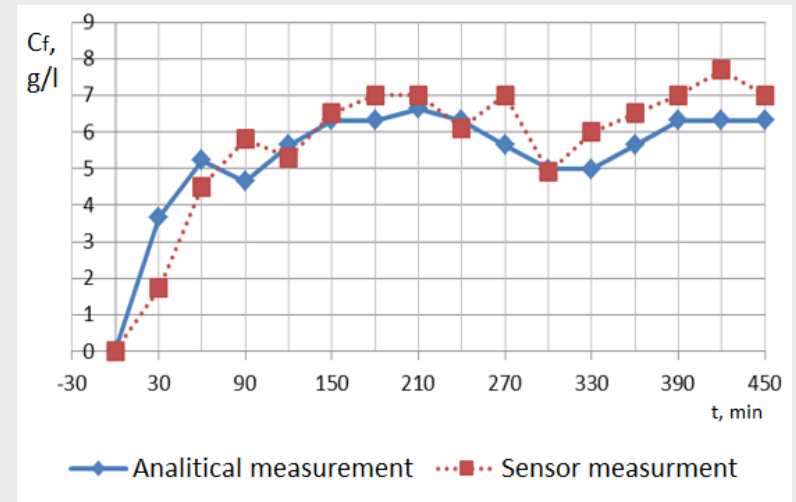
The ferrator (front and backside view)



SCADA interface



Sensor, measuring ferrate concentration in the product



Tests and working parameters of the developed unit (difference from the model $\leq 3\%$)

PARAMETER	MODEL VALUE	MEASURED VALUES					
		Amount of anode chambers, pcs.	Current, A	Current efficiency, %	Power consumption, kW·hour/kg	Voltage, V	Productivity, kg/day (g/hour)
Productivity for Na_2FeO_4	4 kg/day (168 g/hour)	2	300	55,8	5,98	3,43	4,070 (169)
	10 kg/day (417 g/hour)	5	750	55,8	5,98	3,43	10,160 (423)

The ferrate productivity is up to 10 kg/day with the power consumption below 6 kW*hour/kg.

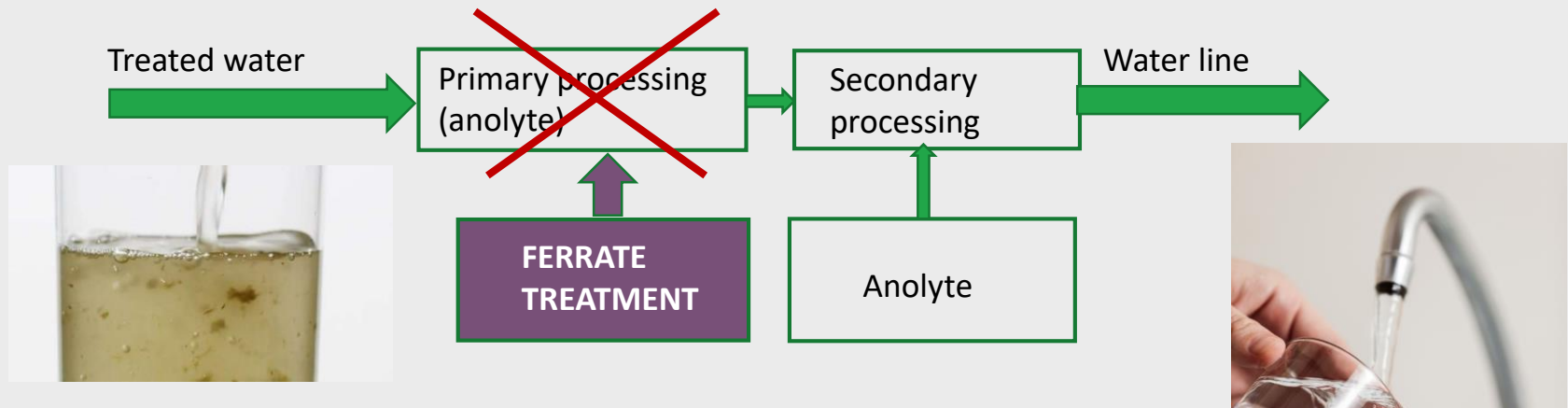
It is capable of disinfecting up to 840 cub.m/hour of drinking water (ferrate dosage is assumed 0,5 mg/l) and up to 2100 cub.m/hour of the sewage waters (dosage is assumed 0,2 mg/l)

Results of drinking water purification using the ferrate:

Probe number	Ferrate dosage, mg/l	Cl2 dosage, mg/l	Main indicators			
			Treatment time, min	Total microbial count (colony forming units в 1 мл)	Total colimorphic bacteria (colony forming units в 100 мл)	Thermotolerant colimorphic (colony forming units в 100 мл)
Objective				≤ 50	absence	absence
Initial				10	18	18
1	0,5		2	< 1	absence	absence
2	1		2	< 1	absence	absence
3	1,5		2	< 1	absence	absence
4	2		2	< 1	absence	absence
5	2,5		2	< 1	absence	absence
6		4,5	2	< 10	absence	absence

Drinking water purification at the water treatment plants

- chlorine (anolyte) usage only for secondary water processing for water conservation after the disinfection
- reduction of concentration of chlorine-containing organic compounds in 3-10 times
- reduction or closing usage of additional coagulants and flocculants



Results of sewage water fining using the ferrate:

Probe number	Ferrate dosage, mg/l	pH after injection (in 15 min.)	Main indicators				
			Total colimorphic bacteria (colony forming units – CFU – in 100 ml)	E. coli in 100 ml	Coliphages in 100 ml	Enterococcus in 100 ml	Staphylococcus in 100 ml
Initial	-	7,8	400000		1000		
Objective	-	9	<1000 CFU	< 100 KOE	< 10 BFU	< 10 CFU	10 CFU
1	0,1	8,25 (8,15)	< 50 CFU	< 50 CFU	0 BFU	0 CFU	8 CFU
2	0,2	8,35 (8,25)	< 50 CFU	< 50 CFU	0 BFU	0 CFU	0 CFU
3	0,3	8,49 (8,39)	230 CFU	< 50 CFU	0 BFU	0 CFU	0 CFU
4	0,4	8,80 (8,70)	< 50 CFU	< 50 CFU	0 BFU	0 CFU	0 CFU
5	0,5	9,20 (9,09)	230 CFU	60 CFU	0 BFU	0 CFU	0 CFU
6	0,6	9,49 (9,38)	230 CFU	< 50 CFU	0 BFU	0 CFU	0 CFU

Fining and disinfection of the domestic sewage using ferrate

- Twice cheaper than the electrolytic hypochlorite
- Disposals contain no chlorine and its byproducts



Treatment of industrial wastewater, including liquid toxic wastes

- Ferrate was used for purification of industrial wastes, stored at acid landfill cells, and the landfill sewage (toxic landfill “Krasniy Bor” at Saint-Petersburg, Russia).
- Maximum allowable concentration of the water components were met for sewage using ferrate dosage about 10-20 mg/l, for acid cells – 50-60 mg/l.
- The nitrogen concentration in one of the cells has decreased from 480 to 48 mg/l, chloridiums – from 1500 to 520 mg/l, pH has increased from 4,0 to 9, the cell water meets the domestic sewage requirements.
- In other two cells the Cd concentration has decreased more then 2000 times, Pb – 100 times, meeting the same requirements.
- Shown results prove the high efficiency of the toxic wastes treatment using the ferrate.



Sewage before (to the right) and after the oxidation with 15 mg/l of ferrate



Initial cells' waters



After oxidation with 60 mg/l of ferrate

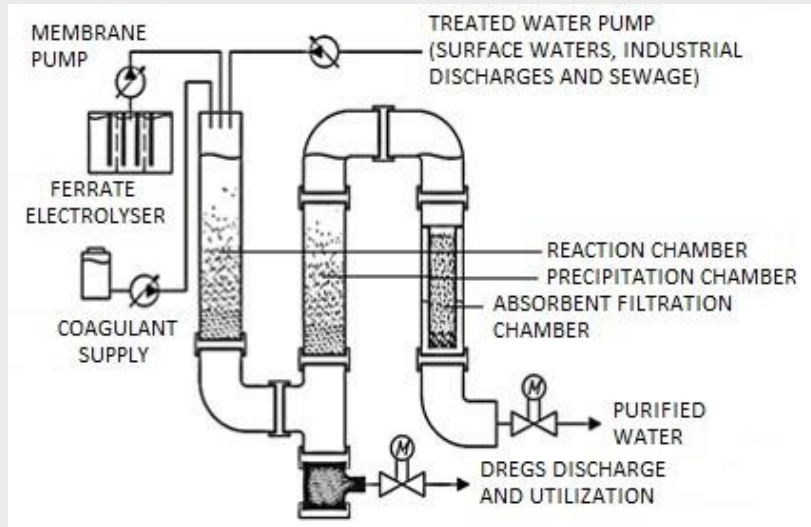


After the detention and filtration

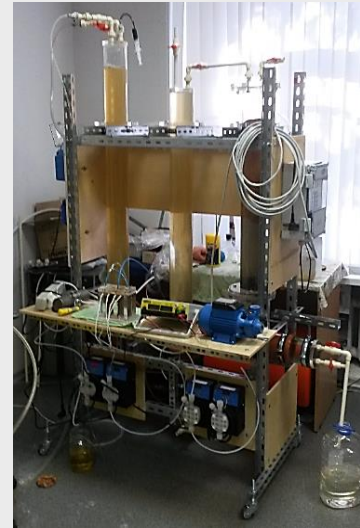


After oxidation, filtration and sorbent usage

Complex unit for water purification of industrial and liquid toxic landfill wastes



Flow diagram



The experimental model tests on toxic landfill sewage

- Experimental model comprises ferrate production module and water purification module, including oxidation, precipitation and filtration chambers.
- Can be used for treatment of industrial and liquid toxic landfill wastes.

Comparison with the known technologies

Reagent, sorbent	Reagent costs, \$/g	Reagent dosage, g/cub.m	Treatment costs, \$/cub.m.
Drinking water secondary processing (Dzerzhinsk city water station)			
Sodium ferrate (costs 1,6 times more)	0,00908	0,5	0,0046
Chlorine in anolyte	0,00063	4,5	0,0028
Drinking water secondary processing (Nizhny Novgorod city water station)			
Sodium ferrate (costs 1,4 time more)	0,00908	0,2	0,0018
Chlorine in anolyte	0,00063	2	0,0013
Fining of sewage water			
Sodium ferrate (costs 2 times less)	0,00908	0,1	0,00091
Electrolytic hypochlorite	0,00078	2,5	0,00195
Drinking water primary and secondary processing (Nizhny Novgorod city water station)			
Sodium ferrate (costs 7 times less)	0,00908	1	0,00908
Electrolytic chlorine + aluminium oxychloride + flocculent Praestol 650			0,0624
- Chlorine in anolyte	0,00063	2	0,0013
- Coagulant aluminium oxychloride (dry)	0,0047	12	0,0564
- Flocculent Praestol 650	0,0047	1	0,0047

In cooperation with out Chinese Partners:

- Cooperative pilot project
- Creation of cooperative scientific-research laboratory, based on the Peter the Great Saint-Petersburg Polytechnic University
 - Existing technology adaptation for usage in China
 - Further technology development in order to increase its efficiency
 - Research of technology usage in new areas
- Cooperative commercialization

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